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SERPENTINES OF THE SAN FRANCISCO BAY REGION: VEGETATION, FLORISTICS, DISTRIBUTION AND SOILS

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INTRODUCTION

Serpentine soils are of worldwide distribution. However, these soils are relatively rare and tend to be localized and sporadic in their distribution as a result of the complex geological events which formed them. The significance of serpentine soils, from a botanical perspective, is the relatively high degree of endemism and diversity of plant taxa associated with them. As a result of the spotty distribution of serpentines, geographic disjunctions of plant taxa are also commonly observed. Within California, serpentine soils are found west of the Sierra Nevada Range from Santa Barbara County northward into Oregon.

This report concentrates on the serpentine soils, vegetation and floristics in the San Francisco Bay Region. This Region is delineated arbitrarily in a geological sense since the San Francisco serpentines are associated with the Franciscan formation which also occurs elsewhere in the state. Floristically, however, the Region is distinct. Therefore, for the purposes of botanical studies, for which this survey was undertaken, the geographic limitations with respect to the soil are warranted.

Geographic Distribution

The San Francisco Bay Region serpentines occur in the counties of Marin, San Francisco, San Mateo, Santa Clara, Alameda and Contra Costa (Map 1). Thirteen areas were observed to have serpentine soils covering more than forty acres each and covering a total of nearly 3000 acres

(Table 1, Maps 2-14). Historically, areas such as those in San Mateo County, i.e. Edgewood Park, Crystal Springs Reservoir and Pulgas Ridge, formed an extensive continuum. Urban development and especially local highway systems have fragmented these serpentine areas and reduced the amount of exposed undisturbed serpentine soils. As a result of fragmentation of the serpentine habitat numerous small serpentine islands exist and are not fully incorporated in this study.

Serpentine Vegetation

The San Francisco Bay Region serpentine vegetation is floristically distinct. One of the reasons for this uniqueness is the climate. The climate controlling the vegetation in this area can be classified into three zones based on Russell's classification (Sharsmith 1982): 1) Western cool-summer mediterranean climate, 2) Interior zone of hot-summer mediterranean climate, 2) Interior zone of hot-summer mediterranean climate and 3) Eastern zone of arid steppe climate.

The first climatic zone, in a strict sense, is limited to the Presidio where summer fog is the cause of the cool summer condition. The hot-summer zone predominates elsewhere with the arid steppe climate perhaps only represented on Mt. Diablo. The following vegetation types can be recognized on the serpentines in the San Francisco Bay Region, and in some cases represent finer divisions than those found in the Natural Diversity Data Base's Terrestrial Natural Communities of California (Holland 1986).

Serpentine Bunchgrass Grassland - Over sixty percent of the serpentine vegetation in the San Francisco Bay Region is Serpentine Bunchgrass Grassland. The soil is generally deeper in the bunchgrass habitats than in others. The native bunchgrass species associated with this community are *Calamagrostis ophitidis, Elymus glaucus, Festuca idahoensis, Koeleria macrantha, Melica torreyana, Poa scabrella, Sitanion jubatum* and *Stipa pulchra* (also see Appendix I). The diversity and density of this vegetation appears to be a function of disturbance and localized habitat conditions. Grazing and other disturbances of the bunchgrass reduces density and diversity often resulting in a sparse vegetation dominated by annual grasses and with *Stipa pulchra* representing the only bunchgrass species. Localized soil and moisture conditions also exist that result in very dense hummocks of single species such as *Calamagrostis ophitidis, Elymus glaucus, Koeleria macrantha*, or *Sitanion jubatum*.

Mixed Serpentine Chaparral - The Mixed Serpentine Chaparral community is characterized in this region by *Adenostoma fasciculatum, Arctostaphylos glauca. A. viscida, Ceanothus jepsonii* var. *albiflora, Quercus durata* and *Rhamnus californica*. The specific components of this community and their frequencies are site specific and probably dependent on the climate and soil. This community occurs at Carson Ridge, Mt. Tamalpais, Edgewood Park and Mt. Diable. Both Carson Ridge and Mt. Diablo have a temporally enriched vegetation containing many bunchgrass and annual species as a result of chaparral fires in the recent past.

Serpentine Wildflower Field - An often extensive area situated between the Serpentine Barrens habitat and Serpentine Bunchgrass Grassland is dominated by ephemerals and leaf annuals i.e.

those species having bulbs or rootstocks and seasonally deciduous leaves. The diversity of plant species in the Serpentine Wildflower Field is most likely the highest of all the serpentine plant communities. Characteristic leaf annuals are *Allium* spp., *Brodiaea* spp., *Calochortus* spp., *Chlorogalum pomeridianum*, *Delphinium* spp., *Muilla maritima*, *Triteleia* spp., *Sanicula bipinnatifida* and *Zygadenus fremontii*. Characteristic ephemerals are *Agoseris* spp., *Calycadenia* spp., *Clarkia* spp., *Collinsia heterophylla*, *Eschscholzia californica*, *Gilia* spp., *Hemizonia* spp., *Lasthenia californica*, *Linanthus* spp., *Minuartia douglasii*, *Orthocarpus* spp., *Plantago hookeriana* var. *californica* and *Trifolium* spp. to name but a few taxa (see Appendix I). Many rare taxa such as *Acanthomintha obovata* ssp. *duttonii*, *Erysimum franciscanum*, *Fritillaria liliacea*, *Hesperolinon congestum* and *Pentachaeta bellidiflora* are associated with the Serpentine Wildflower Field community.

Franciscan Serpentine Coastal Scrub - The cool summer climate at the Presidio as a result of extensive summer fog produces the most distinct serpentine vegetation. Along the immediate coast is an unusual Northern Coastal Scrub called Franciscan Serpentine Coastal Scrub (McCarten 1986) which contains *Artemisia californica*, *Baccharis pilularis* var. *consanguinea*, *Erigeron glaucus*, *Eriophyllum staechadifolium* var. *artemisiaefolium*, *Grindelia maritima*, *Mimulus aurantiacus*, *Plantago maritima*, *Rubus ursinus* and *Toxicodendron diversilobum*.

Decumbent Manzanita Serpentine Scrub - This vegetation type is dominated by *Arctostaphylos montana* on Carson Ridge and Mt. Tamalpais, *Arctostaphylos hookeri* ssp. *ravenii* at the Presidio and historically elsewhere in San Francisco along with the now extinct *Arctostaphylos hookeri* ssp. *franciscana*. Vegetation in this community is sparse with serpentine barrens or sparse bunchgrass grassland in close proximity. This is undoubtedly one of the rarer plant communities in this region.

Sargent Cypress Woodland - A small localized area of *Cupressus sargentii* exists on Mt. Tamalpais. The Sargent Cypress Woodland is characteristically dense and devoid of an understory or any other plant associates.

Serpentine Seep Vegetation - The occurrence of seasonally active springs in serpentine areas has resulted in the formation of a Serpentine Seep plant community. This community is characterized by *Cirsium campylon* or *C. fontinale* var. *fontinale* with *Mimulus guttatus* and *Calamagrostis ophitidis*. This community type is found at the Triangle, Pulgas Ridge, Crystal Springs Reservoir and Metcalf Canyon. Another localized subset of the Serpentine Seep Vegetation is characterized by *Carex serratodens* and *Mimulus guttatus* in serpentine seeps at Mt. Tamalpais, Carson Ridge and the Tiburon Peninsula.

Serpentine Barrens - The Serpentine Barrens are areas where the parent serpentinite rock is well exposed and local soil chemistry may result in nearly sterile or toxic conditions (see Kruckeberg 1984). Whatever the cause, Serpentine Barrens characteristically have very few taxa and extremely low population densities. In the San Francisco Bay Region *Allium falcifolium*, *Streptanthus batrachopus*, *S. glandulosus* and *S. hispidus* are most often found in the Serpentine Barrens which may only cover a few square meters. This plant community can be found in

Carson Ridge, Mt. Tamalpais, Edgewood Park, The Triangle and Crystal Springs Reservoir.

Serpentine Rock Succulent Vegetation - Areas having a high degree of exposed parent rock have a specialized vegetation of succulent plants. The fact that the plants are succulent is probably due to the high level of drainage in the rock crevices creating an extremely arid condition. Characteristic species are *Dudleya setchellii* (sensu Bartel) occurring at Metcalf Canyon and Tulare Hill, *Dudleya farinosa* occurring at Ring Mountain, and *Lewisia rediviva* occurring at Metcalf Canyon, Tulare Hill, Edgewood Park and Mt. Diablo.

Serpentine Floristics

The inventory of taxa (Appendix I) is probably numerically incomplete since only a few of the serpentine areas i.e. Edgewood Park, The Triangle, Ring Mt., Jasper Ridge and Redwood Park have had extensive checklists developed over the last several years. The remaining areas are represented by data from a single year of field research collected in 1986 during the course of this study. However, with the present information, several noteworthy observations of the floristics of the serpentine habitats in the San Francisco Bay Region can be made. Table 2 lists the 55 families and the number of taxa associated with each of those families from all of the sites. In all there are 402 taxa listed in Appendix I. The genera having the highest number of taxa are *Trifolium* with 16 taxa, *Allium* with 8 taxa, *Orthocarpus* with 7 taxa, and *Brodiaea, Bromus, Clarkia, Calochortus, Hordeum, Linanthus, Microseris, Sanicula* and *Streptanthus* all represented by 6 taxa. Leaf annuals or those having bulbs, corms or perennial rootstocks are represented by 17 genera containing 48 species and comprise over 12 percent of the serpentine flora. The grasses also account for a significant percent of the flora and include 50 species, seventeen of which are native bunchgrasses. However, it is the Asteraceae, with seventy-four taxa, that is the largest family and represents over eighteen percent of the flora. In addition, there are six fern species and one native conifer, *Cupressus sargentii*. Finally, there are 33 extant taxa that are rare (see discussion below) and make up ten percent of the flora. These figures are significant considering they represent the flora of an area of less than 3,000 acres.

Rare Plants - Based on information from the California Natural Diversity Data Base and the California Native Plant Society (Smith and York 1984) there are 35 taxa from the region that have been recognized as rare (Table 3). Three of these rare taxa are believed to be extinct in their native habitat, *Arctostaphylos hookeri* ssp. *franciscana*, *Plagiobothrys diffusus* and *Trifolium amoenum*. The two latter species are annuals and may yet be rediscovered in their serpentine habitat. However, *Arctostaphylos hookeri* ssp. *franciscana* is now only represented by one individual cultivated in Tilden Park Botanical Garden in Berkeley following destruction of its native habitat.

The remaining thirty rare taxa, which represent eight percent of the flora, display various degrees of rarity (Table 3) and geographic distribution patterns (Table 4). *Arctostaphylos hookeri* ssp. *ravenii* is represented by only a single individual on serpentine in the Presidio of San Francisco. Cuttings from the Presidio Manzanita are successfully being grown at Tilden Botanical Garden. Another extremely rare taxon *Acanthomintha obovata* ssp. *duttonii*, is an ephemeral which is restricted to one site in deep serpentine clay soils in San Mateo County. A number of other taxa are represented by only a few small occurrences such as *Calochortus tiburonensis, Castilleja neglecta* and *Clarkia franciscana*. These species are rare primarily because they are edaphic endemics to the serpentine soil habitat. Their ranges have been further reduced by human-caused disturbance.

Some of these rare taxa, such as *Arctostaphylos hookeri* ssp. *ravenii*, are apparently facultative edaphic endemics as evidenced by their survival on non-serpentine soils such as at Tilden Botanical Garden (McCarten 1986b). Other species, such as *Clarkia franciscana*, are not restricted to a particular type of serpentine habitat and have successfully been introduced into other serpentine habitat and have successfully been introduced into other serpentine areas such as Redwood Park in Oakland. However, some rare plants, like the San Mateo thornmint, have an extremely restricted habitat requirement, in this case, for deep serpentine clays and apparently can not be grown off this substrate (McCarten 1986c).

Factors contributing to the rarity of a taxon are complex. *Acanthomintha obovata* ssp. *duttonii* provides a case of extreme edaphic endemism in which the habitat has also always been rare. Other taxa may have once had larger geographic ranges and are becoming rarer as a result of fragmentation of their habitat possibly leading to genetic depression (see Fiedler 1986, p. 508). The reasons for rarity thus must be determined on a case-by-case basis. However, the loss of appropriate habitat will most likely always remain the main cause of rarity for these and many other taxa.

Serpentine Soil Chemistry

Serpentine is a generic term for a complex of soils derived from minerals that are commonly high in magnesium and iron, but extremely low in calcium and other nutrients. Serpentinite is a ferro-magnesium silicate that is most often considered the parent mineral of serpentine soils (Kruckeberg 1984). In addition to iron and magnesium, heavy metals such as chromium, manganese, zinc, nickel, cobalt and copper have been found to occur in relatively high concentrations in some serpentine complexes and are potential sources of metal toxicity to plants (Fitter and May 1983, Kruckeberg 1984, see also Fiedler 1985). Other chemical constituents such as phosphorus, molybdenum, boron and potassium have been observed to have extremely low concentrations possibly causing nutrient deficiencies in plants.

The high concentration of magnesium relative to calcium is the most characteristic feature of serpentine soils. Both calcium and magnesium are important nutrients in plants. The similarities of these two as divalent cations and their often overlapping biochemical roles in plant metabolism create a degree of competition. Non-serpentine soils have a calcium concentration two to ten times higher than that of magnesium. Perhaps as a result of the fact that the calcium/magnesium ratio is high in most soils, plants require more calcium than magnesium in their primary metabolism. Serpentine soils characteristically have a calcium/magnesium ratio of less than one. The extreme serpentine condition displays a calcium/magnesium ratio of less than 0.2.

METHODS

Soil Samples

Sixteen soil samples (Table 1) from twelve serpentine sites in the San Francisco Bay Area were analyzed for: carbon, nitrogen, phosphorus, calcium, magnesium, potassium, sodium, manganese, nickel and chromium elements; cation exchange capacity (CEC), pH, bulk density, permanent wilting point (PWP) and field capacity (FC). The soil analysis determined the concentrations of exchangeable cations, which are those available to the plant as opposed to cations bound within a mineral matrix and unavailable for plant uptake. The values for field capacity and permanent wilting point are in percent moisture in the soil and represent the range between which plant roots can absorb water. Field samples were made for the following ranges of soil depth: 0-5 centimeters, 5-10 cm, 10-20 cm and 20-30 cm. The depth of each sample was a function of the depth of the parent rock below the surface. Serpentine soils are characteristically shallow and rocky. Soil collections were made using a 10 cm soil cylinder. Each sample was oven dried, weighed, and sieved with a 0.2 cm mesh sieve to separate out gravel and rock. Nutrients and trace elements were extracted and determined using an atomic absorption spectrophotometer. Extraction for nickel and chromium was done with a DPTA chelate. Serpentine soil was sampled from Carson Ridge (Map 2), from Mt. Tamalpais (Map 3), from Ring Mt. (Map 4), from the Presidio (Map 5) including the site of *Arctostaphylos hookeri* ssp. *ravenii*, from three sites in Edgewood County Park (Maps 7 & 8) including the known site of *Acanthomintha obovata* ssp. *duttonii* (California Natural Diversity Data Base element occurrence #5, see McCarten 1986c). Samples were also taken from the Triangle (Maps 7 & 8) and Pulgas Ridge (Maps 7 & 9) which are part of the San Francisco Water District, Stanford University's Jasper Ridge Preserve (Maps 7 & 10), Tulare Hill (Map 11), Metcalf Canyon (Map 12), Redwood Regional Park (Map 13), and from Mt. Diablo (Map 14).

