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Journal
Madroño, 63(4)

ISSN
0024-9637

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Publication Date
2016-10-01

DOI
10.3120/0024-9637-63.4.293

Peer reviewed

MADROÑO, Vol. 63, No. 4, pp. 293–328, 2016

CALIFORNIA'S HISTORIC LEGACY FOR LANDSCAPE CHANGE, THE WIESLANDER VEGETATION TYPE MAPS

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ABSTRACT

This paper presents the digitized edition of the Wieslander Vegetation Type Maps (VTMs). The VTMs were part of the first statewide systematic survey of California's vegetation, conducted 1928–1939. Under the direction of Albert Wieslander, crews recorded the patterns of vegetation that they observed from vantage points across the state. The survey covers 176,901 km^2 including border and lake polygons and 165,652 km^2 of landscapes that we describe in more detail. There are 251,541 polygons in the full extent of the maps, with 249,630 in the analysis extent. These polygons are annotated with codes indicating the dominant plant species, for which voucher specimens were collected. The maps contain 655 species codes, representing 535 species or sub-species in 229 genera, including 34 *Arctostaphylos* Adans. and 16 *Quercus* L. species. The 249,630 polygons contain 26,013 unique combinations of species and levels of disturbance. These can be classified into 525 vegetation alliances or provisional alliances using the 2009 edition of the Manual of California Vegetation, or into 53 of the simpler California Wildlife Habitat Relationships (WHR) classes. The most extensive WHR types in the VTMs are Annual grasslands (25,733 km^2) Chamise-redshank chaparral (14,771 km^2), Mixed chaparral (9314 km^2), and Coastal Scrub (7088 km^2). California's Southwestern ecoregion is the most completely surveyed, with 93% of the area mapped, followed by the Central Western ecoregion (88.2%, including the Bay Area), the Sierra Nevada (71.6%), and the Great Valley (39.7%). The VTMs in these ecoregions provide a baseline for assessment of landcover change across large areas, and are an important legacy of the biogeographic patterns of plants and vegetation in California. This paper provides the methods used to digitize the collection and suggestions about how the data may be properly used in future studies.

Key Words: biogeography, ecology, historical landscape monitoring, VTMs, Wieslander Vegetation Type Maps.

The Wieslander Vegetation Type Map (VTM) Project was an effort to inventory the forests and natural lands of California. Lands were surveyed by United States Forest Service (USFS) crews under the direction of Albert Wieslander between 1928 and 1939. It has been considered among the finest vegetation maps ever made in the western hemisphere, and foundational for the subsequent development of other landcover mapping efforts such as the Soil Vegetation Survey (Küchler 1967). In addition to the vegetation maps, ~18,000 vegetation plots were surveyed, over 3000 photographs taken, and over 25,000 VTM voucher specimens were collected (Wieslander 1935a, 1935b, 1935c, 1986). Additional maps were produced showing the location of the plots and photographs. This remarkable vegetation survey eventually ended due to funding restrictions during World War Two. The entire collection of reference materials was housed at the University of California, Berkeley, where parts of it were nearly thrown away on two occasions, but survived and in the last decade photographs, maps, and original vegetation plot cards have been registered into the collections of the UC Bancroft Library (2008). The VTM herbarium voucher specimens are housed at the UC Berkeley Jepson Herbarium (JEPS). Systematic efforts to digitize the collection began around 2002 and have produced a database of the plot data with online access (http://vtm.berkeley.edu/), and also online access to scanned versions of the photographs (http://www.lib.berkeley.edu/BIOS/vtm/) (Kelly et al. 2005; Kelly et al. 2008). Digital production of the vegetation maps is the subject of this paper.

As anticipated by Wieslander (1935a), the Vegetation Type Map Project materials have formed the basis for many studies and publications, particularly the plot data, for which we provide a separate list of publications (Appendix 1). There are several references pointing to the intent to use plot and map data together for landscape assessments (Weeks et al. 1934, 1943; Wieslander and Jensen 1946; Wieslander 1986). The VTM vegetation maps were used in early assessments of regional conditions which include a general assessment for Eldorado County (Weeks et al. 1934) and a land use study across the entire northern Sierra Nevada, which includes a map of forest fire perimeters (Weeks et al. 1943). Elevational transect maps of California dominant trees and vegetation were developed (Critchfield 1971) and statewide maps of California's tree ranges (Griffin and Critchfield 1972) and shrubs (Sampson and Jespersen 1963) have been published. Regional studies that used the VTMs include a landcover change study (Bradbury 1974) and grassland dynamics (Freudenberger et al. 1987). Scans of the VTMs were used as base data for the first edition of California's Gap Analysis Program vegetation maps (Davis et al. 1995, Davis et al. 1998). Efforts to digitize the VTMs (Kelly et al. 2005; Thorne et al. 2006) have resulted in the digital GIS versions of the VTMs becoming available. These have been used in a few local or regional landscape studies to date, including landscape change and conservation studies in the Bay Area (Thorne et al. 2013; Santos et al. 2014). The maps have also been used in studies on the dynamics of small Sierra Nevadan mammals (Santos et al. 2015), of forest change in the Sierra Nevada (Thorne et al. 2008) and for an educational movie about Sierra Nevada forest dynamics (Thorne and McQuinn 2012).

Albert Wieslander organized the field survey crews, many of whose names are found on VTM quadrangles throughout the duration of the survey. These crews were responsible for all the data collected, and they compiled each data type at the same time. The crews followed detailed protocols for all parts of the survey, which was established by 1933, and that are provided in the field manual (Wieslander et al. 1933, Wieslander et al. unpublished [1933] a, Wieslander et al. unpublished [1933] b). For the field creation of the vegetation maps, these include establishing view points on ridges, and tracing the patterns of the observed vegetation onto topographic maps. Up to nine dominant species were then recorded by species codes, written in the polygons where they were observed. At the start of this work, aerial photography was not yet developed, and was not used during this study, although in most instances the surveyors were looking down on, or laterally across a valley to, the vegetation they were mapping. Sixteen of the vegetation map quadrangles were published by the USFS, a beautiful series of maps with heavily annotated margins. Few collections of this series have survived. These published VTM quadrangles are of reduced detail relative to the original survey maps because of the limited space available in paper maps. The entire vegetation map collection has never been digitized.

The survey methods used to develop the vegetation maps were applied to large areas of the state, and were also used by the National Park Service (NPS), which produced maps for Lassen, Yosemite and Sequoia national parks, as an independent but coordinated effort to the USFS surveys. Areas outside the national parks were mapped by the USFS crews and were intended for use by natural resource managers, who would use the colors on the maps to identify different vegetation types for both timber and fire planning, and by researchers, who would use the more detailed species-specific information contained in each polygon for forestry, ecology, and landscape dynamics studies (Wieslander 1935a).

This paper presents the fully digitized VTM vegetation maps, a snapshot of California's vegetation in the 1930's. We describe the methods used to render the original maps to a geographic information system, report on the characteristics of the GIS product, and describe the extent and types of species and vegetation that were recorded. We identify the number of species reported, and the extent of landcover types according to the California Wildlife Habitat Relationship classification (WHR; Mayer & Laudenslayer 1988; California Department of Fish and Wildlife 2004), and the Manual of California Vegetation classification (MCV; Sawyer and Keeler Wolf 1995, Sawyer et al. 2009). We report the registration errors for each quadrangle, and provide a discussion of the types of analyses the maps have been used for, and their potential to inform future research and resource management.