RESULTS

Soil sample data for each site surveyed are provided in Appendix II. The data show considerable variation from site to site, even within a single general locality such as Edgewood Park. For example, the three soil samples from Edgewood Park are from three different serpentine habitats. Edgewood sample 1 is from the serpentine clay supporting *Acanthomintha obovata* ssp. *duttonii*, sample 2 is from beneath the Mixed Serpentine Chaparral community and sample 3 is from the Serpentine Wildflower Field community. These three Edgewood soil samples are from within 50 meters of each other and differ considerably in calcium/magnesium ratio, nitrogen content, cation exchange capacity, soil percent moisture and soil depth.

The soil variation corresponds with the vegetation in several respects. The soil supporting the Serpentine Bunchgrass Grassland (Ring Mt. sample 1, Pulgas Ridge, Jasper Ridge, Metcalf Canyon, Tulare Hill, Presidio sample 2, and Redwood Park) are generally deeper, have consistently low calcium/magnesium ratios, high cation exchange capacities and tend to have high soil moisture values with a relatively wide range between field capacity and permanent wilting point. Soil from beneath Mixed Serpentine Chaparral (Carson Ridge, Mt. Diablo and

Edgewood Park sample 2) are generally shallow, have moderate calcium/magnesium ratios due to higher concentrations of calcium and lower concentrations of magnesium, have lower cation exchange capacities, high percent soil moisture and high carbon concentrations. The soil associated with *Arctostaphylos montana* and the surrounding Serpentine Barrens vegetation on Mt. Tamalpais is extremely shallow and characteristically nutrient poor even though it has a higher calcium/magnesium ratio. This sample also has a very low percent soil moisture with a narrow range between field capacity and permanent wilting point (5.3%), and an extremely low cation exchange capacity (11.70). A similarly unusual soil habitat is that of *Acanthomintha* (Edgewood sample 1, see also The Triangle). This is a very deep clay soil with an extremely low calcium/magnesium ratio due to very low calcium and very high magnesium (47.85 Meq), very high percent moisture with a broad range between field capacity and permanent wilting point (22%), and a very high cation exchange capacity.

Site Summaries

Carson Ridge - The Mixed Serpentine Chaparral at Carson Ridge is floristically similar to that at Mt. Tamalpais. However, a recent fire has opened the vegetation allowing bunchgrasses and ephemerals to colonize, which has added significantly to the plant species diversity. Four rare plant species occur on Carson Ridge. This site covers approximately 150 acres and is an ecological preserve under the jurisdiction of the Marin County Water District.

Mt. Tamalpais - Varied soil and topographic conditions create microhabitats which support five localized vegetation types of Mixed Serpentine Chaparral, Sargent Cypress Woodland, Decumbent Manzanita Serpentine Scrub, Serpentine Seep Vegetation and Serpentine Barrens. Two rare plant species occur on Mt. Tamalpais. This site covers approximately 60 acres and is under the jurisdiction of the California Department of Parks and Recreation.

Tiburon Peninsula - The California Nature Conservancy's Ring Mountain Preserve and St. Hilary's Preserve account for over eighty percent of the predominantly Serpentine Bunchgrass Grasslands on the peninsula. These serpentine grasslands are floristically distinct especially with respect to rare taxa, which may reflect the unique soil characteristics. Six rare plant species are recorded from the Tiburon Peninsula. These serpentines cover about 225 acres.

Presidio - The exposed Pacific coastline supports a distinct vegetation type of Franciscan Serpentine Coastal Scrub. At Inspiration Point, Serpentine Bunchgrass Grassland exists. Eight rare plant species have been recorded from the Presidio. The serpentine habitats cover about 50 acres. The National Park Service has jurisdiction over properties within the Golden Gate National Recreation Area, while the Department of Defense maintains jurisdiction over the remaining Presidio area.

Edgewood Park - Nearly three hundred acres of serpentine vegetation, most of it Serpentine Bunchgrass Grassland, occurs at Edgewood Park. Other local vegetation types include Mixed Serpentine Chaparral, Serpentine Wildflower Fields and Serpentine Barrens. This site represents the largest contiguous serpentine area remaining in San Mateo County and has an extremely high level of plant diversity due to numerous localized soil and topographic characteristics. There are five rare plant species associated with the serpentines, as well as the bay checkerspot butterfly. Edgewood Park is under the jurisdiction of San Mateo County.

The Triangle - Formerly contiguous with the Edgewood Park serpentines, The Triangle now represents a 75 acre subset of the Edgewood Park Serpentine Bunchgrass Grasslands and Serpentine Wildflower Fields. Neither of the two rare plant species found in The Triangle occur in Edgewood Park. The Triangle is a Game Refuge of the California Department of Fish and Game, but under the jurisdiction of the San Francisco Water District.

Pulgas Ridge - The Serpentine Bunchgrass Grassland at Pulgas Ridge is an excellent example of a true bunchgrass community with native bunchgrass species forming extensive hummocks. In addition, a well-developed Serpentine Seep Vegetation is present which contains one of the two rare plant species that occur at this locality. This 300 acre site is part of the State Game Refuge system in the San Francisco watershed and under the jurisdiction of the San Francisco Water District.

Crystal Springs Reservoir - Serpentine Bunchgrass Grassland and Serpentine Seep Vegetation occur along the east side of Crystal Springs Reservoir. Four rare plant taxa have been recorded from this site in addition to the rare bay checkerspot butterfly. This site covers nearly 400 acres and is part of the State Game Refuge system in the San Francisco watershed and under the jurisdiction of the San Francisco Water District.

Jasper Ridge - Stanford University's Jasper Ridge Preserve has three areas of Serpentine Bunchgrass Grasslands which are actively used for research. There are no rare plants associated with these serpentine grasslands, but it does have the bay checkerspot butterfly. The serpentines cover about 60 acres.

Tulare Hill - Serpentine Bunchgrass Grasslands under various degrees of cattle grazing pressure occur on Tulare Hill. This 80 acre site supports one rare plant and is under private ownership.

Metcalf Canyon - An extensive area of Serpentine Bunchgrass Grassland perhaps covering more than 1000 acres, occurs along the east side of the Coyote Creek drainage. Metcalf Canyon is a major access point to these serpentines and includes Serpentine Seep Vegetation. Three rare plant taxa occur at this privately owned site.

Redwood Regional Park - Approximately fifty acres of Serpentine Bunchgrass Grassland exists in the southeast end of Redwood Regional Park. This site supports one introduced rare plant taxa, and is under the jurisdiction of the East Bay Regional Park District.

Mt. Diablo - A Mixed Serpentine Chaparral vegetation is becoming reestablished after a 1977 fire. Openings created by the fire still support native bunchgrass species and a high diversity of ephemerals. Three rare plant taxa occur on the serpentines at this site. The site covers about 150 acres and is under the jurisdiction of the California Department of Parks and Recreation.

Site Quality and Protection

Each of the thirteen sites mentioned above has one or more characteristics that make them unique. Floristic diversity, rare plants, vegetation types, size, and quality create distinct characteristics for each site. Though it is difficult to rank these sites relative to each other since each contains a unique set of rare plants and vegetation types, it is still useful to make recommendations for each sites protection and management.

The two sites under private ownership at Metcalf Canyon and Tulare Hill should be purchased by private conservation organizations or the State and set aside as preserves. Cattle grazing at all sites should be terminated as soon as possible. The San Francisco Water District lands including The Triangle, Pulgas Ridge and Crystal Springs Reservoir should be designated as ecological preserves. Edgewood Park should be given preserve status so that it can be permanently protected from alternate land usage. Jasper Ridge is currently being used for intensive study of the serpentine grasslands and should continue in order to provide better understanding of these poorly known systems. The Redwood Park serpentine area is currently managed for equestrian trails, which does not appear inconsistent with the previously disturbed grasslands. The Presidio serpentine habitat is the most disturbed and in need of protection and intensive management. Fencing may be necessary to protect some areas such as Inspiration Point in addition to habitat improvement elsewhere in the Presidio (see below). Both the Ring Mountain and St. Hilary's preserves provide excellent permanent protection for the Tiburon Peninsula serpentines. Carson Ridge, Mt. Tamalpais and Mt. Diablo appear to be adequately protected legally.

Legal protection of many of these sites does not necessarily mean habitat protection in a real sense. All of the thirteen areas mentioned should be considered vulnerable to habitat destruction, particularly from illegal off-road vehicle use. Invasive non-native plants, particularly *Eucalyptus*, continue to eliminate the native vegetation. Management should concentrate on removal of exotic trees and shrubs. The few introduced herbaceous plants on the other hand have become a part of the flora and could not be realistically eliminated.

DISCUSSION

The vegetation and flora associated with the serpentine soils of the San Francisco Bay Area are related to the local climate and soil. The climate is the principal regulator of the vegetation. The vegetation, which can be generally classified as Chaparral and Coastal Prairie, is consistent with the Region's Mediterranean climate. The floral components of this vegetation follow a distribution which is more closely allied to edaphic factors. The high species diversity is probably due to the numerous microhabitats that are characteristic of the complex serpentine environment. Differences in vegetation types such as Serpentine Bunchgrassland and Mixed Serpentine Chaparral are probably related primarily to soil depth and percent moisture. Sargent Cypress Woodland is found growing on the most nutrient poor soils. Extremely localized floristic associations of a vegetation type are probably a function of several aspects of the soil including calcium/magnesium ratio and specific nutrient concentrations such as those of nitrogen and phosphorus.

Related species follow a distribution pattern that appears to be associated with vegetation types and microhabitats within those types. For example, *Hesperolinon congestum* occurs on soils that have very low calcium/magnesium ratios (<0.1) at Ring Mountain (sample 2) and Edgewood Park (sample 3), while *Hesperolinon micranthum* was found to occur on soils with much higher calcium/magnesium ratios (0.5-0.6) at Edgewood Park (sample 2) and Mt. Tamalpais. *Hesperolinon breweri*, at Mt. Diablo, also grows on soils with a higher calcium/magnesium ratio (ca. 0.5), but has higher soil nitrogen and phosphorus than is true for the other species. *Hesperolinon micranthum* and *H. breweri* are found in Mixed Serpentine Chaparral communities while *H. congestum* occurs in Serpentine Grassland vegetation. Similarly, species of *Arctostaphylos* follow a soil related distribution but one involving the nutrients nitrogen and phosphorus. *Arctostaphylos montana* and *A. hookeri* ssp. *ravenii* both occur on soils very low in those nutrients while *A. glauca* is associated with soils having higher concentrations of those nutrients. There is a distinct distributional pattern of these species in relation to soil components, but whether the patterns are related to evolutionary adaptations is yet to be proven. Heavy metal accumulation and tolerance by plants has been thought to represent an evolutionary adaptation of plants growing on serpentines (Kruckeberg 1969, 1984), but this concept has not held true for all plants (Fiedler 1985). However, adaptation to extremely low calcium/magnesium ratios has been demonstrated in some serpentine endemics. Growth of *Helianthus bolanderi*, a serpentine endemic, was found to be unaffected by increasing soil calcium cation concentrations (Fitter and Hay 1983, p. 217 fig. 6.5, see also Turitzen 1982).

The numerous microhabitats created by the local soil and climatic conditions that occur in the San Francisco Bay Area has undoubtedly had a profound influence on the vegetation and plant species diversity. The high number of closely related species, subspecies and varieties of plants that occur in different habitats within this relatively small geographic area is evidence of the evolutionary significance of the serpentine environment. Kruckeberg (1984) has shown that nearly ten percent of the plant species diversity in California is associated with the serpentine habitats. The serpentines of the San Francisco Bay Area probably support a much higher percent diversity for this region.

The serpentine vegetation, flora and soils in the San Francisco Bay Area are unique as are, no doubt, the serpentines in other regions. This study and inventory is but an initial step in the understanding of one of California's many floristically diverse habitats. The information presented in this report should be used as a baseline with which to begin preserving habitat for serpentine vegetation in California in order to protect significant areas of our natural heritage.

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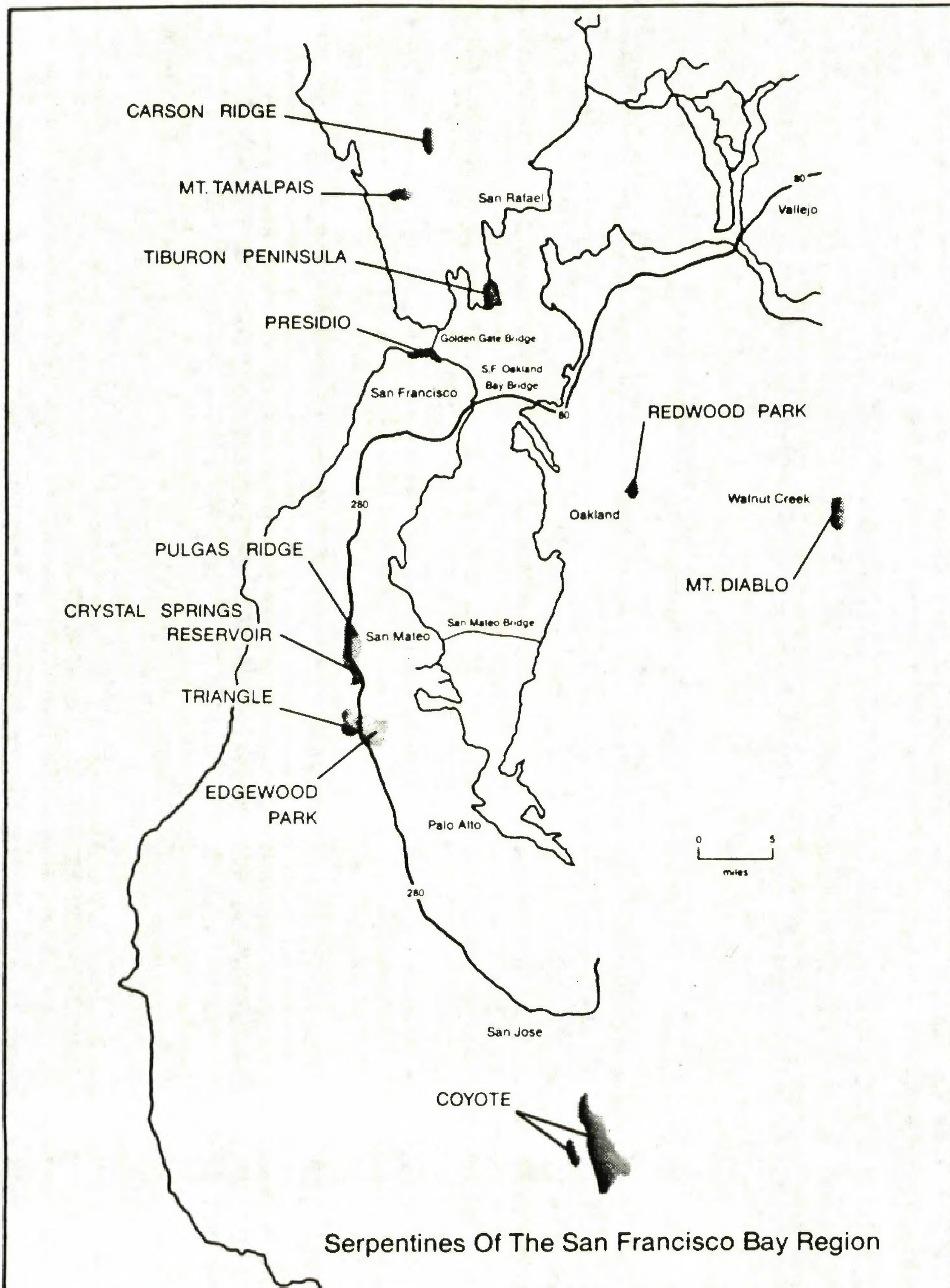
APPENDIX A - MAPS

Serpentine soil habitats are outlined on topographic maps. The boundaries of the serpentine soil habitats represent non-specific edges and may include non-serpentine soils and exclude more localized patches of serpentine soil. These maps are meant to represent the general vicinity of significant and representative serpentine soil habitats in the greater San Francisco Bay region.