Methods

Scanning

The original VTMs were drawn on U.S. Geological Survey (USGS) topographic maps and in some cases U.S. Army Corps of Engineers maps, here termed base maps. Some of the base maps were originally surveyed as part of the coastal geodetic survey of the late 1800's (earliest topographic base maps surveyed in 1893). At the beginning of the VTM effort, only 30' quadrangles were available, and these make up the majority of the VTM extent surveyed. However, 15' quadrangles were used when those became available to the VTM crews, particularly in the San Francisco Bay Area and south along California' central coast. Additionally, some 7.5' quadrangles were used late in the survey effort. In all cases, when survey work on a quadrangle was completed, it was cut into sections, or 'tiles' (16 tiles for 30' quadrangles and four tiles for 15 and 7.5' tiles), and glued to a canvas backing to prevent loss of map data when the maps were folded (and they are stored folded). Reassembly of these maps was therefore the primary task of transitioning the patterns of species and vegetation to digital form. Most of these quadrangles were found in the collection at UC Berkeley. Thanks for recovery for some southern California quadrangle are due to the USFS office in Redlands; and to Michael Zinke, whose father, UC Berkeley professor Paul Zinke, helped survey some of the maps and who held some of them in his home; and to Sequoia, Yosemite and Lassen National Parks for allowing the maps in their collections to be scanned and added to the overall effort to digitize the collection.

We scanned the VTM vegetation map tiles individually, using a flatbed scanner at 300 dpi resolution. The tiles are arrayed four to each piece of canvas, meaning that the 30' quadrangles have four canvases per quad. The canvas was folded, and one or two tiles were scanned at each scan. The tiles are assigned a name according to the naming convention of the VTM maps: each quadrangle has a numeric code, and the tiles are numbered in counterclockwise rotational sequence with the upper right hand tiles listed as A1, A2, A3, and A4; the upper left tiles as B1, B2, B3, and B4; the lower left quadrant tiles C1, C2, C3, and C4; and the lower right tiles as D1, D2 D3, and D4. This pattern is consistent across all tiles on all 30' maps. The four tiles comprising 15 and 7.5' quadrangle tiles are also numbered in counter-clockwise fashion, starting in the northeast corner. The 15' quadrangles codes are numeric followed by upper case letters (e.g., 105A, 105B, 105C, 105D), while 7.5' quadrangles are numeric followed by lower case letters (e.g., 88c, 88d, etc.). The scans are stored in a directory structure that reflects the schema used by the VTM project surveyors, of sequential numbers starting in the northeast corner of the state and running back and forth by each row of 30' quadrangle to the highest number, 192D for the quadrangle covering San Diego (Fig. 1).

The NPS effort covered Lassen, Yosemite and Sequoia National Parks. The Lassen and Sequoia National Park maps were created separately from the USFS VTMs. Protocols for VTM mapping in the national parks (Coffman 1934) mention that the effort was intended to support planning in different land cover types, in particular for fire hazard and protection planning, planning insect and disease control, determination of proper land use and treatment such as for "recreation, camp ground development, wild life, re-forestation, erosion control, etc.", augmenting knowledge concerning the flora and other natural features and providing an inventory as part of the nation-wide inventory survey. A report on the results of the VTM effort in Sequoia National Park (Frost 1935) identifies the effort as, "part of a vegetative-type survey of the State of California under the direction of the California Forest Experiment Station; and as a part of the nation-wide forest survey authorized by the McSweeney-McNary Research Act of 1928". There are two copies of the vegetation maps for Yosemite National Park; the NPS-surveyed copy that resides in that park shows only the area inside the boundaries of the park, while the USFS version is housed at the UC Berkeley Bancroft library and contains continuously mapped vegetation across the park boundary. It is difficult to determine which of these maps the original is; however we digitized the version from the UC Bancroft library, which has slight differences from the version in the Yosemite National Park archives.

Map Registration

The base topographic maps have been scanned by various map libraries around the state, particularly the University of California Berkeley Geology Library, University of California Santa Barbara Alexandria Digital Library, and California State University Chico Meriam Library California Historic Topographic Map Collection. These maps have typically been sheet scanned using a standard of 300 dots per inch (dpi) resolution, to produce an image file (.tif) of approximately 200 megabytes. We obtained scans from these institutions, in many cases donated, to use in the digital development of the VTM quadrangles. We georeferenced the base maps using their corners and tic marks.

The base topographic maps use Clarke's spheroid of 1866 datum, and the polyconic projection, which was the standard for the U.S. Geological Survey during this time (U.S. Department of Commerce, Coast and Geodetic Survey 1917; Snyder 1983). The base maps were registered by projecting the degree-decimal geographic coordinates from the base map into a polyconic projection for the continental U.S., and using the central meridian for each individual base map. These polyconic coordinates were then used as control points to rectify the base map image. The registered base map was then used as the reference for registering each individual vegetation tile for that quadrangle.

Using ArcGIS (ESRI 2010), the scanned VTM tiles were registered onto the USGS topographic base maps, resulting in a projected version of the vegetation map, reassembled from the multiple tiles. We used 64 control points on the 16 digital VTM tile images, four per tile for a 30' quadrangle. Additionally, for 15' and 7.5' quadrangles, 16 control points were used on the four digital VTM tiles, four per tile. Control points were first selected based on matching geographic coordinates from the VTM tiles to the basemap. When geographic coordinates were not apparent (either faded or cut off), specific topographic lines with the border or parts of text that occur on both VTM tile and basemap were used. Once the digital topographic base map and VTM tiles were in their native projection, it was possible to digitize vegetation polygon boundaries, assemble polygons, and enter their vegetation attributes into the GIS.

Digitizing

Automated line digitizing options failed to efficiently record the complex patterns on the VTMs (Fig. 2). The hand-drawn and colored vegetation polygons on the original Wieslander VTM tiles were therefore digitized on-screen to create a digital polygon coverage of the Wieslander vegetation maps. On-screen digitizing was performed by hand-digitizing the polygon boundaries with a pen tablet using the registered VTM tile as the background image. A pen tablet (Wacom Digitizing Tablet; Wacom 2004) allows the user to draw polygon boundaries directly on the screen using a pen or stylus. Lines were digitized at an onscreen scale of no less than 1:6000 so that the precision of digitized lines was high, with $<$10 m spatial error introduced for line accuracy digitization (Thorne et al. 2006, 2008).

Attributing

Once the polygon layer had been created for a quadrangle, the species codes written on the maps

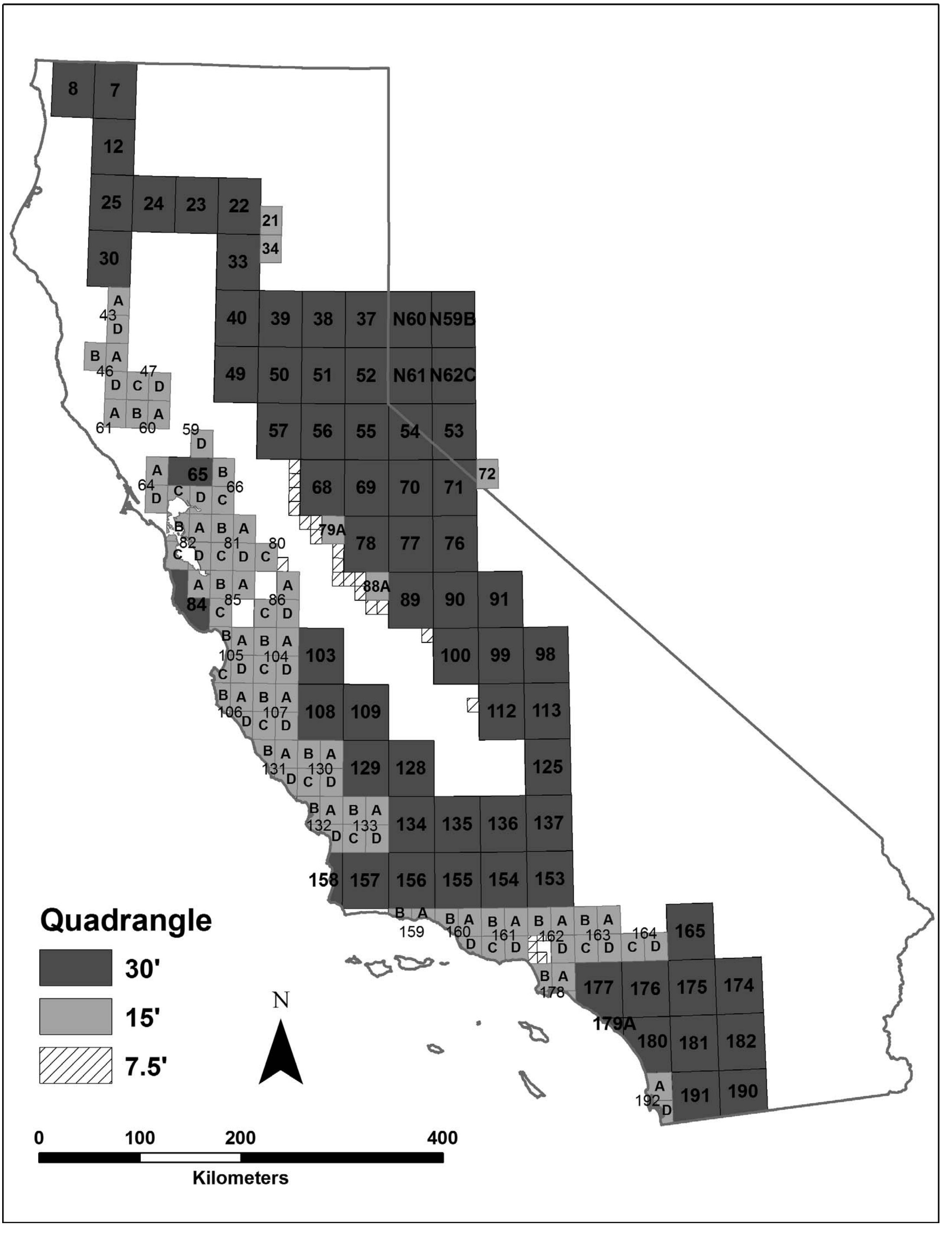

FIG. 1. The 30, 15, and 7.5 minute quadrangles surveyed during the VTM survey. The numbers are the VTM quadrangle ID numbers, while the letters represent the quarter quadrangles, which proceed counterclockwise from the northeast corner of any given quad. Quadrangle IDs are not shown for 7.5' quads.

were assigned to each polygon. There are multiple species codes for most polygons, reflecting the diversity of dominant trees, shrubs, and herbs in that polygon. Strings of species codes written in each polygon consist of up to nine species codes. Single species records mean that species covered at least 80% of the polygon. Two or more species mean that no species covered at least 80% of a polygon. Species

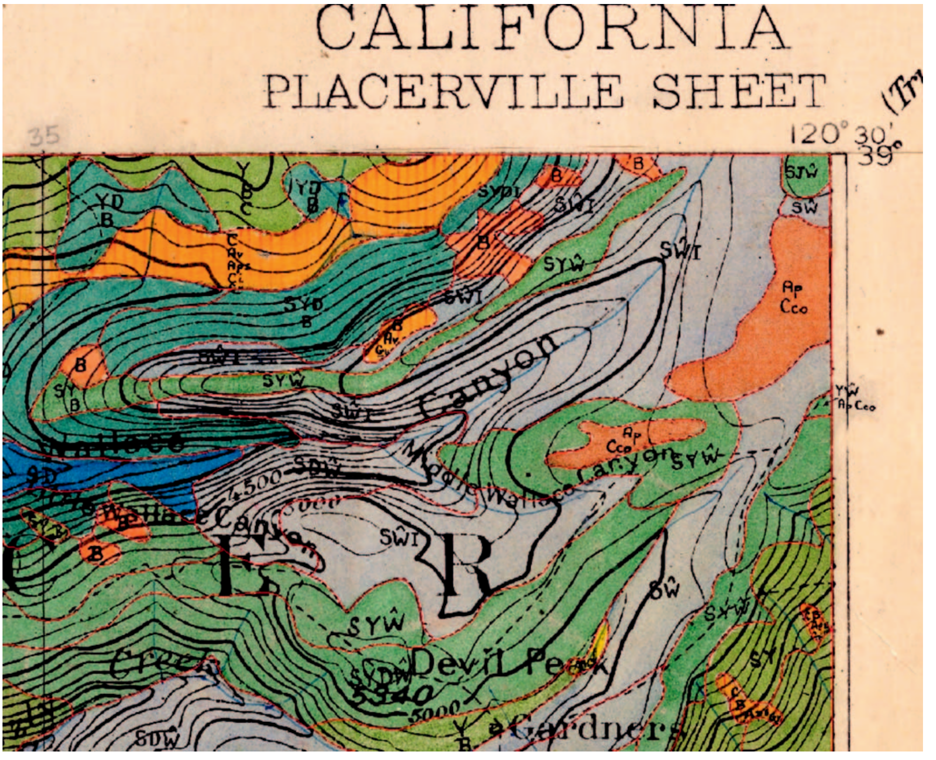

FIG. 2. An example of part of a scanned VTM, quadrangle 56. Lines demarcating different types of vegetation were traced over at a resolution such that the digitized line (shown in red) is less wide than the VTM's polygon boundary. Lines demarcating different types of vegetation were traced over at a resolution such that the digitized line (shown in red) is less wide than the VTM boundary. The polygon colors refer to the vegetation types as the VTM crews defined them; the codes in the polygons refer to the dominant species recorded; and the vertical red lines refer to a recent burn. The complex topographic lines and text on the base map made automated generation of polygon boundaries impractical.

are presented in rank-order dominance, excepting mosaic polygons in which trees and then shrubs, or shrubs and then annuals/perennials are listed (Wieslander 1935a). The species codes were entered in the polygon attribute table in the same order as they appear in the polygon.

Since the attributing process required close inspection of each individual polygon to read the species codes recorded for it, this process also provided an opportunity to double check and correct the line digitizing work. The species codes on the maps were created by the Wieslander project, and are not standard taxonomic codes, and can be cryptic. A list of species and codes is available in the VTM field handbook. We digitized this list, and used it in addition to margin notes on various quadrangles, to develop a lookup table for translating codes to species names and to populate the GIS attribute table with plant species names. We used the first edition Jepson manual (Hickman 1993) as the standard nomenclature, but later provided the additional newly updated Jepson names (Baldwin et al. 2012) as determined through the Jepson Interchange website (http://ucjeps.berkeley.edu/interchange/). Most polygons consist of a single vegetation type. However there are many cases where the species listed in polygons represent a mosaic of vegetation types within the polygon. Where these could be identified, species comprising the primary dominant type of the polygon were assigned two thirds of a polygon's area, and the secondary types one third (Thorne et al. 2008).