MAP 1

SERPENTINES OF THE SAN FRANCISCO BAY REGION

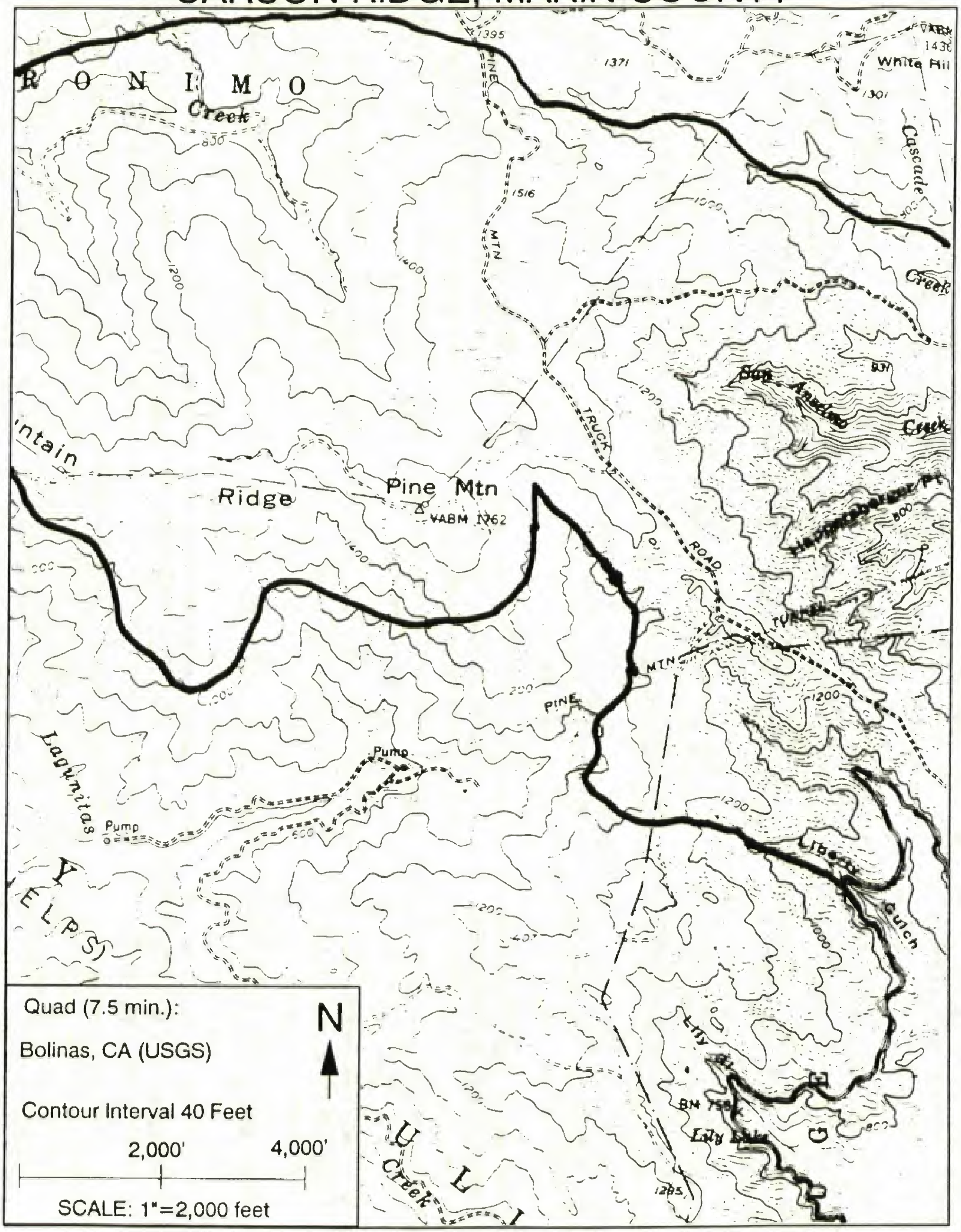


Serpentines Of The San Francisco Bay Region

MAP 2

CARSON RIDGE, MARIN COUNTY

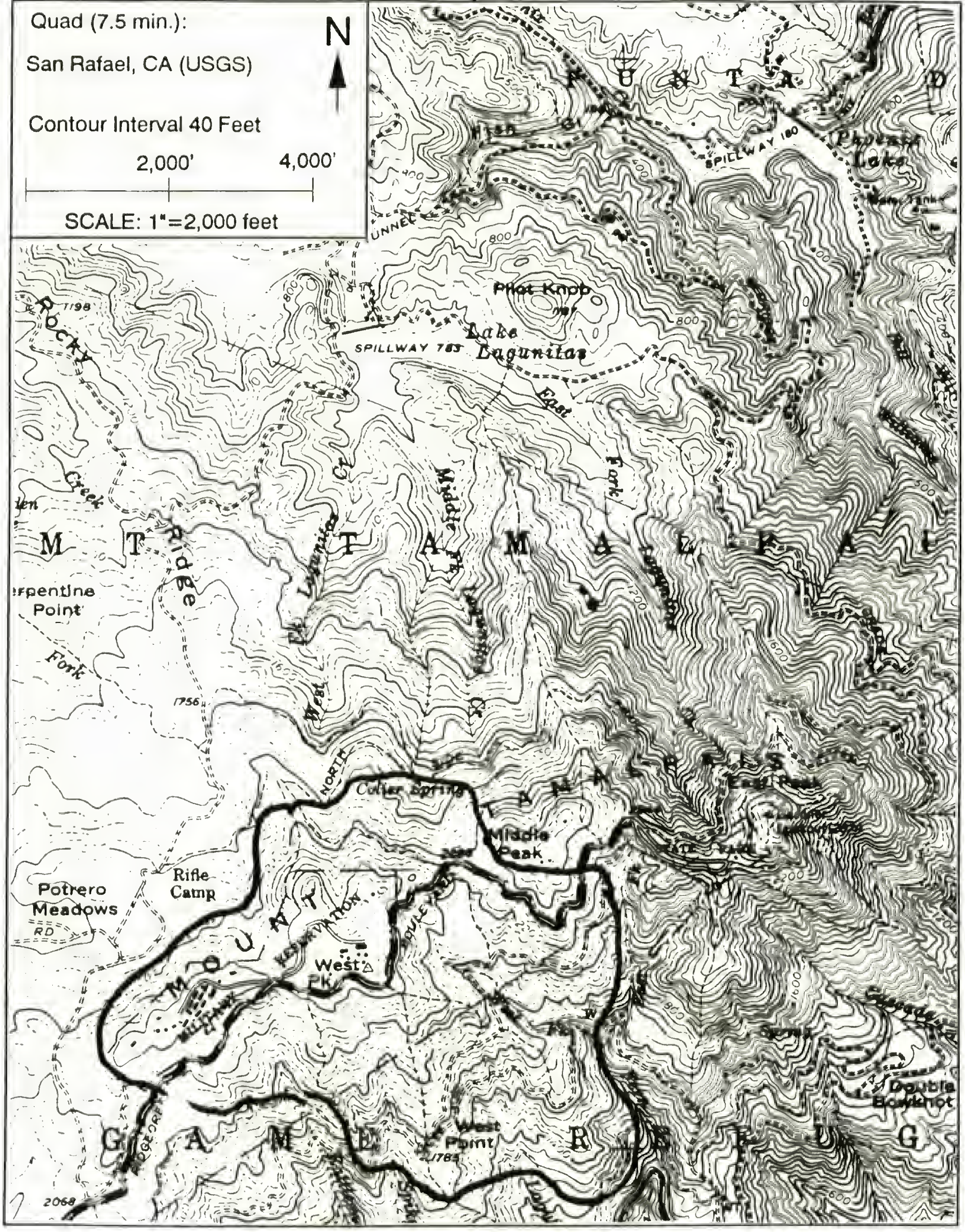
MAP 2
CARSON RIDGE, MARIN COUNTY



MAP 3

MT. TAMALPAIS, MARIN COUNTY

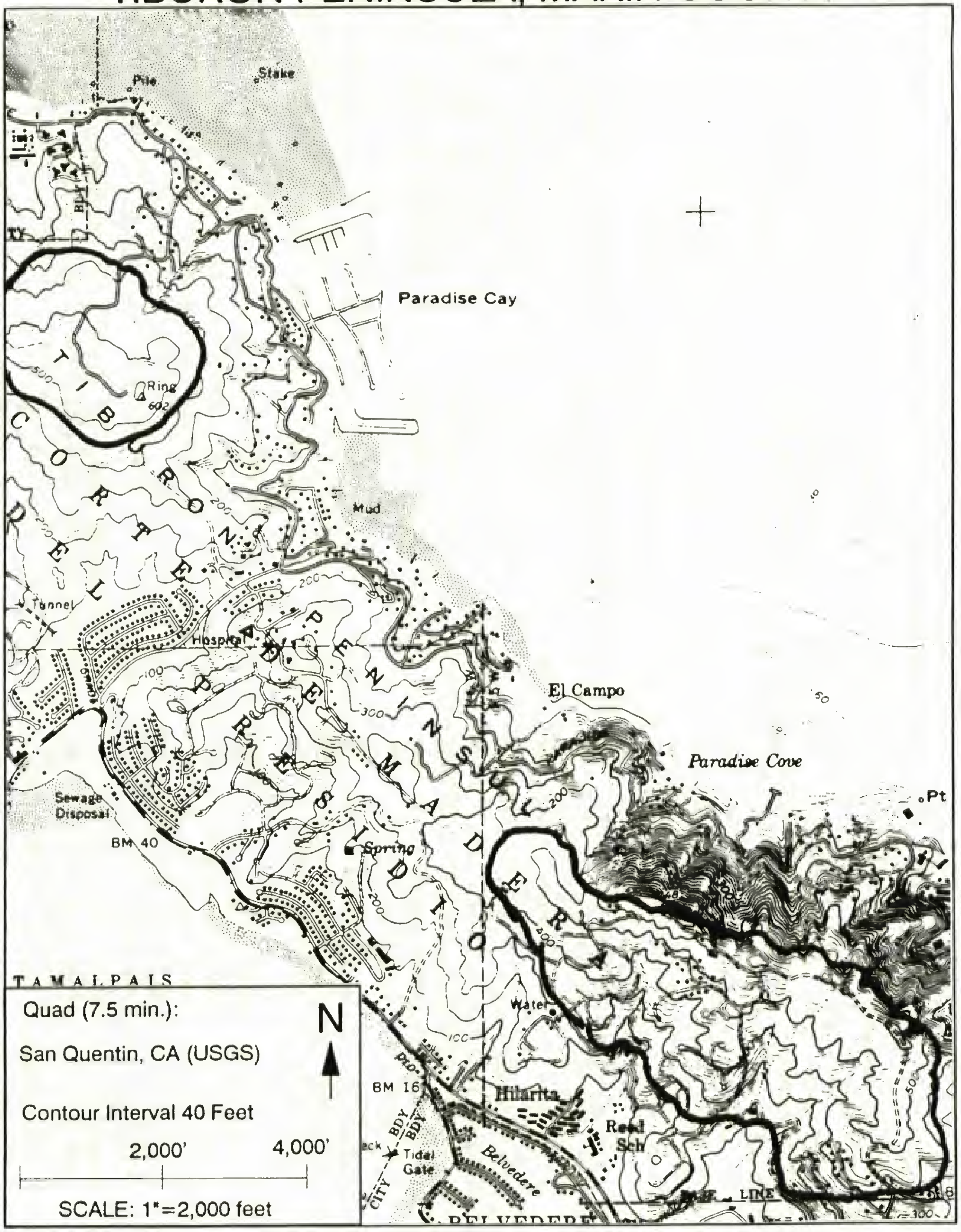
MAP 3
MT. TAMALPAIS, MARIN COUNTY



MAP 4

TIBURON PENINSULA, MARIN COUNTY

MAP 4
TIBURON PENINSULA, MARIN COUNTY



MAP 5

THE PRESIDIO, SAN FRANCISCO COUNTY

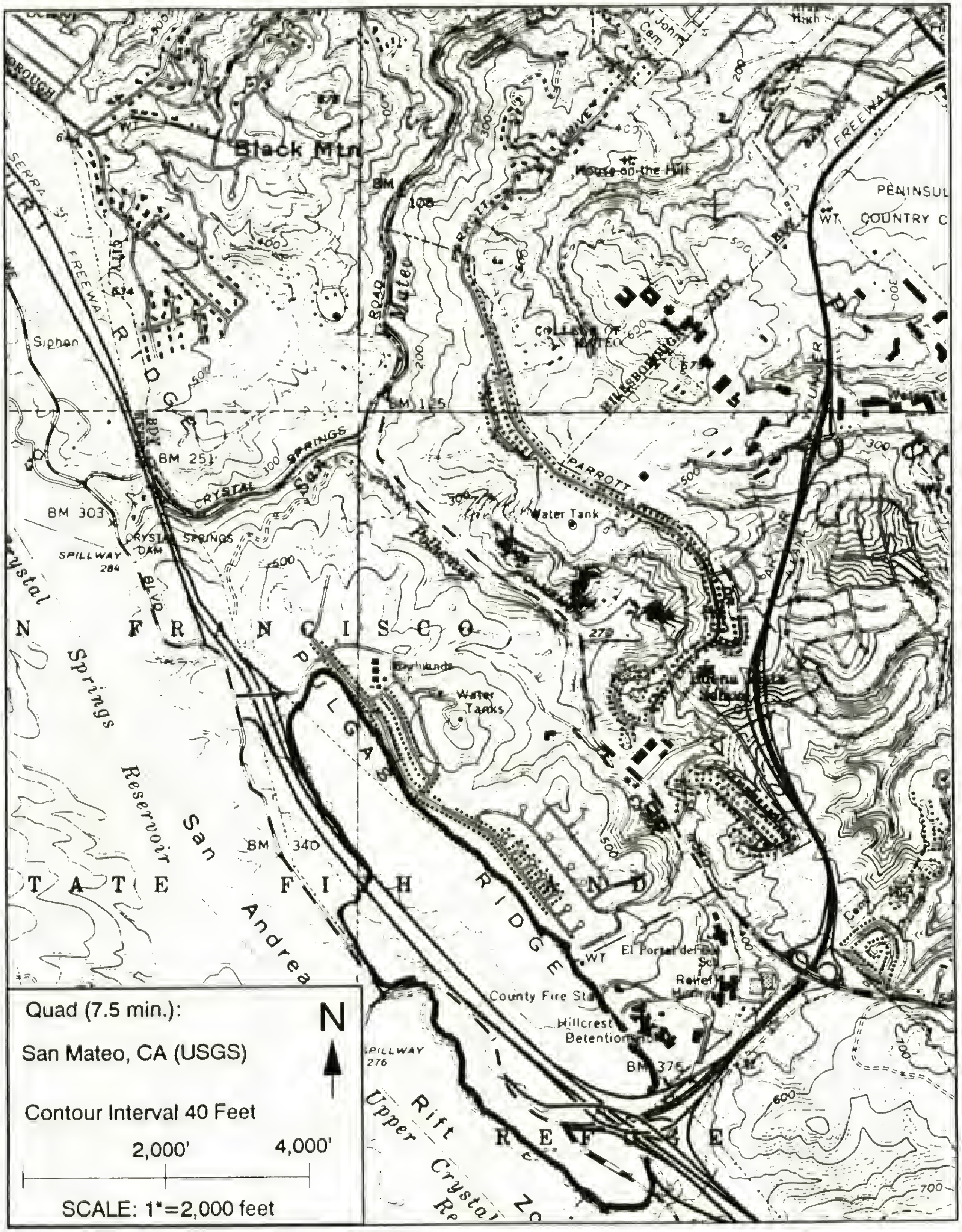
MAP 5
THE PRESIDIO, SAN FRANCISCO COUNTY

MAP 6

PULGAS RIDGE & CRYSTAL SPRINGS RESERVOIR, SAN MATEO COUNTY

MAP 6

PULGAS RIDGE & CRYSTAL SPRINGS RESERVOIR, SAN MATEO CO.