VTM polygons are also colored and in some cases marked with dashed lines that vary in their angle. The colors are the VTM assignment to major vegetation types, and the handbook identifies specific pencil brands and numbers to be used for specific vegetation types. The lines indicate that a polygon is in early seral condition at the time of mapping, due to either fire or logging. The cross hatching and angle was noted in the GIS attribute table. Explanation of the data fields is provided in Appendix 2.

From Species to Vegetation Types

The species strings from each polygon were used to assign vegetation classifications. We assigned vegetation and habitat types for the Manual of California Vegetation (MCV) classification system (Sawyer and Keeler Wolf 1995), and the California Wildlife Habitat relationships (WHR) Types (Mayer and Laudenslayer 1988; California Department of Fish and Wildlife 2004). We used the colors in the original polygons to help confirm the vegetation type designation derived from our species- and seral condition-based vegetation designations. Polygons with mosaic types were given a primary and secondary MCV and WHR types. Some important and recurring species combinations were classified into provisional vegetation classes and habitat types if they had not yet been classified in the MCV. The second edition of the California MCV (Sawyer et al. 2009) was published during this phase of the work, and the final GIS attributes also provide a crosswalk to this classification.

Data Vetting

Species strings were checked when assigning MCV/WHR type names, and species found outside their known range were checked to make sure no transcription error had occurred when the codes were originally entered. Species strings were checked a second time in collaboration with a plant ecologist from the USFS, who used distribution and unusual combinations of species as a screen to seek for transcription errors. Major tree species extents were checked spatially with a tree species distribution publication (Griffin and Critchfield 1972), and other species were checked against the Jepson Interchange. Anomalies were corrected where possible, however some codes indicate "true" species occurrences beyond known extents or possible errors that we could not decipher. Accepted anomalies are notated in the comments field for the corresponding polygon in the final GIS products.

Evaluation of Registration Error

Historical map error was investigated using Root Mean Square Error (RMSE). The RMSE for each quadrangle was determined by georeferencing the VTM base map to a modern map. Modern reference maps used were Digital Raster Grids downloaded from the Cal-Atlas Geospatial Clearinghouse (http://portal.gis.ca.gov/geoportal). The RMSE in meters between the same locations on each VTM quadrangle and corresponding modern map was calculated by registering control points. These control points were selected from coordinate tick marks, mountain peaks, and some rail and road intersections, if evidence was the roads had not been moved. By choosing the same locations on both maps the spatial accuracy (RMSE) can be determined. The RMSE value indicates how far off any point can be on the base map by comparison to modern topography, and by extension the spatial error of the VTM map.

The RMSE value has been used as the basis for determining the size of grid cells to select to calculate changes on the landscape through comparison with contemporary landcover maps (Thorne et al. 2008). Since the RMSE indicates the spatial accuracy between the historical and contemporary maps, selecting a grid cell size larger than a quadrangle's RMSE assures that the grid cells being compared through time overlap.

Map Compilation

We finalized two versions of each scanned VTM quadrangle, with and without the margins. The version with the margins cut off can be used to assemble visualizations of the original surveys for large extents of California. The margins in many cases contain considerable notes made by the surveyors, and were therefore retained in the second copy.

We generated the GIS version of the VTMs by quadrangle. Each quadrangle was completed as an original and is associated with the georectified scan of the topographic base map. The quad-by-quad VTMs were then combined, creating a single GIS of the entire survey. As each quadrangle was added to the compiled version, polygons that contained the same species combinations on either side of a quadrangle line were dissolved. In many cases, however, the adjacent species combinations differ, in which case the quadrangle line was retained. Finally, the data vetting exercises described above were conducted a second time on the final GIS layer.

This paper presents the summary information from the compiled digital work, including the number of species, extents of vegetation types, polygon size distribution, and RMSE values. We describe two versions of the GIS. The first includes large polygons on the edges of the survey that may be less well-mapped, and water bodies. The second, used for reporting extents of vegetation types, and information related to the vegetation such as the number of species, excludes the water bodies and large boundary polygons.

Results

The VTMs digitized cover 70 30' quadrangles, 86 15' quadrangles, and 31 7.5' quadrangles (Figs. 1, 3). The extent mapped including the border and lake polygons is 176,901.5 km^2, and excluding them is 165,652 km^2 (Fig. 4), here called the "analysis extent" and used to report areas of landcover types. Of the total, 7541 km^2 including border polygons and 7299 km^2 excluding them occur in Nevada, near Reno, while the remainder are in California. Secondary WHR types in mosaic polygons occupy 2094 km^2 under both map extents.

The total number of polygons surveyed is 251,541 polygons in the full extent and 249,630 in the analysis extent. A good way to determine the resolution of the mapping is to examine the size distribution of the mapped polygons. The polygon size ranges from 0.34 ha to 137,195 ha for the full extent (Table 1) and to 86,933 ha for the analysis extent. The smallest polygon is a wetland also recorded on the USGS base map. For the full extent, the mean polygon size

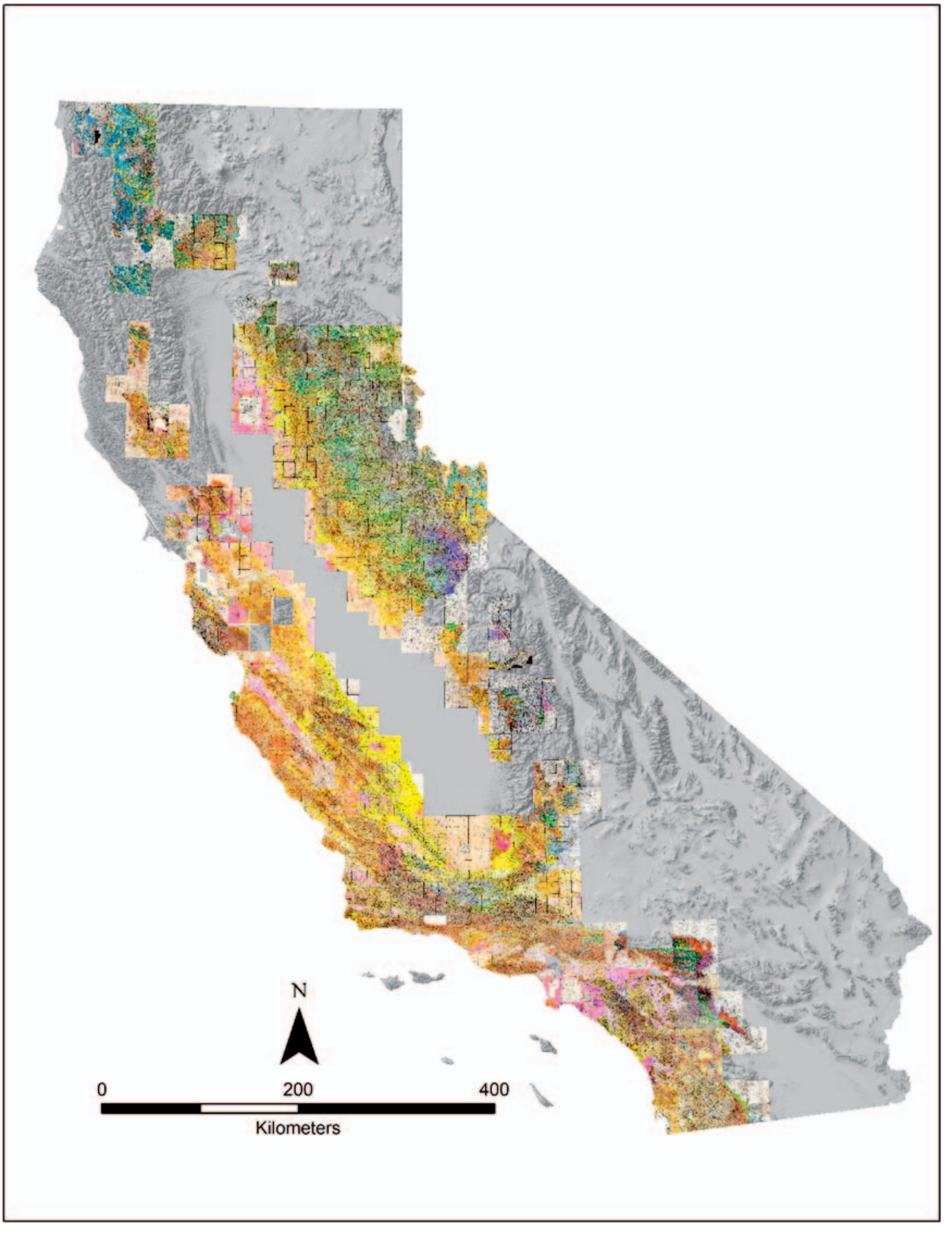

FIG. 3. Scans of the original VTMs showing the extent of the vegetation mapping.

is 70.3 ± 890.9 ha, while the median size is 12.9 ha. The maximum number of polygons is in the 8–16 ha size class, with 48,566. And, 54.5% of all the polygons range in size from 4–32 ha (Table 1).

The mean RMSE when registering the VTM topographic base maps to current topographic maps across all quadrangles is 59.7 m, median 48.3 m, and SD 50 m (Appendix 3). Seven quadrangles (five 30',

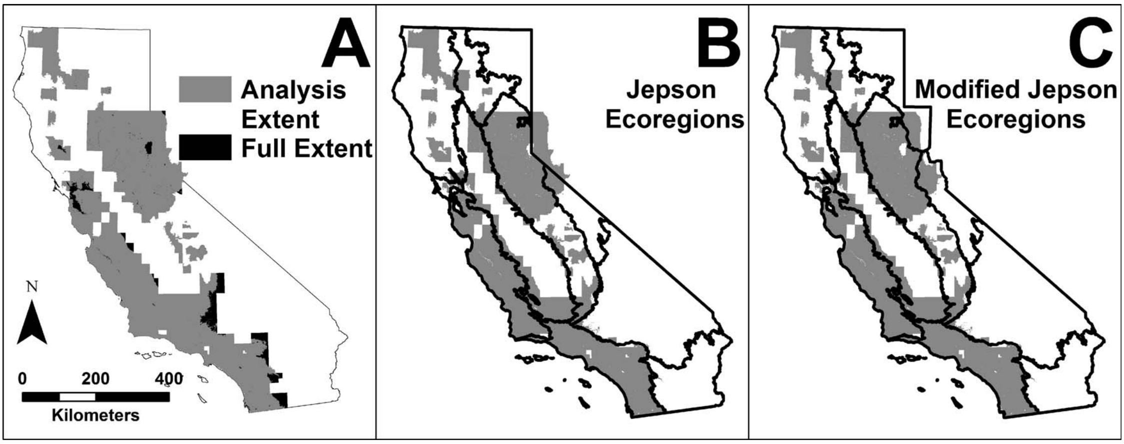

FIG. 4. Figure 4A portrays the extent of the VTM surveys with and excluding large water bodies and polygons on the borders of some surveyed areas. The map excluding border polygons is the one used for reporting extents of vegetation types, here called the "analysis extent". Figure 4B shows the extent of the analyzed maps overlaid on the Jepson (Hickman 1993) ecoregions. Because mapped areas extend beyond some ecoregion boundaries, we report ecoregional vegetation extents using modified ecoregions shown in Figure 4C. The two ecoregions we modified are the Modoc Plateau and East of the Sierra Nevada.

one full 15' and a partially surveyed 15') have RMSE above 150m.

There are 655 codes on the original maps (Appendix 4), representing 535 species or subspecies named in the maps. These represent 229 genera. There are 34 species or subspecies of *Arctostaphylos* Adans. identified, 12 for *Artemisia* L., 31 for *Ceanothus* L., 17 for *Eriogonum* Michx., 16 for *Pinus* L., and 16 for *Quercus* L. Thirty of the genus codes do not include a species name. There are eight codes for human-related landcover such as airport, residence, cultivated, etc., and 12 codes indicate habitat types ranging from rock and glacier, to deserts, marsh and meadow. There are 27 repeating codes but marked with parentheses which indicate the species is present but dead, snags after a burn, or that there is some cultivation or the area will likely be cultivated (specifically for the Cu code). There are 35 codes that refer to species that also have another code. There are seven unidentified codes, and we added a category for polygons with no species listed, termed 'no data'.

There are 26,013 unique combinations of species and cross-hatching codes. These were classed into 525 of vegetation Alliances or Provisional Alliances using the 2009 Manual of California Vegetation classifications (Sawyer et al. 2009), which correspond to 439 Alliances or Provisional Alliances in the 1995 version (Sawyer and Keeler Wolf 1995). The combinations also correspond to 53 California Wildlife Habitat Relationship Classes (Appendix 5; Mayer and Laudenslayer 1988; California Department of Fish and Wildlife 2004).We report historical landcover extents using the WHR classification, because of the lower number of landcover types into which the VTM species codes can be grouped. Those interested in the extents and patterns classed by Alliance should refer to the GIS version of the maps. Across the whole survey, 98.7% of the landcover is in the primary class (163,547 km^2), and 1.2% is in the secondary (2094 km^2), indicating mixed vegetation types within those polygons (Table 2). Among the natural vegetation types, the lowest extents mapped

TABLE 1. The polygon size distribution of the mapped extent of the VTM survey.

Polygon size distribution by hectare size class	Number of polygons (full VTM survey extent)
0–0.25	147
0.5	468
1	2674
2	11,910
4	30,356
8	45,890
16	48,760
32	42,584
64	30,659
128	18,975
256	10,158
512	5016
1024	2242
2048	958
4096	379
8192	183
16,384	109
32,768	45
65,536	17
>65,536	11
Total # of polygons	251,541
Average size (ha)	70.33
Median size (ha)	12.95
Standard deviation	890.96
Polygon size range(ha)	0.034–137,195.80

TABLE 2. The mapped area of landcover types identified in the VTM survey, using California's Wildlife Habitat Relationships classification and the analysis extent of the VTMs (Fig. 4).