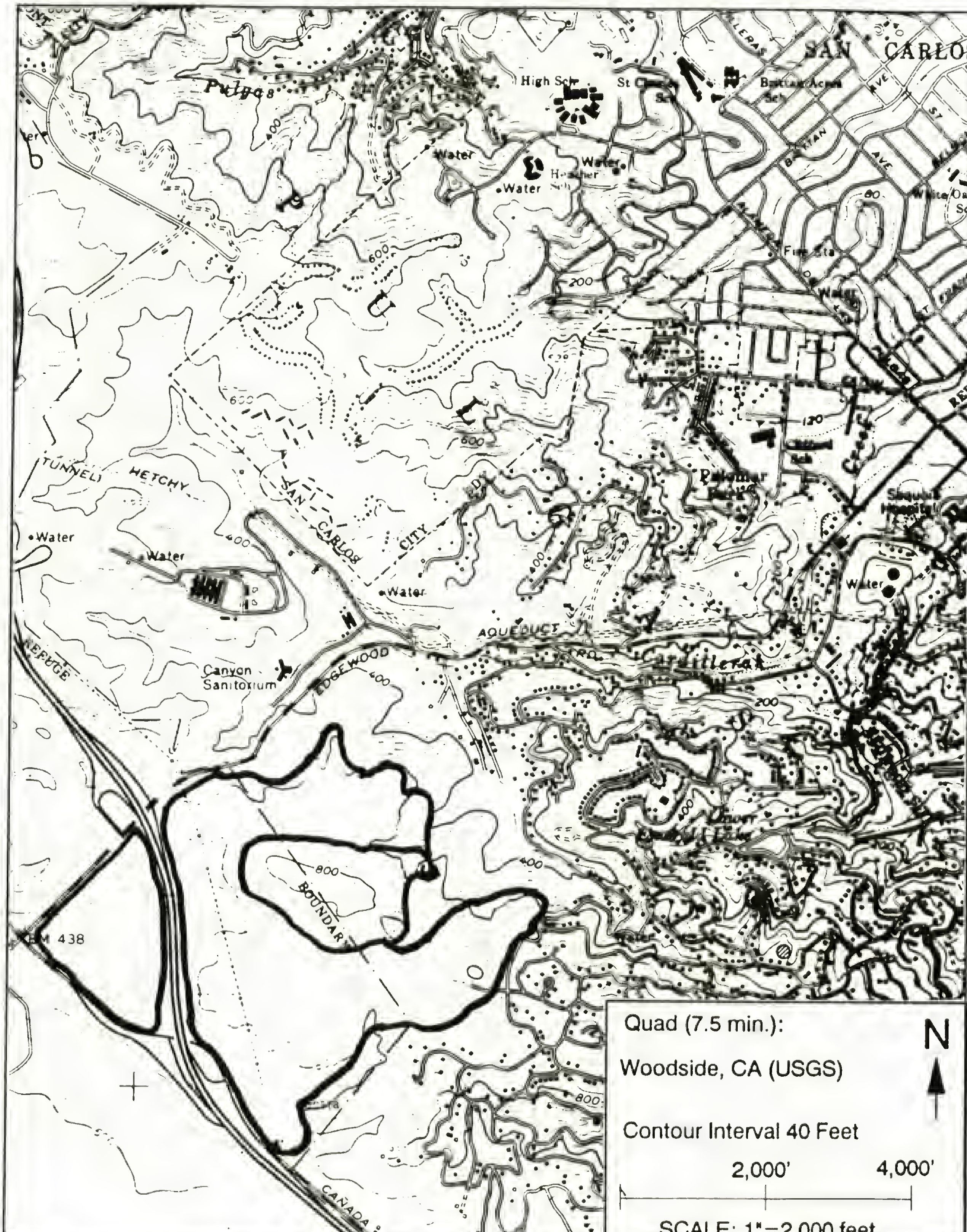


MAP 7

EDGEWOOD PARK & TRIANGLE, SAN MATEO COUNTY

MAP 7

EDGEWOOD PARK & TRIANGLE, SAN MATEO COUNTY



MAP 8

JASPER RIDGE, SAN MATEO COUNTY

MAP 8
JASPER RIDGE, SAN MATEO COUNTY

Quad (7.5 min.):

Palo Alto, CA (USGS)

N

Contour Interval 40 Feet

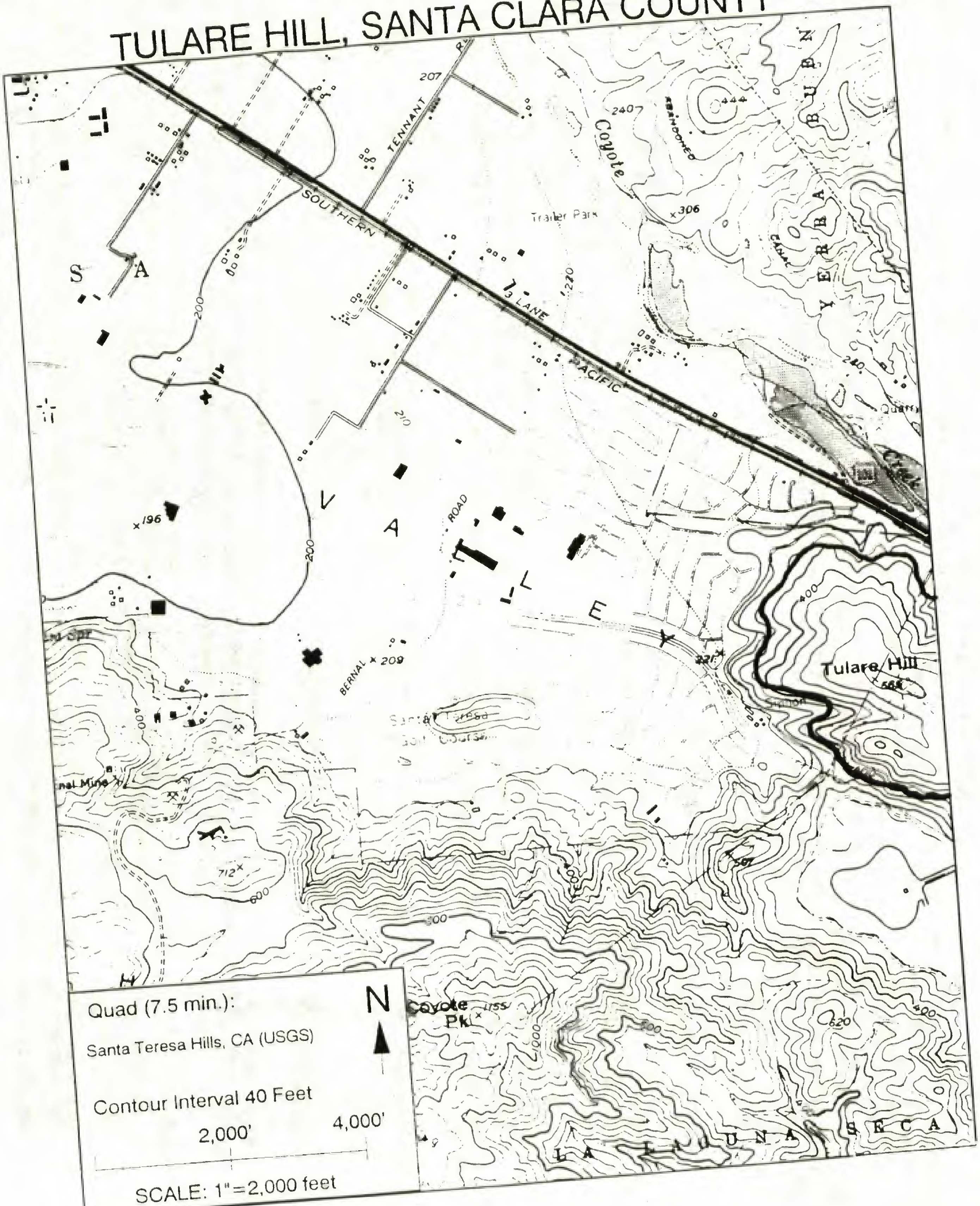
2,000' 4,000'

SCALE: 1"=2,000 feet

MAP 9

TULARE HILL, SANTA CLARA COUNTY

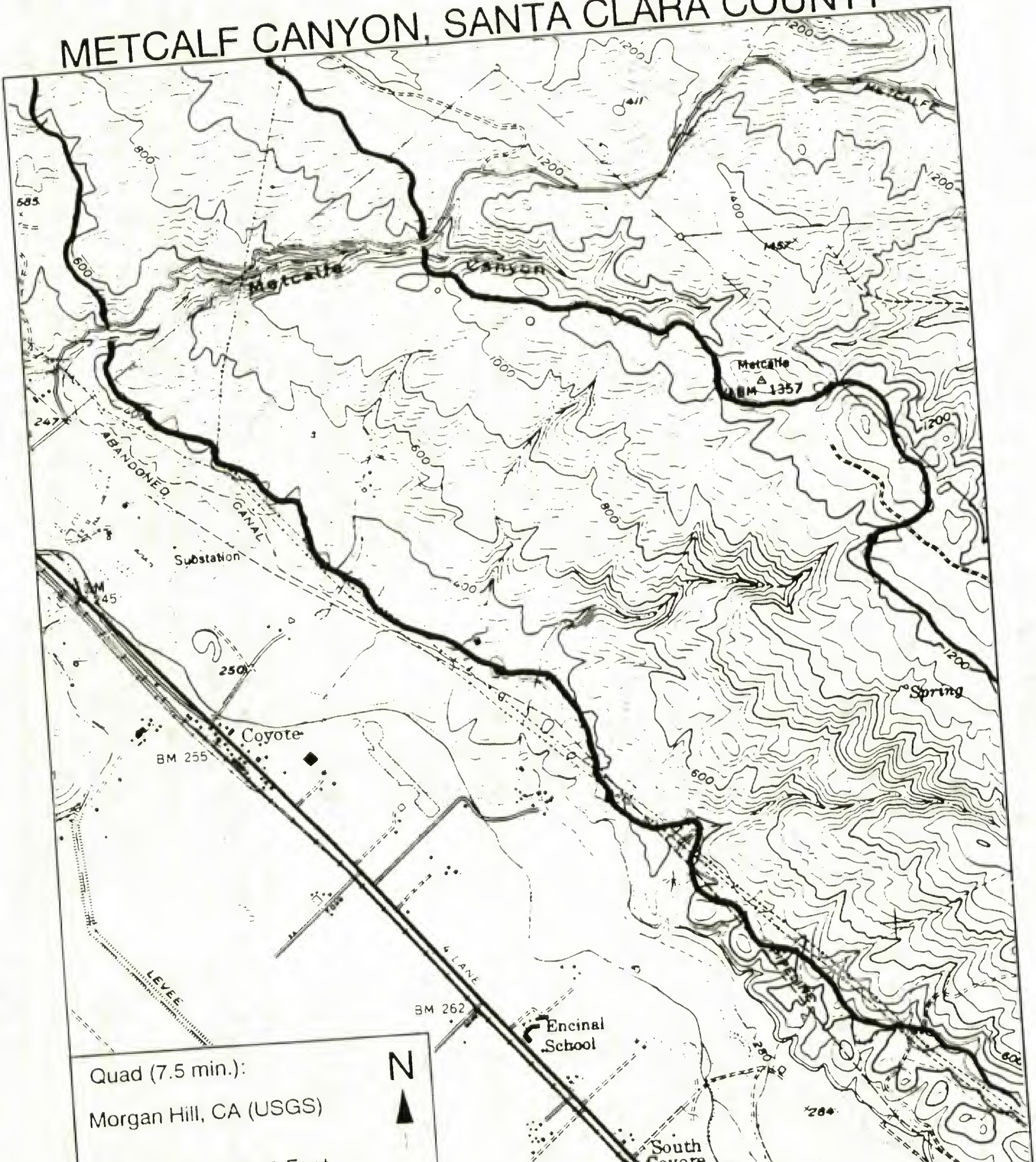
MAP 9
TULARE HILL, SANTA CLARA COUNTY



MAP 10

METCALF CANYON, SANTA CLARA COUNTY

MAP 10
METCALF CANYON, SANTA CLARA COUNTY



Quad (7.5 min.):

Morgan Hill, CA (USGS)

Contour Interval 40 Feet

2,000' 4,000'