		Total		
WHR	WHR name	Total WHR1 (km^2)	Total WHR2 (km^2)	Total (km^2)
ADS	Alpine Dwarf-Scrub	0.11	0	0.11
AGS	Annual Grassland	24,390	1343	25,733
ASC	Alkali Desert Scrub	1580	0	1580
ASP	Aspen	160	24	184
BAR	Barren	2360	1	2361
BBR	Bitterbrush	399	0	399
BCDF	Bigcone Douglas-Fir	406	15	421
BOP	Blue Oak-Foothill Pine	5628	0	5628
BOW	Blue Oak Woodland	5377	0	5377
COW	Coastal Oak Woodland	3941	0	3941
CPC	Closed-Cone Pine-Cypress	424	8	432
CRC	Chamise-Redshank Chaparral	14,763	8	14,771
CRP	Cropland	22,811	41	22,852
CSC	Coastal Scrub	7084	4	7088
DFR	Douglas Fir	4626	0	4626
DGR	Dryland Grain Crops	1	0	1
DRI	Desert Riparian	138	0	138
DSC	Desert Scrub	813	0	813
DSS	Desert Succulent Scrub	1	0	1
DSW	Desert Wash	152	0	152
EOR	Evergreen Orchard	0	0	0
EPN	Eastside Pine	553	0	553
EUC	Eucalyptus	83	0	83
FEW	Fresh Emergent Wetland	73	0	73
GLA	Glacier	1	0	1
JPN	Jeffrey Pine	4227	0	4227
JST	Joshua Tree	41	0	41
JUN	Juniper	1954	118	2072
KMC	Klamath Mixed Conifer	2466	0	2466
LAC	Lacustrine	5	0	5
LPN	Lodgepole Pine	1848	0	1848
LSG	Low Sage	130	0	130
MCH	Mixed Chaparral	9313	2	9314
MCP	Montane Chaparral	3707	2	3709
MHC	Montane Hardwood-Conifer	440	0	440
MHW	Montane Hardwood	6573	232	6805
MRI	Montane Riparian	242	49	290
PAS	Pasture	2	0	2
PGS	Perennial Grassland	715	0	715
PJN	Pinyon-Juniper	4278	0	4278
PPN	Ponderosa Pine	6604	0	6605
RDW	Redwood	715	12	727
RFR	Red Fir	3621	0	3621
SCN	Subalpine Conifer	1899	0	1899
SEW	Saline Emergent Wetland	605	0	605
SGB	Sagebrush	5631	0	5631
SMC	Sierran Mixed Conifer	6179	0	6179
UKW	Unknown	1684	0	1684
URB	Urban	1511	70	1581
VOW	Valley Oak Woodland	721	29	750
VRI	Valley Foothill Riparian	536	91	627
WFR	White Fir	1213	0	1213
WTM	Wet Meadow	926	46	972
	Total:	163,547	2094	165,641
	Overall Area			424,314.3
	Percent Area Mapped			39.0

include Alpine dwarf scrub (0.1 km^2), Desert Succulent Scrub (0.9 km^2), and Joshua Trees (41.01 km^2); while grasslands (25,733 km^2) Chamise-redshank chaparral (14,771 km^2), Mixed chaparral (9314 km^2), and Coastal Scrub (7088 km^2) are among the most extensively mapped natural vegetation types (Table 2). Agriculture covers and additional 22,852 km^2, there was 1581 km^2 of urban, 83

km^2 in Eucalyptus, and 1684 km^2 of unknown landcover, while only small amounts of the deserts were mapped (Fig. 4, Table 2).

Since the survey covers parts of 10 ecoregions, it is informative to examine landcover by ecoregion, which can provide a sense of the relative proportions of different landcover types within major ecoregions of the state (Table 3A–C). These tables provide the area of WHR landcover types using the analysis extent and the for modified Jepson ecoregions from the 1993 Jepson flora (Fig. 4C, Hickman 1993). The Southwestern ecoregion is the most completely surveyed region, with 93% of the area mapped, followed by the Central Western ecoregion (88.2%) which includes the Bay Area, the Sierra Nevada (71.6%), and the Great Valley (39.7%).

Discussion

The Wieslander Vegetation Type Map project was the first attempted systematic survey of the forests and woodlands of California. Encompassing nearly half the state, it represents a tremendous opportunity for assessment of landscape change. The ecoregions with particular promise, because of the extent of surveys within them are the Central Western Coast, Southwestern Coast, the Transverse Ranges, and the Central and Northern Sierra Nevada Mountains. Large areas in the Klamath Mountains and west of Reno, NV were also mapped and could be used for landscape change analyses.

Most of the USFS administrative units in California had been established shortly before the survey, and three were established during the survey. The VTM maps and plot data were used by the USFS to make projections of timber volume and of land condition. Timber volume calculations in tabular form, derived from a 1930's combination of the VTM plot data and maps remain a part of the VTM collection that has not been analyzed, although the data are now digital. Assessments of timber could easily have become the focus of the VTM field effort, and critiques of the VTM plot data are that it is therefore biased in the direction of recording more forested areas and of biasing locations sampled towards relatively bigger trees than surrounding conditions (Bouldin 1999, Keeley 2004). However, the leader of the project, Albert Wieslander, asserts the actual methods used during his 1986 interviews for the Berkeley History project. He reminds us of what the VTM field manual instructs — that the surveyors were to map the existing vegetation, and that each vegetation plot surveyed concurrently with the mapping effort is intended to portray the average condition of the trees and shrubs of the polygon within which it was taken. Regarding the suggested bias towards big trees, both resurveys of VTM plots and comparisons of VTM plot data to contemporary independent plot data, have found declines in large trees (e.g., Lutz et al. 2009; Fellows and Goulden 2008; Dolanc et al. 2013; 2014; McIntyre et al. 2015). However, other historical comparison studies that do not use the VTM plot data (e.g., van Mantgem et al. 2007) have found similar patterns, so it seems difficult to prove that there is a bias in the VTM plot data. There is no way we know of to disprove the suggestions of over-estimation of tree size and oversampling of forest plots relative to forest proportion on the landscape, other than to point out that the head of the program had a different perception of how the data were to be recorded and used, that many of the VTM plot data locations are in chaparral, and that far more research publications have found utility in the VTM plot data (Appendix 1) than have determined it inaccurate (Bouldin 1999, Keeley 2004).

These critiques however, do not relate to the VTM's vegetation maps, which are the subject of this paper. Without doubt these make up one of the most complete and taxonomically extensive field survey efforts ever conducted in California (Colwell 1977). The results include one of the foundational collections of vascular plants for the Jepson Herbarium, which was used to confirm the species mapped, and cartographically exquisite (Figs. 5–9), highly information dense maps that portray large extents of the natural landscapes of California.

Approaches to Handling the Spatial Accuracy

We reproduced the VTM maps to their original level of spatial accuracy, and each map has varying levels of topographic fidelity relative to modern terrain maps. Our reasoning was that it was important to get an exact replica of the original VTMs. More intensive transformations of the VTMs to match modern topography are technically feasible, and have been conducted for two areas. Based on more than 14,000 total photo interpreted tiepoints in the Yosemite National Park VTMs (6793 total polygons), Walker (2000) recorded an RMSE in the park VTMs of 242.5 m. The latter could involve a convolution of 1980's-era digitizing errors, plus the original VTM errors. Positional errors were much more pronounced in some areas due to the compounding effects of extreme relief (which caused larger than average base map inaccuracies), and the difficulty of VTM crews in accessing adequate viewing vantage points, which even then often offered only high-oblique angles to look at the ground, such as across canyons. However, Walker's study did not have the benefit of scans of the original maps- he worked with polygons that another, unknown contractor had developed from the hardcopy maps, set upon a digitizing table. We observed similar patterns of higher RMSE in topographically complex regions, but generally found lower RMSE values for the majority of VTM quads after using the scans of the original maps for registration purposes.

In 2008, National Park Service vegetation ecologists at the Santa Monica Mountains National

TABLE 3A. The extent of WHR types mapped by the VTM survey within modified Jepson Ecoregions using the analysis extent (Fig. 4C). All area values are in km^2.

	Cascade Ranges			Central Western CA			East of Sierra Nevada			Great Valley		
WHR	Total WHR1	Total WHR2	Total	Total WHR1	Total WHR2	Total	Total WHR1	Total WHR2	Total	Total WHR1	Total WHR2	Total
ADS	0	0	0	0	0	0	0	0	0	0	0	0
AGS	163	79	242	6904	455	7359	16	3	19	11,511	266	11,777
ASC	0	0	0	3	0	3	1	0	1	1556	0	1556
ASP	1	0	1	0	0	0	77	5	82	0	0	0
BAR	44	0	44	160	0	160	220	0	220	41	0	41
BBR	4	0	4	0	0	0	17	0	17	11	0	11
BCDF	0	0	0	27	1	27	0	0	0	0	0	0
BOP	558	0	558	2088	0	2088	0	0	0	40	0	40
BOW	143	0	143	1822	0	1822	0	0	0	250	0	250
COW	0	0	0	2660	0	2660	0	0	0	4	0	4
CPC	6	0	6	116	1	117	0	0	0	0	0	0
CRC	0	0	0	4507	1	4508	0	0	0	6	0	6
CRP	78	0	78	6040	20	6059	54	15	69	7714	1	7715
CSC	0	0	0	2470	0	2470	0	0	0	148	0	148
DFR	38	0	38	65	0	65	0	0	0	2	0	2
DGR	0	0	0	0	0	0	0	0	0	0	0	0
DRI	0	0	0	0	0	0	0	0	0	131	0	131
DSC	0	0	0	5	0	5	185	0	185	177	0	177
DSS	0	0	0	0	0	0	0	0	0	0	0	0
DSW	0	0	0	2	0	2	0	0	0	110	0	110
EOR	0	0	0	0	0	0	0	0	0	0	0	0
EPN	0	0	0	0	0	0	50	0	50	0	0	0
EUC	0	0	0	53	0	53	0	0	0	1	0	1
FEW	0	0	0	28	0	28	0	0	0	1	0	1
GLA	0	0	0	0	0	0	1	0	1	0	0	0
JPN	132	0	132	13	0	13	56	0	56	0	0	0
JST	0	0	0	0	0	0	0	0	0	0	0	0
JUN	0	0	0	209	65	274	28	0	28	19	5	24
KMC	381	0	381	0	0	0	0	0	0	0	0	0
LAC	0	0	0	5	0	5	0	0	0	0	0	0
LPN	64	0	64	0	0	0	104	0	104	0	0	0
LSG	0	0	0	0	0	0	23	0	23	0	0	0
MCH	691	0	691	2233	0	2233	0	0	0	77	0	77
MCP	196	0	196	0	0	0	115	0	115	0	0	0
MHC	3	0	3	118	0	118	0	0	0	0	0	0
MHW	418	1	419	837	108	945	1	0	1	61	13	74
MRI	4	2	6	26	0	27	13	8	21	46	1	46
PAS	0	0	0	2	0	2	0	0	0	0	0	0
PGS	3	0	3	562	0	562	0	0	0	107	0	107
PJN	0	0	0	10	0	10	1185	0	1185	17	0	17
PPN	312	0	312	36	0	36	0	0	0	0	0	0
RDW	0	0	0	604	2	606	0	0	0	0	0	0
RFR	182	0	182	0	0	0	1	0	1	0	0	0
SCN	64	0	64	0	0	0	196	0	196	0	0	0
SEW	0	0	0	202	0	202	2	0	2	365	0	365
SGB	0	0	0	5	0	5	1840	0	1840	2	0	2
SMC	660	0	660	13	0	13	0	0	0	0	0	0
UKW	22	0	22	252	0	252	21	0	21	135	0	135
URB	1	0	1	464	4	468	1	0	1	43	0	43
VOW	16	0	17	442	11	454	0	0	0	63	7	70
VRI	1	1	2	192	14	207	0	0	0	142	13	155
WFR	20	0	20	0	0	0	5	0	5	0	0	0
WTM	8	1	9	36	0	36	158	5	164	195	0	195
Total:	4213	84	4298	33,212	682	33,894	4371	36	4407	22,978	304	23,282
Area of Ecoregion			20,754.8			38,412.6			18,925.4			58,630.3
Percent of Ecoregion Mapped			20.7			88.2			23.3			39.7

TABLE 3B. The extent of WHR types mapped by the VTM survey within modified Jepson Ecoregions using the analysis extent (Fig. 4C). All area values are in km^2.

	Modoc Plateau and Nevada			Mojave Desert			Northwestern CA		
WHR	Total WHR1	Total WHR2	Total	Total WHR1	Total WHR2	Total	Total WHR1	Total WHR2	Total
ADS	0	0	0	0	0	0	0	0	0
AGS	230	47	277	348	9	357	523	12	534
ASC	2	0	2	2	0	2	0	0	0
ASP	5	0	5	0	0	0	0	0	0
BAR	8	0	8	181	0	181	97	0	97
BBR	91	0	91	85	0	85	0	0	0
BCDF	0	0	0	0	0	0	0	0	0
BOP	0	0	0	7	0	7	272	0	272
BOW	0	0	0	6	0	6	304	0	304
COW	0	0	0	0	0	0	203	0	203
CPC	0	0	0	0	0	0	259	6	265
CRC	0	0	0	23	0	23	975	1	976
CRP	277	2	279	277	0	277	428	0	429
CSC	0	0	0	12	0	12	14	0	14
DFR	0	0	0	0	0	0	4218	0	4218
DGR	0	0	0	0	0	0	0	0	0
DRI	0	0	0	0	0	0	0	0	0
DSC	169	0	169	52	0	52	0	0	0
DSS	0	0	0	0	0	0	0	0	0
DSW	0	0	0	0	0	0	0	0	0
EOR	0	0	0	0	0	0	0	0	0
EPN	8	0	8	0	0	0	0	0	0
EUC	0	0	0	0	0	0	0	0	0
FEW	0	0	0	1	0	1	0	0	0
GLA	0	0	0	0	0	0	0	0	0
JPN	60	0	60	0	0	0	122	0	122
JST	0	0	0	37	0	37	0	0	0
JUN	751	0	751	334	2	335	0	0	0
KMC	0	0	0	0	0	0	2085	0	2085
LAC	0	0	0	0	0	0	0	0	0
LPN	4	0	4	0	0	0	18	0	18
LSG	26	0	26	0	0	0	0	0	0
MCH	0	0	0	150	0	150	674	0	674
MCP	51	0	51	0	0	0	798	0	798
MHC	0	0	0	0	0	0	124	0	124
MHW	0	0	0	2	0	2	1601	19	1620
MRI	4	1	5	1	0	1	12	1	13
PAS	0	0	0	0	0	0	0	0	0
PGS	0	0	0	1	0	1	25	0	25
PJN	523	0	523	139	0	139	0	0	0
PPN	2	0	2	0	0	0	584	0	584
RDW	0	0	0	0	0	0	111	10	121
RFR	2	0	2	0	0	0	776	0	776
SCN	5	0	5	0	0	0	20	0	20
SEW	11	0	11	0	0	0	0	0	0
SGB	2039	0	2039	14	0	14	0	0	0
SMC	0	0	0	0	0	0	0	0	0
UKW	41	0	41	6	0	6	771	0	771
URB	16	0	16	1	0	1	9	0	9
VOW	0	0	0	4	0	4	44	2	46
VRI	4	0	4	0	0	0	7	2	8
WFR	1	0	1	0	0	0	357	0	357
WTM	36	0	36	0	0	0	11	0	11
Total:	4364	51	4415	1683	11	1694	15,443	54	15,497
Area of Ecoregion			30,294.9			73,982.8			55,937.5
Percent of Ecoregion Mapped			14.6			2.3			27.7