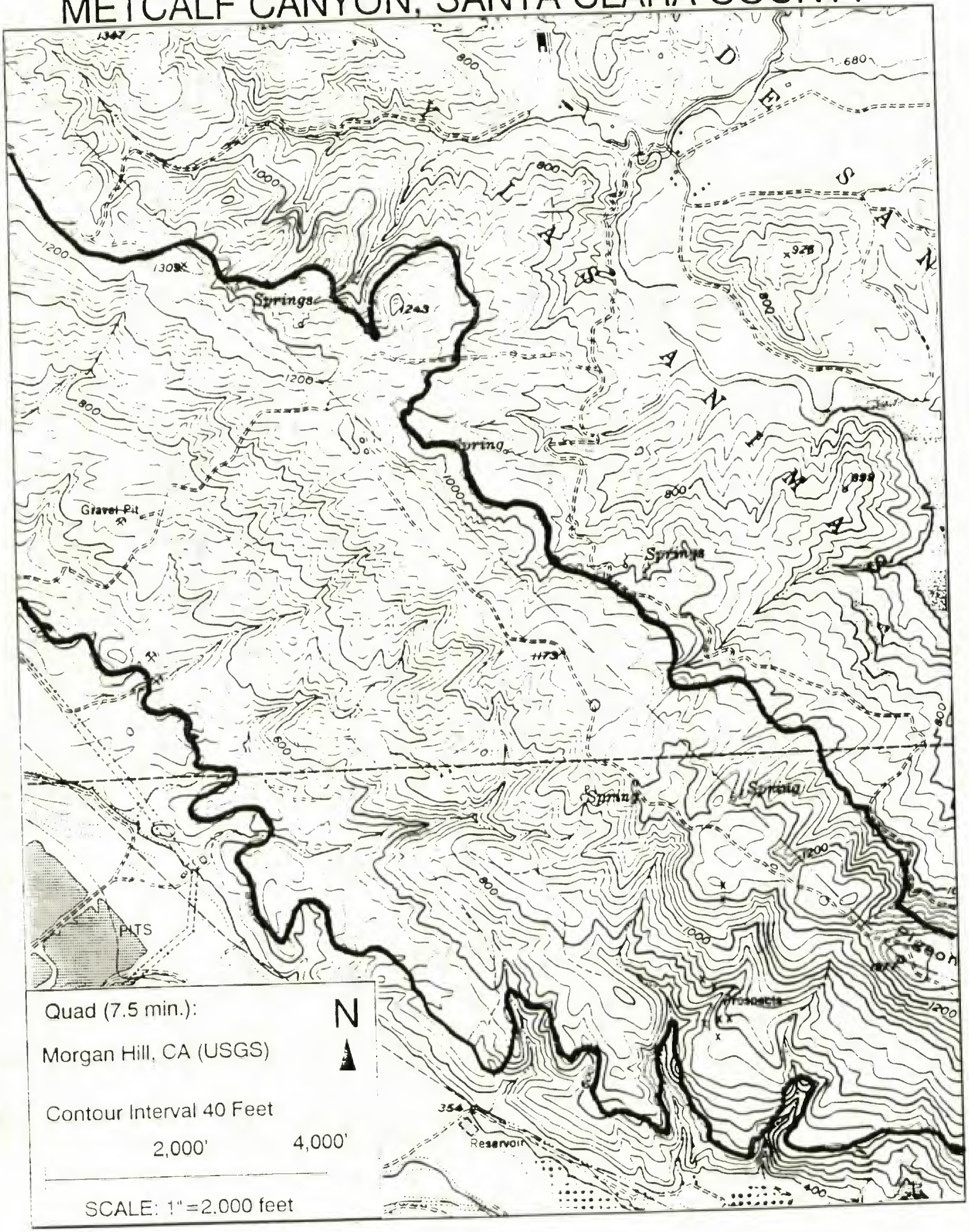
SCALE: 1"=2,000 feet

N

MAP 11

METCALF CANYON, SANTA CLARA COUNTY

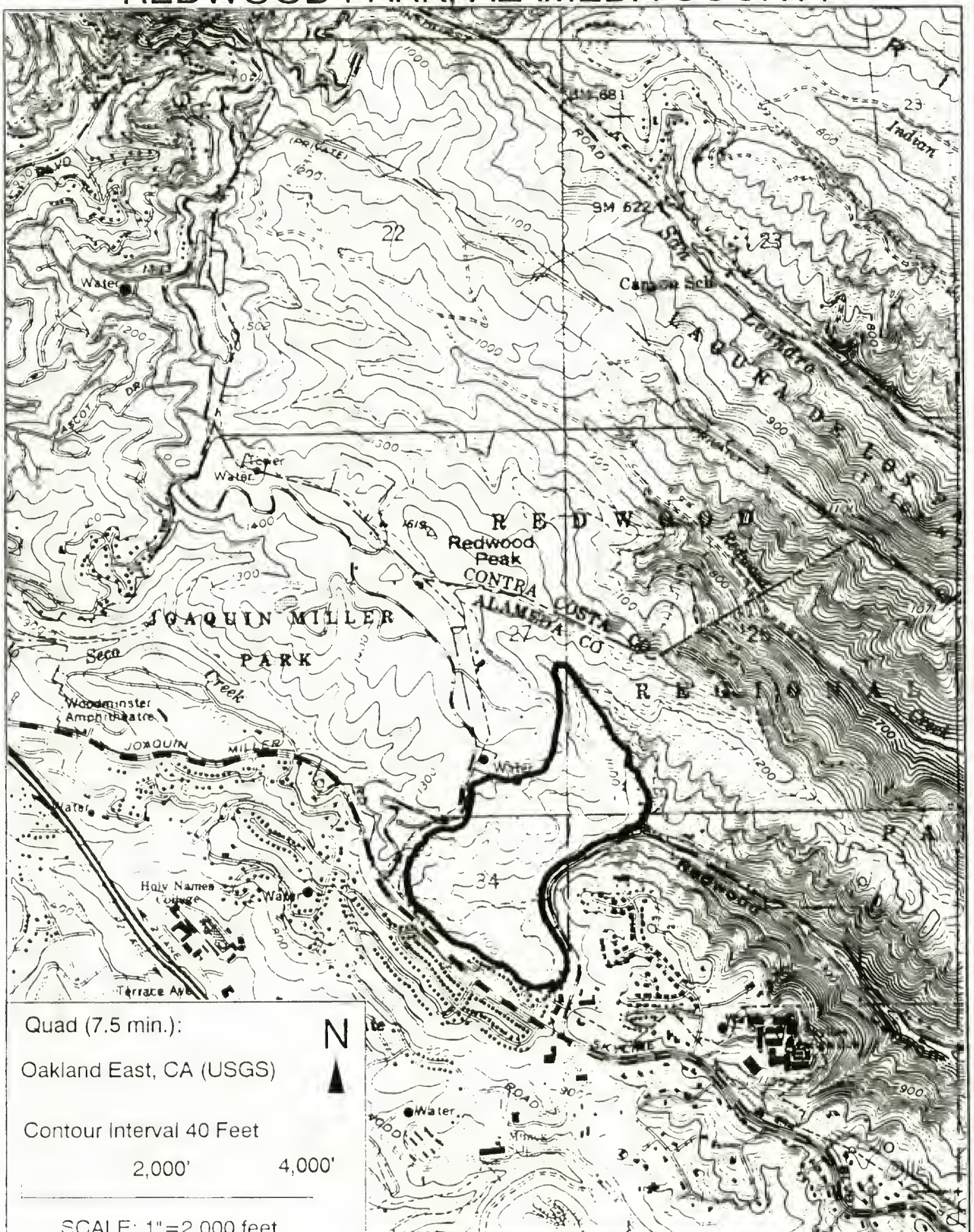
MAP 11
METCALF CANYON, SANTA CLARA COUNTY



MAP 12

REDWOOD PARK, ALAMEDA COUNTY

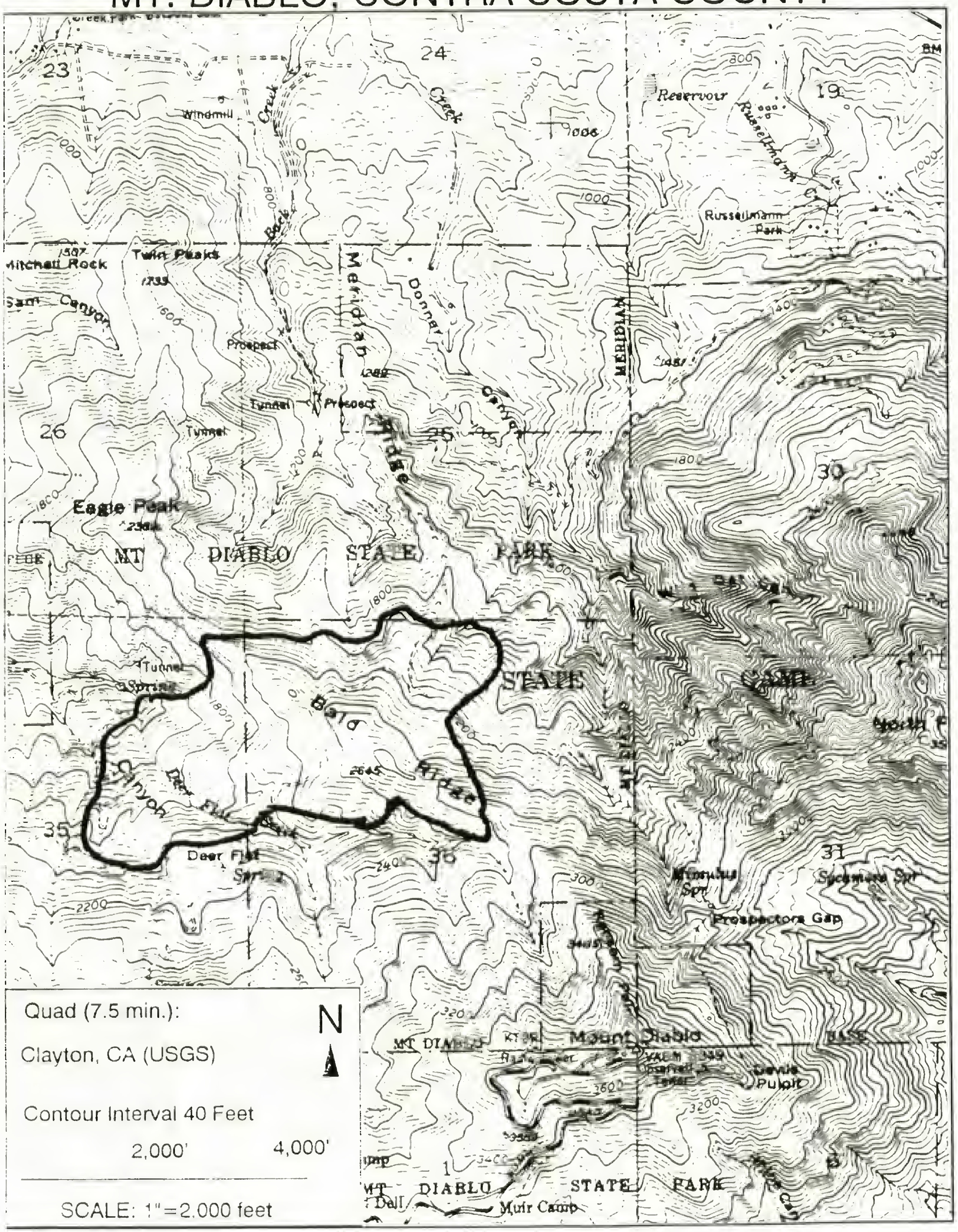
MAP 12
REDWOOD PARK, ALAMEDA COUNTY



MAP 13

MT. DIABLO, CONTRA COSTA COUNTY

MAP 13
MT. DIABLO, CONTRA COSTA COUNTY



APPENDIX B - TABLES

TABLE 1

Serpentine Sites in the San Francisco Bay Area

County	Site	Map
Marin	Carson Ridge	2
Marin	Mt. Tamalpais	3
Marin	Tiburon Peninsula	4
San Francisco	Presidio	5 & 6
San Mateo	Edgewood Park	7 & 8
San Mateo	Triangle	7 & 8
San Mateo	Pulgas Ridge	7 & 9
San Mateo	Crystal Springs Reservoir	7 & 9
San Mateo	Jasper Ridge	7 & 10
Santa Clara	Tulare Hill	11
Santa Clara	Metcalf Canyon	12
Alameda	Redwood Park	13
Contra Costa	Mt. Diablo	14

TABLE 2

Floristic Analysis

Family	Genera	Species	Family	Genera	Species
Amaryllidaceae	5	18	Lauraceae	1	1
Anacardiaceae	1	1	Liliaceae	5	11
Apiaceae	10	16	Linaceae	2	6
Asclepiadaceae	1	1	Malvaceae	2	3
Asteraceae	43	74	Myrtaceae	1	1
Boraginaceae	4	6	Onagraceae	3	10
Brassicaceae	8	14	Orobanchaceae	1	1
Campanulaceae	1	1	Papaveraceae	2	2
Caprifoliaceae	3	3	Plantaginaceae	1	3
Caryophyllaceae	4	8	Poaceae	24	50
Convolvulaceae	2	3	Polemoniaceae	3	12
Crassulaceae	2	3	Polygonaceae	3	6
Cupressaceae	1	1	Polypodiaceae	1	1
Cyperaceae	1	2	Portulacaceae	3	4
Dipsacaceae	1	1	Primulaceae	2	3
Ericaceae	2	5	Pteridaceae	4	5
Euphorbiaceae	2	3	Ranunculaceae	3	5
Fabaceae	9	32	Rhamnaceae	2	3
Fagaceae	1	5	Rosaceae	6	6
Garryaceae	1	1	Rubiaceae	2	5
Gentianaceae	2	3	Salicaceae	1	1
Geraniaceae	2	5	Saxifragaceae	2	2
Grossulariaceae	1	1	Scrophulariaceae	9	23
Hippocastinaceae	1	1	Solanaceae	1	1
Hydrophyllaceae	3	6	Valerianaceae	1	4
Iridaceae	1	1	Verbenaceae	1	1
Juncaceae	1	5	Violaceae	1	1
Lamiaceae	6	11			

TABLE 3

Rare Plants and Their Status

Species	Status
Acanthomintha obovata ssp. *duttonii*	FE, CE, NDDB, CNPS
Arctostaphylos hookeri ssp. *franciscana*	EXTINCT
Arctostaphylos hookeri ssp. *ravenii*	FE, CE, NDDB, CNPS
Arctostaphylos montana	C2, NDDB, CNPS
Calamogrostis ophitidis	CNPS
Calochortus tiburonensis	C2, CR, NDDB, CNPS
Castilleja neglecta	C1, CR, NDDB, CNPS
Cirsium campylon	C2, NDDB, CNPS
Cirsium fontinale var. *fontinale*	C1, CE, NDDB, CNPS
Clarkia franciscana	C1, CE, NDDB, CNPS
Collinsia franciscana	CNPS
Cordylanthus nidularius	C1, CR, NDDB, CNPS
Dudleya setchellii	C1, NDDB, CNPS
Eriogonum caninum	CNPS
Erysimum franciscanum	C2, CNPS
Fritillaria liliacea	C2, NDDB, CNPS
Grindelia maritima	C2, NDDB, CNPS
Hemizonia multicaulis ssp. *vernalis*	C2, CNPS
Hesperolinon breweri	C2, NDDB, CNPS
Hesperolinon congestum	C1, NDDB, CNPS
Lessingia germanorum var. *germanorum*	C1, CE, NDDB, CNPS
Orthocarpus floribundus	C2, NDDB, CNPS
Pedicularis dudleyi	C3C, CR, NDDB, CNPS
Pentachaeta bellidiflora	C2, NDDB, CNPS
Plagiobothrys diffusus	EXTINCT, C2, CE, NDDB, CNPS
Sanicula maritima	C2, CR, NDDB, CNPS
Silene verecunda ssp. *verecunda*	C2, NDDB, CNPS
Streptanthus albidus ssp. *albidus*	C1, NDDB, CNPS
Streptanthus batrachopus	C2, NDDB, CNPS
Streptanthus glandulosus ssp. *pulchellus*	C3C, NDDB, CNPS
Streptanthus hispidus	C2, NDDB, CNPS
Streptanthus niger	C1, CE, NDDB, CNPS
Trifolium amoenum	EXTINCT, C2, NDDB, CNPS

Status: FE = Federally Endangered
C1, C2 & C3C = Federal Candidate for listing
CE = Listed as Endangered by the State of California
CR = Listed as Threatened by the State of California
NDDB = Tracked by the California Natural Diversity Data Base
CNPS = Listed in the Inventory (see Smith and Berg, 1988)

TABLE 4

Rare Plant Distributions

Location Species	Element Occurrence*
Carson Ridge	
Arctostaphylos montana	003
Hesperolinon congestum	028
Streptanthus batrachopus	003
Streptanthus glandulosus ssp. *pulchellus*	003
Mt. Tamalpais	
Arctostaphylos montana	008, 010, 011
Streptanthus glandulosus ssp. *pulchellus*	-
Presidio	
Arctostaphylos hookeri ssp. *ravenii*	004
Clarkia franciscana	002, 003
Grindelia maritima	005, 015
Hesperolinon congestum	020
Lessingia germanorum var. *germanorum*	001
Orthocarpus floribundus	019
Plagiobothrys diffusus	002
Silene verecunda ssp. *verecunda*	009
Tiburon Peninsula (Ring Mtn. & St. Hilary's)	
Calochortus tiburonensis	001
Castilleja neglecta	001-004
Hemizonia multicaulis ssp. *vernalis*	-
Hesperolinon congestum	006-010
Streptanthus niger	001, 002
Trifolium amoenum	022
Mt. Diablo	
Cordylanthus nidularius	001
Hesperolinon breweri	002-006, 021, 022
Streptanthus hispidus	001-004, 006, 007
Redwood Regional Park	
Clarkia franciscana	004
Portrero Hill	
Sanicula maritima	005

TABLE 4 (continued)

Location Species	Element Occurrence*
Pulgas Ridge	
Cirsium fontinale var. *fontinale*	002
Fritillaria liliacea	019
Crystal Springs Reservoir	
Acanthomintha obovata ssp. *duttonii*	004
Cirsium campylon	029
Hesperolinon congestum	001, 003, 019
Pentachaeta bellidiflora	007
Edgewood Park	
Acanthomintha obovata ssp. *duttonii*	003, 005
Fritillaria liliacea	-
Hesperolinon congestum	004, 017
Pedicularis dudleyi	009
Silene verecunda ssp. *verecunda*	010
Triangle	
Cirsium fontinale var. *fontinale*	004
Pentachaeta bellidiflora	001
Tulare Hill	
Dudleya setchellii	-
Metcalf Canyon	
Cirsium campylon	007-016
Dudleya setchellii	-
Streptanthus albidus ssp. *albidus*	002, 004

* These occurrences do not necessarily represent extant populations.

APPENDIX C

PLANT SPECIES INVENTORY FOR THE SERPENTINES

IN THE SAN FRANCISCO BAY REGION

INVENTORY INFORMATION

This inventory includes 402 taxa which are known to grow on serpentine soils at the locations marked by an "X". Introduced exotic species included in this list are limited to those that have become well established and form distinct populations. Thus, a few exotic species that were only represented by a single plant and may be removed for management reasons have been excluded.

The inventory is based on a number of plant species checklists and floras, Cahill 1975, Culligan 1982, Howell 1970, Howell et al. 1958, Porter 1962 and Sommers 1986, plus species lists for the Ring Mountain Preserve supplied by Greg Wolley of The California Nature Conservancy and field notes for Mt. Diablo supplied by Mary Ann Showers. Some of these plant species sources include plants not growing on serpentine soils and therefore have been edited to reflect only serpentine species. The determination of serpentine plant taxa at these sites is further based on numerous field surveys during 1986 specifically for this study.

The thirteen localities have been roughly divided into two groupings with Mt. Diablo, Mt. Tamalpais and Carson Ridge designated as Serpentine Chaparral and the remaining sites as Serpentine Grassland. However, Serpentine Chaparral and a variety of shrub species do occur, to a limited extent, in Edgewood Park and a couple other localities.

Locality Designations

The following are the sites corresponding to the four-letter codes in the columns of the inventory.

Metc = Metcalf Canyon

Tula = Tulare Hill

Redw = Redwood Regional Park

Jasp = Jasper Ridge Preserve

Edge = Edgewood County Park

Tria = The Triangle

Pulg = Pulgas Ridge

Crys = Crystal Springs Reservoir

Pres = Presidio

Tibu = Tiburon Peninsula

Tama = Mt. Tamalpais

Cars = Carson Ridge

Diab = Mt. Diablo

Species	SERPENTINE GRASSLANDS										SERPENTINE CHAPARRAL		
	Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	Tama	Cars	Diab
Acacia decurrens						X							
Acanthomintha obovata ssp *duttonii*					X								
Achillea borealis ssp *californica*					X					X			
Achillea millefolium	X	X	X		X	X	X	X	X	X	X	X	X
Achyrachaena mollis	X	X	X	X	X	X	X	X	X	X			
Adenostoma fasciculatum					X						X	X	X
Adiantum jordanii					X	X							
Aesculus californica						X							
Agoseris apargioides			X								X		
Agoseris grandiflora				X		X				X			
Agoseris heterophylla	X	X		X	X	X		X			X		
Agropyron trachycaulum										X			
Agrostis exarata					X								
Agrostis hallii										X			
Agrostis microphylla				X									
Aira caryophyllea	X	X		X	X	X			X	X			
Alchemilla occidentalis	X	X		X	X	X		X	X	X			
Allium amplectens	X	X	X	X	X	X	X	X	X	X	X	X	X
Allium breweri				X									
Allium dichlamydeum					X	X							
Allium falcifolium					X	X		X		X	X		X
Allium lacunosum				X	X					X			
Allium serratum	X	X				X							
Allium triquetrum					X								
Allium unifolium										X			
Amsinckia intermedia	X	X	X	X	X	X							
Anagallis arvensis	X				X	X		X		X			
Angelica tomentosa						X							
Aquilegia eximia											X		
Arbutus menziesii						X							
Arctostaphylos glauca	X												X
Arctostaphylos hookeri ssp *ravenii*									X				
Arctostaphylos montana											X	X	
Arctostaphylos viscida											X	X	
Artemisia californica	X	X			X			X	X	X			
Artemisia douglasiana					X								

	SERPENTINE GRASSLANDS										SERPENTINE CHAPARRAL		
Species	Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	Tama	Cars	Diab
Asclepias fascicularis				X	X	X		X					
Aster chilensis					X					X			
Astragalus gambelianus	X	X	X	X	X	X		X	X	X			X
Avena barbata	X	X	X	X	X	X	X	X	X	X	X		X
Avena fatua				X	X	X							
Avena sativa						X							
Baccharis pilularis var *consanguinea*	X		X		X	X	X	X	X	X			
Bellardia trixago					X	X							
Bidens laevis						X							
Bowlesia incana						X							
Brassica nigra						X							
Briza minor				X		X							
Brodiaea congesta	X	X			X	X	X	X		X			
Brodiaea coronaria	X	X		X	X	X	X			X			
Brodiaea elegans				X	X	X				X			
Brodiaea hyacinthina				X	X	X							
Brodiaea peduncularis										X			
Brodiaea pulchella	X	X	X	X	X	X	X	X	X	X			
Bromus carinatus				X		X	X	X					
Bromus diandrus					X								X
Bromus madritensis					X					X			
Bromus mollis	X	X	X	X		X	X	X			X		X
Bromus rubens	X	X	X	X	X	X	X	X	X	X	X	X	X
Bromus tectorum											X		
Calamagrostis ophitidis			X				X	X		X	X	X	
Calandrinia ciliata var *menziesii*	X	X		X	X	X	X	X		X			
Calochortus albus					X	X							
Calochortus luteus				X	X	X							
Calochortus superbus	X	X											
Calochortus tiburonensis										X			
Calochortus umbellatus										X			
Calochortus venustus				X	X	X							
Calycadenia mulitglandulosa var *cephalotes*			X							X	X		
Calycadenia multiglandulosa ssp *robusta*			X	X									
Calystegia malacophylla										X			X
Calystegia subacaulis	X	X	X	X	X	X	X	X	X	X	X		

Species	SERPENTINE GRASSLANDS										SERPENTINE CHAPARRAL		
	Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	Tama	Cars	Diab
Cardamine oligosperma					X								
Carex mendocinensis											X		
Carex serratodens	X	X			X	X		X		X			
Castilleja neglecta										X			
Castilleja stenantha											X		
Caucalis microcarpa	X	X				X	X	X					
Ceanothus cuneatus					X								X
Ceanothus jepsonii var *albiflorus*											X	X	
Centaurea calcitrapa					X								
Centaurea melitensis						X							
Centaurea solstitialis					X								
Centaurium davyi					X	X							
Centaurium muehlenbergii										X			
Chaetopappa alsinoides				X									
Cheilanthes siliquosa											X		
Chlorogalum pomeridianum	X	X	X	X	X	X	X	X	X	X	X	X	
Cirsium campylon	X					X							
Cirsium fontinale var *fontinale*							X						
Cirsium vaseyi											X		
Cirsium vulgare					X	X							
Clarkia affinis			X										
Clarkia franciscana			X						X				
Clarkia purpurea ssp *purpurea*					X								
Clarkia purpurea var *quadrivulnera*				X						X			
Clarkia purpurea ssp *viminea*				X	X								
Clarkia rubicunda ssp *rubicunda*					X					X			
Collinsia franciscana					X								
Collinsia heterophylla	X	X			X	X	X	X		X			
Collinsia sparsiflora var *collina*					X			X					X
Convolvulus occidentalis						X							
Cordylanthus nidularius													X
Cordylanthus pilosus				X	X								
Cordylanthus rigidus					X	X							
Corethrogyne californica							X	X					
Cortaderia selloana			X							X			
Crassula erecta	X	X		X	X	X	X	X		X			

Species	Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	Tama	Cars	Diab
	SERPENTINE GRASSLANDS										SERPENTINE CHAPARRAL		
Cryptantha flaccida				X	X	X				X			
Cupressus sargentii			X								X		X
Danthonia californica	X	X			X	X	X	X					
Daucus pusillus						X				X			
Delphinium hesperium				X	X	X							
Delphiniun variegatum	X	X		X	X	X	X	X		X			
Deschampsia danthonoides					X					X			
Dipsacus sylvestris						X		X					
Dodecatheon hendersonii ssp *cruciatum*				X	X	X				X			
Dodecatheon hendersonii ssp *hendersonii*													
Dudleya farinosa									X	X			
Dudleya setchellii	X	X											
Elymus glaucus				X	X	X		X		X		X	X
Elymus triticoides										X			
Epilobium foliosum										X			
Epilobium minutum				X	X	X				X			X
Epilobium paniculatum						X				X			
Eremocarpus setigerus	X	X		X	X								
Erigeron foliosus				X									
Eriodictyon californicum					X								
Eriogonum caninum	X	X	X	X	X	X				X	X		
Eriogonum nudum	X	X		X	X	X	X	X	X	X			
Eriogonum virgatum						X							
Eriophyllum confertiflorum	X	X		X	X	X		X		X			
Eriophyllum lanatum var *achillaeoides*											X		
Eriophyllum staechadifolium var *artemisiaefolium*									X				
Erodium botrys				X						X			
Erodium cicutarium	X	X	X	X	X	X	X	X		X			
Erodium obtusiplicatum				X									
Erysimum franciscanum							X	X					
Eschscholzia californica	X	X	X	X	X	X	X	X	X	X			
Eucalyptus globulus						X			X				
Euphorbia crenulata	X	X			X		X	X					
Euphorbia spathulata						X				X			
Evax sparsiflora	X	X	X	X	X	X	X	X	X	X	X		
Festuca californica													X

Species	Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	Tama	Cars	Diab
	SERPENTINE GRASSLANDS										SERPENTINE CHAPARRAL		
Festuca idahoensis			X							X	X	X	
Festuca rubra			X										
Filago californica										X	X		
Foeniculum vulgare					X	X		X					
Fritillaria lanceolata					X								
Fritillaria liliacea					X		X						
Galium andrewsii													X
Galium aparine	X	X				X		X		X			X
Galium nuttallii		X			X	X	X			X			
Galium parisense						X							
Garrya congdoni											X		
Gastridium ventricosum				X						X			
Geranium dissectum			X	X	X			X		X			
Geranium molle				X									
Gilia achilleaefolia ssp *achilleaefolia*	X		X			X				X			
Gilia capitata	X	X				X		X		X			
Gilia clivorum				X	X		X	X		X			
Gilia tricolor		X			X	X							
Gnaphalium californicum						X							
Gnaphalium purpurium				X									
Grindelia camporum var *camporum*			X	X									
Grindelia hirsutula			X	X						X			
Grindelia maritima									X				
Grossularia californica						X							
Gutierrezia californica			X										
Helenium bigelovii										X	X		
Helianthella californica				X									
Helianthus annuus						X							
Hemizonia luzulaefolia var *lutescens*										X			
Hemizonia luzulaefolia ssp *luzulaefolia*			X										
Hemizonia luzulaefolia ssp *rudis*			X	X	X	X							
Hemizonia multicaulis ssp *vernalis*										X			
Hemizonia pungens ssp *maritima*						X							
Heserolinon breweri													X
Hesperolinon californicum									X			X	
Hesperolinon congestum					X			X	X	X		X	

Species	SERPENTINE GRASSLANDS										SERPENTINE CHAPARRAL		
	Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	Tama	Cars	Diab
Hesperolinon micranthum					X	X					X	X	
Heterocodon rariflorum											X		
Heteromeles arbutifolia					X	X				X	X		X
Hieracium albiflorum										X			
Holocarpha virgata					X								
Hordeum brachyantherum	X	X			X	X	X	X	X	X			
Hordeum californicum										X			
Hordeum geniculatum					X								
Hordeum hystrix				X						X			
Hordeum leporinum	X	X		X	X	X		X	X				X
Hordeum vulgare						X							
Hypochoeris glabra			X	X						X	X		
Hypochoeris radicata										X			
Juncus bufonius	X	X	X	X	X	X	X	X	X	X			
Juncus effusus var *brunneus*										X			
Juncus effusus var *pacificus*										X			
Juncus patens					X	X							
Juncus phaeocephalus				X									
Koeleria macrantha			X		X		X	X		X	X		X
Lactuca saligna			X										
Lactuca serriola	X	X	X	X	X	X		X		X			
Lagophylla ramosissima				X	X								
Lamarckia aurea	X	X											
Lasthenia californica	X	X	X	X	X	X	X	X		X			
Lasthenia glabrata						X							
Layia platyglossa ssp *campestris*	X		X	X	X	X	X	X		X			
Lepidium lasiocarpum													
Lepidium nitidum	X	X	X	X	X	X	X	X	X	X			
Lessingia germanorum var *tenuipes*				X									
Lessingia hololeuca var *hololeuca*				X	X	X							
Lewisia rediviva	X	X			X								X
Linanthus ambiguus					X	X							
Linanthus androsaceous			X	X	X			X		X			
Linanthus bicolor				X	X								
Linanthus dichotomus		X		X		X							
Linanthus liniflorus	X			X	X	X		X					

Species	SERPENTINE GRASSLANDS										SERPENTINE CHAPARRAL		
	Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	Tama	Cars	Diab
Linanthus pygmaeus					X								
Linaria texana				X	X								
Linum bienne										X			
Lolium multiflorum	X	X	X	X	X	X	X	X	X	X		X	X
Lolium perenne					X								
Lomatium dasycarpum	X			X	X	X				X			X
Lomatium macrocarpum			X		X					X			
Lomatium utriculatum			X	X	X	X				X			
Lonicera hispidula					X	X							
Lotus corniculatus						X							
Lotus humistratus													X
Lotus micranthus	X				X	X				X			
Lotus subpinnatus	X	X	X	X	X	X	X	X	X	X	X		
Lupinus bicolor				X	X								
Lupinus densiflorus				X						X			
Lupinus nanus				X						X			
Lupinus subvexus			X										
Lupinus succulentus	X	X			X	X				X			
Madia elegans ssp *densifolia*						X							
Madia exigua						X							
Madia gracilis				X	X								
Madia sativa										X			
Malacothrix floccifera	X												
Malva parviflora	X												
Medicago polymorpha						X							
Melica californica					X		X	X		X			X
Melica imperfecta	X			X									
Melica torreyana			X			X				X	X	X	X
Melilotus indicus					X	X							
Mentha pulegium						X							
Microcala quadrangularis				X	X								
Micropus californicus	X	X	X	X	X	X				X			
Microseris acuminata			X										
Microseris bigelovii										X			
Microseris decipiens			X										
Microseris douglasii ssp *douglasii*				X		X				X			

Species	SERPENTINE GRASSLANDS										SERPENTINE CHAPARRAL		
	Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	Tama	Cars	Diab
Microseris lindleyi	X		X				X						
Microseris linearifolia						X							
Mimulus aurantiacus						X			X				
Mimulus douglasii			X	X	X								
Mimulus guttatus	X	X			X	X		X		X	X	X	
Minuartia douglasii	X	X	X	X		X	X	X		X	X		X
Monardella douglasii ssp *douglasii*			X										
Monardella villosa ssp *neglecta*						X		X		X	X		
Monardella villosa ssp *villosa*				X	X								
Montia perfoliata	X	X	X	X	X	X	X	X		X			
Montia spathulata var *exigua*	X		X	X	X	X				X			
Muilla maritima	X	X		X	X	X	X	X					
Navarretia heterodoxa					X	X							
Navarretia heterodoxa ssp *rosulata*											X		
Nemophila heterophylla					X								
Nemophila menziesii var *atomaria*				X						X			
Nemophila menziesii var *menziesii*				X	X								
Oenothera ovata				X	X					X			
Orobanche fasciculata		X			X								
Orthocarpus attenuatus				X									
Orthocarpus densiflorus		X		X	X	X	X						
Orthocarpus erianthus var *erianthus*				X	X								
Orthocarpus floribundus									X				
Orthocarpus lithospermoides	X		X	X	X	X	X	X		X			
Orthocarpus purpurascens var *purpurascens*	X	X		X	X	X		X					
Orthocarpus pusillus		X		X	X								
Parnassia palusstris var *californica*											X		
Pectocarya penicillata	X												
Pedicularis densiflora						X							
Pedicularis dudleyi					X								
Pellaea andromedaefolia			X										
Pellea mucronata	X	X			X						X		
Pentachaeta bellidiflora						X		X					
Perideridia kelloggii	X		X		X		X			X			
Phacelia californica					X	X	X	X					
Phacelia distans		X			X								

	SERPENTINE GRASSLANDS										SERPENTINE CHAPARRAL		
Species	Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	Tama	Cars	Diab
Phacelia divaricata								X					
Phalaris californica						X							
Photinia arbutifolia						X							
Pityrogramma triangularis	X	X			X	X				X	X		X
Plagiobothrys diffusus									X				
Plagiobothrys fulvus var *campestris*	X	X											
Plagiobothrys nothofulvus				X	X								
Plantago hookeriana var *californica*	X	X	X	X	X	X	X	X	X	X			
Plantago lanceolata			X		X	X			X				
Plantago maritima									X				
Platystemon californicus	X	X	X	X	X					X			
Plectritis ciliosa ssp *ciliosa*													
Plectritis ciliosa ssp *insignis*				X		X							
Plectritis congesta						X							
Plectritis macrocera			X	X	X								
Poa annua						X			X				
Poa melitensis													
Poa scabrella	X		X	X	X	X	X	X	X	X	X	X	X
Pogogyne serpylloides				X	X	X							
Polypodium californicum		X			X	X	X	X			X		X
Polypogon monspeliensis						X							
Psilocarphus tenellus				X		X				X			
Pterostegia drymarioides		X			X						X		X
Quercus agrifolia						X							
Quercus douglasii						X							
Quercus durata	X			X	X	X		X	X		X	X	X
Quercus kelloggii						X							
Quercus lobata						X							
Rafinesguia californica													X
Ranunculus californicus						X							
Ranunculus occidentalis	X	X		X	X	X	X	X					
Raphanus sativus						X							
Rhamnus californica	X	X			X	X		X	X		X	X	X
Rigiopappus leptocladus	X	X	X	X	X	X				X	X		
Rosa californica						X							
Rubus ursinus		X			X	X			X				

	SERPENTINE GRASSLANDS										SERPENTINE CHAPARRAL		
Species	Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	Tama	Cars	Diab
Rumex crispus			X		X	X	X						
Rumex pulcher						X							
Sagina apetala var *barbata*						X							
Sagina occidentalis					X								
Salix lasiolepis						X			X				
Salvia columbariae	X			X									
Sambucus mexicana					X								
Sanicula arctopoides										X			
Sanicula bipinnatifida var *bipinnatifida*		X	X		X	X	X	X		X			
Sanicula bipinnatifida ssp *patula*				X									
Sanicula crassicaulis					X	X				X			
Sanicula tuberosa			X		X					X	X		
Saxifraga californica			X										
Scandix pecten-veneris					X			X		X			
Scribneria bolanderi						X					X		
Scrophularia californica	X				X	X	X	X					
Sherardia arvensis					X	X							
Sidalcea diploscypha	X	X			X	X							
Sidalcea malvaeflora	X	X			X								
Silene californica					X	X					X		
Silene gallica	X	X		X				X		X			
Silene verecunda ssp *verecunda*					X					X			
Silybum marianum						X							
Sisymbrium altissimum		X			X	X							
Sisyrinchium bellum	X	X	X	X	X	X	X	X	X	X			
Sitanion jubatum	X	X	X		X	X	X	X	X	X			
Smilacina racemosa var *amplexicaulis*						X							
Solanum umbelliferum					X	X							
Sonchus asper					X	X							
Spartium junceum						X							
Stachys arvensis							X						
Stachys bullata						X							
Stachys pycnacantha					X					X	X		
Stachys rigida ssp *quercetorum*					X	X							
Stellaria media					X								
Stellaria nitens					X	X							

Species	Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	Tama	Cars	Diab
	SERPENTINE GRASSLANDS										SERPENTINE CHAPARRAL		
Stipa lepida					X	X					X		X
Stipa pulchra	X	X	X	X	X	X	X	X	X	X	X	X	X
Streptanthus albidus ssp *albidus*	X												
Streptanthus batrachopus											X	X	
Streptanthus glandulosus var													X
Streptanthus glandulosus var *pulcehellus*											X	X	
Streptanthus hispidus													X
Streptanthus niger										X			
Stylocline filaginea						X							X
Symphoricarpos mollis					X	X							
Tauschia kelloggii						X				X			
Thelypodium lasiophyllum					X	X							
Toxicodendron diversilobum	X	X			X	X		X	X				
Trifolium albopurpureum						X		X					
Trifolium amoenum										X			
Trifolium amplectens		X			X								
Trifolium barbigerum				X	X								
Trifolium bifidum var *decipiens*				X									
Trifolium ciliolatum				X			X						
Trifolium dubium										X			
Trifolium fucatum				X	X	X	X			X			
Trifolium fucatum var *virescens*										X			
Trifolium gracilentum		X		X									
Trifolium macraei										X			
Trifolium microcephalum				X									
Trifolium microdon						X							
Trifolium olivaceum var *griseum*										X			
Trifolium tridentatum	X	X	X		X	X				X			
Trifolium variegatum				X		X							
Trillium chloropetalum						X							
Triteleia laxa		X		X	X	X				X			
Triteleia lutea					X								
Umbellularia californica						X				X	X		
Verbena lasiotachys						X							
Vicia angustifolia						X							
Vicia angustifolia var *segetalis*										X			

Species	SERPENTINE GRASSLANDS Metc	Tula	Redw	Jasp	Edge	Tria	Pulg	Crys	Pres	Tibu	SERPENTINE CHAPARRAL Tama	Cars	Diab
Viola ocellata											X		
Vulpia microstachys	X	X	X	X	X	X	X	X	X	X	X	X	X
Vulpia myuros	X	X	X					X					
Vulpia pacifica				X									
Wyethia angustifolia								X		X			
Zygadenus fremontii					X	X		X		X	X		

APPENDIX D

Soil Analysis for Serpentine Areas in the San Francisco Bay Region

CARSON RIDGE

SOIL COMPONENT	0-5	5-10	10-20	20-30
	SOIL DEPTH (CENTIMETERS)			
Carbon	2.59			
Nitrogen	0.19			
Phosphorus	0.45			
Calcium	3.68			
Magnesium	26.77			
Ca++/Mg++	0.14			
Potassium	0.49			
Sodium	0.22			
Manganese	0.81			
Nickel	-			
Chromium	-			
pH	6.1			
C.E.C	31.6			
Bulk Density	0.79			
F.C.	34.96			
P.W.P.	20.66			

MT. TAMALPAIS STATE PARK

SOIL COMPONENT	0-5	5-10	10-20	20-30
	SOIL DEPTH (CENTIMETERS)			
Carbon	1.34			
Nitrogen	0.07			
Phosphorus	0.32			
Calcium	5.17			
Magnesium	7.42			
Ca++/Mg++	0.70			
Potassium	0.04			
Sodium	0.05			
Manganese	0.27			
Nickel	0.005			
Chromium	-			
pH	6.5			
C.E.C	11.7			
Bulk Density	1.23			
F.C.	19.34			
P.W.P.	13.95			

RING MOUNTAIN PRESERVE
Sample #1

	SOIL DEPTH (CENTIMETERS)			
SOIL COMPONENT	0-5	5-10	10-20	20-30
Carbon	1.66	1.34	0.73	
Nitrogen	0.58	0.13	0.07	
Phosphorus	0.68	0.82	0.84	
Calcium	1.92	1.87	1.07	
Magnesium	20.04	20.44	21.11	
Ca++/Mg++	0.10	0.09	0.05	
Potassium	0.34	0.28	0.23	
Sodium	0.11	0.37	0.17	
Manganese	0.22	0.21	0.10	
Nickel	0.01	0.01	0.008	
Chromium	-	-	-	
pH	6.0	5.8	6.0	
C.E.C	24.6	25.08	25.58	
Bulk Density	1.07	-	-	
F.C.	25.44	24.95	22.83	
P.W.P.	15.43	15.33	16.81	

RING MOUNTAIN PRESERVE
Sample #2

	SOIL DEPTH (CENTIMETERS)			
SOIL COMPONENT	0-5	5-10	10-20	20-30
Carbon	0.32			
Nitrogen	0.03			
Phosphorus	0.65			
Calcium	0.68			
Magnesium	15.89			
Ca++/Mg++	0.04			
Potassium	0.05			
Sodium	0.10			
Manganese	0.03			
Nickel	-			
Chromium	-			
pH	6.1			
C.E.C	17.5			
Bulk Density	-			
F.C.	28.17			
P.W.P.	21.65			

PRESIDIO
Sample #1

SOIL COMPONENT	SOIL DEPTH (CENTIMETERS) 0-5	5-10	10-20	20-30
Carbon	3.13	2.32		
Nitrogen	0.28	0.23		
Phosphorus	2.09	0.93		
Calcium	6.44	5.97		
Magnesium	36.44	44.29		
Ca++/Mg++	0.14	0.18		
Potassium	0.89	0.75		
Sodium	0.72	0.69		
Manganese	0.61	0.49		
Nickel	0.03	0.03		
Chromium	-	-		
pH	5.7	5.9		
C.E.C	45.95	53.80		
Bulk Density	0.87	-		
F.C.	42.00	47.04		
P.W.P.	26.92	28.51		

PRESIDIO
Sample #2

SOIL COMPONENT	SOIL DEPTH (CENTIMETERS) 0-5	5-10	10-20	20-30
Carbon	3.00			
Nitrogen	0.29			
Phosphorus	1.41			
Calcium	3.58			
Magnesium	24.45			
Ca++/Mg++	0.15			
Potassium	0.80			
Sodium	0.14			
Manganese	0.89			
Nickel	-			
Chromium	-			
pH	5.9			
C.E.C	30.43			
Bulk Density	0.97			
F.C.	33.20			
P.W.P.	21.81			

EDGEWOOD
Sample #1

SOIL COMPONENT	SOIL DEPTH (CENTIMETERS) 0-5	5-10	10-20	20-30
Carbon	1.17	1.16	1.01	1.04
Nitrogen	0.11	0.10	0.09	0.10
Phosphorus	0.76	0.54	0.37	0.94
Calcium	4.26	3.82	3.58	3.39
Magnesium	47.85	47.85	45.91	48.89
Ca++/Mg++	0.09	0.08	0.08	0.07
Potassium	1.06	0.87	0.82	0.86
Sodium	0.64	0.59	0.30	0.19
Manganese	0.29	0.23	0.13	0.15
Nickel	0.01	0.006	0.002	0.001
Chromium	0.04	-	-	-
pH	6.0	6.2	6.2	6.1
C.E.C	53.10	51.55	52.50	52.55
Bulk Density	1.02	-	-	-
F.C.	53.11	52.03	51.31	52.35
P.W.P.	32.97	30.54	30.11	30.80

EDGEWOOD
Sample #2

SOIL COMPONENT	SOIL DEPTH (CENTIMETERS) 0-5	5-10	10-20	20-30
Carbon	6.16			
Nitrogen	0.37			
Phosphorus	1.80			
Calcium	12.48			
Magnesium	23.89			
Ca++/Mg++	0.52			
Potassium	0.68			
Sodium	0.29			
Manganese	2.20			
Nickel	-			
Chromium	-			
pH	5.6			
C.E.C	38.00			
Bulk Density	-			
F.C.	41.00			
P.W.P.	22.35			

EDGEWOOD
Sample #3

SOIL COMPONENT	SOIL DEPTH (CENTIMETERS) 0-5	5-10	10-20	20-30
Carbon	1.70	1.17		
Nitrogen	0.17	0.12		
Phosphorus	0.77	0.32		
Calcium	4.31	3.92		
Magnesium	30.49	34.48		
Ca++/Mg++	0.14	0.11		
Potassium	0.72	0.54		
Sodium	0.21	0.17		
Manganese	0.75	0.58		
Nickel	0.03	0.03		
Chromium	-	-		
pH	5.6	5.7		
C.E.C	36.80	40.25		
Bulk Density	0.88	-		
F.C.	34.36	36.25		
P.W.P.	18.96	21.05		

THE TRIANGLE

SOIL COMPONENT	SOIL DEPTH (CENTIMETERS) 0-5	5-10	10-20	20-30
Carbon	1.23	0.92	0.75	
Nitrogen	0.12	0.10	0.08	
Phosphorus	0.97	1.89	1.53	
Calcium	3.77	3.46	3.06	
Magnesium	34.20	36.78	37.51	
Ca++/Mg++	0.11	0.09	0.08	
Potassium	0.74	0.68	0.57	
Sodium	0.21	0.25	0.17	
Manganese	0.28	0.21	0.10	
Nickel	0.01	0.01	0.003	
Chromium	-	-	-	
pH	6.4	6.1	6.2	
C.E.C	39.95	39.73	40.35	
Bulk Density	1.06	-	-	
F.C.	43.47	45.49	45.47	
P.W.P.	26.68	27.12	27.04	

PULGAS RIDGE

SOIL COMPONENT	0-5	5-10	10-20	20-30
	SOIL DEPTH (CENTIMETERS)			
Carbon	3.94			
Nitrogen	0.40			
Phosphorus	2.18			
Calcium	6.39			
Magnesium	37.28			
Ca++/Mg++	0.17			
Potassium	0.99			
Sodium	0.26			
Manganese	0.79			
Nickel	0.06			
Chromium	-			
pH	5.6			
C.E.C	49.70			
Bulk Density	0.75			
F.C.	46.75			
P.W.P.	31.84			

JASPER RIDGE PRESERVE

SOIL COMPONENT	0-5	5-10	10-20	20-30
	SOIL DEPTH (CENTIMETERS)			
Carbon	1.99	1.98		
Nitrogen	0.19	0.20		
Phosphorus	1.01	3.27		
Calcium	3.58	3.25		
Magnesium	29.11	29.27		
Ca++/Mg++	0.12	0.11		
Potassium	0.33	0.28		
Sodium	0.22	0.24		
Manganese	0.53	0.52		
Nickel	0.05	0.05		
Chromium	-	-		
pH	6.2	5.6		
C.E.C	35.00	35.75		
Bulk Density	0.90	-		
F.C.	28.96	42.89		
P.W.P.	26.63	26.08		

METCALF CANYON

SOIL COMPONENT	SOIL DEPTH (CENTIMETERS) 0-5	5-10	10-20	20-30
Carbon	0.85	0.58		
Nitrogen	0.09	0.06		
Phosphorus	1.76	1.61		
Calcium	2.55	2.46		
Magnesium	19.97	20.71		
Ca++/Mg++	0.13	0.20		
Potassium	0.53	0.29		
Sodium	0.10	0.10		
Manganese	0.20	0.15		
Nickel	0.02	0.01		
Chromium	-	-		
pH	6.1	6.4		
C.E.C	23.05	23.75		
Bulk Density	1.17			
F.C.	25.74	23.88		
P.W.P.	17.23	16.55		

TULARE HILL

SOIL COMPONENT	SOIL DEPTH (CENTIMETERS) 0-5	5-10	10-20	20-30
Carbon	2.83	1.77		
Nitrogen	0.25	0.19		
Phosphorus	1.76	3.10		
Calcium	4.55	5.25		
Magnesium	24.76	28.34		
Ca++/Mg++	0.18	0.19		
Potassium	0.64	0.69		
Sodium	0.17	0.14		
Manganese	0.62	0.58		
Nickel	0.04	0.03		
Chromium	-	-		
pH	5.7	5.7		
C.E.C	32.70	37.20		
Bulk Density	0.75	-		
F.C.	36.27	40.92		
P.W.P.	22.79	25.21		

REDWOOD PARK

SOIL COMPONENT	0-5	5-10	10-20	20-30
	SOIL DEPTH (CENTIMETERS)			
Carbon	2.13			
Nitrogen	0.18			
Phosphorus	2.43			
Calcium	2.01			
Magnesium	13.18			
Ca++/Mg++	0.15			
Potassium	0.34			
Sodium	0.14			
Manganese	0.64			
Nickel	-			
Chromium	-			
pH	5.7			
C.E.C	15.65			
Bulk Density	0.80			
F.C.	32.31			
P.W.P.	18.79			

MT. DIABLO STATE PARK

SOIL COMPONENT	0-5	5-10	10-20	20-30
	SOIL DEPTH (CENTIMETERS)			
Carbon	4.0			
Nitrogen	0.24			
Phosphorus	4.40			
Calcium	10.70			
Magnesium	21.06			
Ca++/Mg++	0.51			
Potassium	0.64			
Sodium	0.21			
Manganese	0.53			
Nickel	0.005			
Chromium	-			
pH	6.2			
C.E.C	31.6			
Bulk Density	0.78			
F.C.	43.97			
P.W.P.	28.39			

TILDEN BOTANICAL GARDEN

SOIL COMPONENT	SOIL DEPTH (CENTIMETERS) 0-5	5-10	10-20	20-30
Carbon	2.37			
Nitrogen	0.16			
Phosphorus	3.33			
Calcium	24.91			
Magnesium	4.85			
Ca++/Mg++	5.14			
Potassium	1.13			
Sodium	0.44			
Manganese	0.72			
Nickel	-			
Chromium	-			
pH	6.2			
C.E.C	27.05			
Bulk Density	-			
F.C.	22.89			
P.W.P.	11.96			

FIGURES

Photographic figures 1 & 2 taken by Roxanne L. Bittman, all others are by Niall F. McCarten.

FIGURE 1 (TOP)

Mt. Tamalpais serpentines with Sargent Cypress Woodland near top of photo with Decumbent Manzanita Serpentine Scrub characterized by _Arctostaphylos montana_ surrounded by Serpentine Barrens in lower half of photo.

FIGURE 2 (BOTTOM)

Mt. Tamalpais serpentines with Decumbent Manzanita Serpentine Scrub surrounded by Serpentine Barrens.

FIGURE 3 (TOP)

Mt. Tamalpais serpentines with Mixed Serpentine Chaparral in foreground of photo with the Tiburon Peninsula which supports mostly Serpentine Grasslands in upper part of photo.

FIGURE 4 (BOTTOM)

The California Nature Conservancy's Ring Mountain Preserve which supports Serpentine Bunchgrass Grasslands.

FIGURE 5 (TOP)

Upper Crystal Springs Reservoir with Serpentine Bunchgrass Grasslands in foreground.

FIGURE 6 (BOTTOM)

Pulgas Ridge with Serpentine Bunchgrass Grasslands.

FIGURE 7 (TOP)

The Triangle, a game refuge of the California Department of Fish and Game, with Serpentine Bunchgrass Grasslands in background intergrading into Serpentine Wildflower Fields.

FIGURE 8 (BOTTOM)

The Triangle with Serpentine Wildflower Fields in the foreground and a non-serpentine knoll in Edgewood Park in the upper part of the photo.

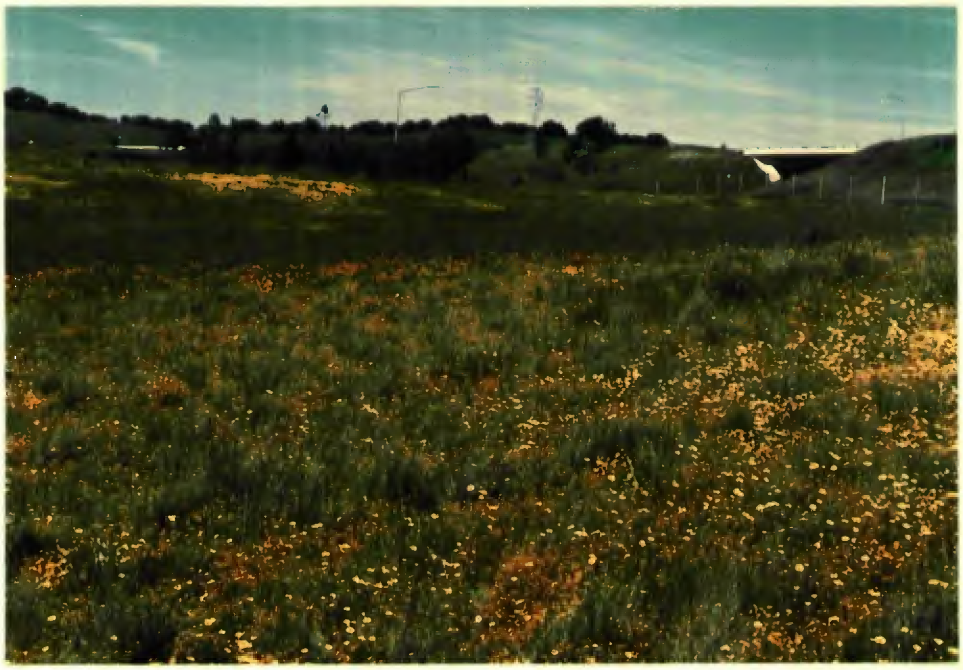


FIGURE 9 (TOP)

Edgewood Park with Mixed Serpentine Chaparral, Serpentine Bunchgrass Grasslands and non-serpentine chaparral in upper part of photo. In the foreground is an unusual Serpentine Wildflower Field vegetation type growing on deep serpentine clays which is the habitat of the rare San Mateo thornmint Acanthomintha obovata ssp. duttonii.

FIGURE 10 (BOTTOM)

Edgewood Park with zones of different vegetation types from Serpentine Bunchgrass Grasslands at top of photo grading into Serpentine Wildflower Fields (yellow band) and into a serpentine scald a localized Serpentine Barren.

FIGURE 11 (TOP)

Edgewood Park with Serpentine Wildflower Fields in foreground with Serpentine Bunchgrass Grassland in background.

FIGURE 12 (BOTTOM)

Tulare Hill Serpentine Bunchgrass Grasslands in foreground with Metcalf Canyon serpentine grasslands in background.

FIGURE 13 (TOP)

Tulare Hill with heavily grazed area of Serpentine Bunchgrass Grasslands in foreground with Metcalf Canyon serpentine grasslands in background.

FIGURE 14 (BOTTOM)

Metcalf Canyon with Serpentine Bunchgrass Grasslands.

FIGURE 15 (TOP)

Redwood Park Serpentine Bunchgrass Grasslands with *Koeleria macrantha* shown here being one of the dominant bunchgrasses.

FIGURE 16 (BOTTOM)

Redwood Park Serpentine Bunchgrass Grasslands.

FIGURE 17 (TOP)

Mt. Diablo North Peak with sparse Mixed Serpentine Chaparral.

FIGURE 18 (BOTTOM)

<u>Calycadenia</u> <u>multiglandulosa</u> ssp. <u>robusta</u> is part of the summer flowering serpentine flora at Redwood Park.

FIGURE 19 & 20

<u>Lewisia</u> <u>rediviva</u>, seen here at Mt. Diablo, is one of the succulent plants that comprise the Serpentine Rock Succulent Vegetation.

FIGURE 21 (TOP)

Dudleya setchellii, seen here at Tulare Hill, is one of the succulents is one of the succulent plants that comprise the Serpentine Rock Succulent Vegetation.

FIGURE 22 (BOTTOM)

Dudleya farinosa, seen here at Ring Mountain, is one of the succulent plants found in the Serpentine Rock Succulent Vegetation.

FIGURE 23 (TOP)

A red flowered form of Lewisia rediviva, seen here at Tulare Hill, is one of the succulents is one of the succulent plants that comprise the Serpentine Rock Succulent Vegetation.

FIGURE 24 (BOTTOM)

Allium falcifolium, seen here at Mt. Tamalpais, is one of the numerous leaf annuals that occur on serpentines and is sometimes found growing on Serpentine Barrens.

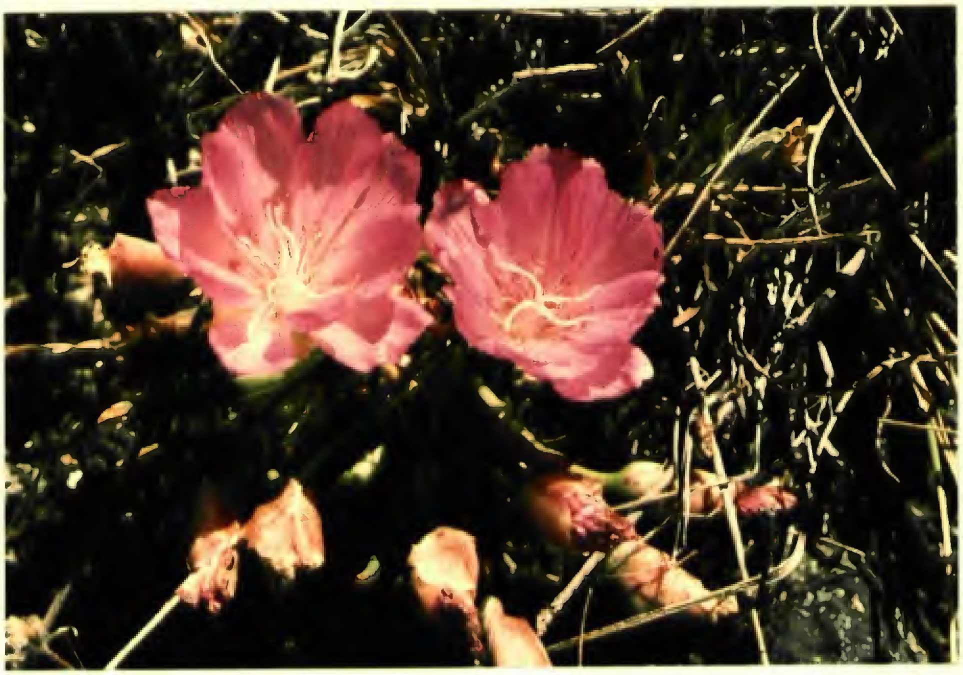


FIGURE 25 (TOP)

Sitanion jubatum, growing at Redwood Park, is one of the common bunchgrass species that comprise the Serpentine Bunchgrass Grassland.

FIGURE 26 (BOTTOM)

Koeleria macrantha, growing at Redwood Park, is one of the many bunchgrasses that comprise the Serpentine Bunchgrass Grasslands.

FIGURE 27 (TOP)

Calochortus luteus, growing at Tulare Hill, is the most common Calochortus species in the San Francisco Bay Region serpentines.

FIGURE 29 (MIDDLE)

Calochortus tiburonensis, growing at Ring Moutain, is the rarest Calochortus in the San Francisco serpentines and is restricted to the Tiburon Peninsula.

FIGURE 30 (BOTTOM)

Calochortus superbus, growing at Tulare Hill. bunchgrasses that comprise the Serpentine Bunchgrass Grasslands.



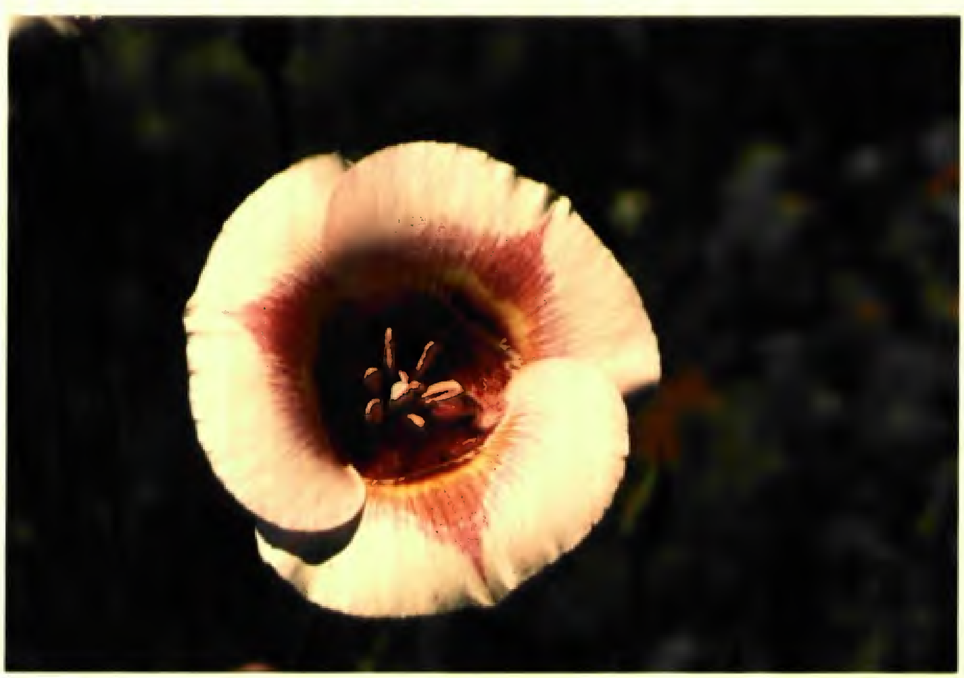


FIGURE 31 & 32

<u>Acanthomintha</u> <u>obovata</u> ssp. <u>duttonii</u>, the extremely rare San Mateo thornmint growing at Edgewood Park in deep serpentine clay.

FIGURE 33 & 34

Hesperolinon congestum, the Marin dwarf flax seen here at Ring Mountain, is one of the rarer serpentine plant species and occurs sporadically from San Mateo County to Marin County.

FIGURE 35& 36

Pentachaeta bellidiflora, seen here growing at the Triangle, is one of the rare serpentine plant species and is part of the Serpentine Wildflower Field vegetation type.

FIGURE 37 & 38

Erysimum fransiscanum, growing at Upper Crystal Springs Reservoir, is one of the rare serpentine plant species.