TABLE 3C. The extent of WHR types mapped by the VTM survey within modified Jepson Ecoregions using the analysis extent (Fig. 4C). All area values are in km^2.

	Sierra Nevada			Sonoran Desert			Southwestern CA		
WHR	Total WHR1	Total WHR2	Total	Total WHR1	Total WHR2	Total	Total WHR1	Total WHR2	Total
ADS	0	0	0	0	0	0	0	0	0
AGS	2447	372	2819	5	0	5	2244	101	2345
ASC	3	0	3	0	0	0	13	0	13
ASP	77	19	96	0	0	0	0	0	0
BAR	1442	0	1443	4	0	4	164	0	164
BBR	166	0	166	0	0	0	26	0	26
BCDF	0	0	0	0	0	0	379	14	393
BOP	2653	0	2653	0	0	0	10	0	10
BOW	2843	0	2843	0	0	0	9	0	9
COW	0	0	0	0	0	0	1074	0	1074
CPC	26	0	26	0	0	0	18	0	18
CRC	920	5	925	31	0	31	8302	0	8302
CRP	884	2	885	1	0	1	7059	2	7061
CSC	21	0	21	60	0	60	4358	4	4362
DFR	303	0	303	0	0	0	0	0	0
DGR	1	0	1	0	0	0	0	0	0
DRI	0	0	0	0	0	0	6	0	6
DSC	32	0	32	13	0	13	180	0	180
DSS	1	0	1	0	0	0	0	0	0
DSW	0	0	0	0	0	0	40	0	40
EOR	0	0	0	0	0	0	0	0	0
EPN	495	0	495	0	0	0	0	0	0
EUC	0	0	0	0	0	0	28	0	28
FEW	0	0	0	0	0	0	42	0	42
GLA	0	0	0	0	0	0	0	0	0
JPN	3540	0	3540	0	0	0	303	0	303
JST	3	0	3	0	0	0	1	0	1
JUN	247	5	252	35	1	37	332	39	371
KMC	0	0	0	0	0	0	0	0	0
LAC	0	0	0	0	0	0	0	0	0
LPN	1591	0	1591	0	0	0	67	0	67
LSG	82	0	82	0	0	0	0	0	0
MCH	1797	2	1798	145	0	145	3545	0	3545
MCP	2489	2	2491	0	0	0	58	0	58
MHC	23	0	23	0	0	0	172	0	172
MHW	3042	92	3134	0	0	0	609	0	609
MRI	84	37	120	1	0	1	50	0	50
PAS	0	0	0	0	0	0	0	0	0
PGS	4	0	4	0	0	0	13	0	13
PJN	1305	0	1305	116	0	116	983	0	983
PPN	5016	0	5016	0	0	0	654	0	654
RDW	0	0	0	0	0	0	0	0	0
RFR	2660	0	2660	0	0	0	0	0	0
SCN	1614	0	1614	0	0	0	0	0	0
SEW	13	0	13	0	0	0	12	0	12
SGB	1444	0	1444	0	0	0	286	0	286
SMC	5254	0	5254	0	0	0	252	0	252
UKW	336	0	336	8	0	8	91	0	91
URB	29	0	30	0	0	0	946	65	1011
VOW	106	9	115	0	0	0	44	0	44
VRI	33	11	44	1	0	1	156	49	205
WFR	787	0	787	0	0	0	42	0	42
WTM	426	39	464	0	0	0	55	1	55
Total:	44,240	594	44,834	421	2	422	32,622	277	32,899
Area of Ecoregion			62,582.6			29,422.6			35,370.7
Percent of Ecoregion Mapped			71.6			1.4			93.0

FIG. 5. Details of the original VTMs from the Oakland area and from the National Park Service Mapping in Lassen National Park.

Recreation Area hired Aerial Information Systems (AIS) to convert the original VTM hardcopy maps into an ArcMap geodatabase. They registered the maps and captured data one small area at a time, edge-mapping and redrafting the original vegetation polygons with reference to modern USGS basemaps and 2001 orthophoto imagery. All attribute data was captured, and all taxonomic references were updated with reference to the 1993 Jepson Manual. The NPS has used these digital maps in a number of projects to study vegetation dynamics. (R. Taylor, personal communication).

For broad landscape analyses, incorporating the spatial inaccuracies of the historic maps can be adequately addressed using a grid-based analysis in which the vegetation polygons are resampled to grids for change analysis by comparison to contemporary vegetation maps. To this end we provide the RMSE values of registering each quadrangle to modern topography (Appendix 3). This has proven effective for change analyses on a single 30' quadrangle in the Sierra Nevada (Thorne et al. 2008) and for a study in the Bay Area (Thorne et al. 2013). The RMSE errors suggest that analyses across large regions could be conducted at 100 m or 150 m resolution. Analyses for smaller areas and finer scales may need to consider further topographically-based modification of the VTMs. Such attempts should also consider the minimum mapping unit limitations of the VTMs. Generally, contemporary vegetation maps have finer spatial grain, and less taxonomic detail than the VTMs. The normalization of these map components with the contemporary data to be used is suggested for spatially-based landscape change analyses using the VTMs.

At the beginning of the survey, the VTM mapping used first edition USGS topographical quadrangles, which were part of the US Geodetic Survey and recorded topography onto 30' quadrangles, often from the late 1800's. The topographic base maps were nearly all developed prior to adoption of the North American Datum of 1927 (NAD27), meaning that the VTMs were drawn on topographic maps made using the 1866 Clarks ellipsoid datum and the polyconic projection (Gannet 1904, United States Department of Commerce, Coast and Geodetic Survey 1917, Beaman 1928, Snyder 1982). During the course of the survey, maps with greater spatial resolution became available and some of the later edition VTM quadrangles are presented on 15' and even 7.5' quads, and use the NAD27 datum. In all cases we converted the final GIS to NAD83, California Teale Albers projection. However, in cases where both 7.5' or 15' quadrangles exist as well as a 30' map, it appears that the finer-resolution quadrangles are copies from the original surveys, conducted using the 30' quadrangle.

Opportunities

An interesting perspective that archival agency data permit, is the tracking of prevailing practice and thought within agencies through administrative changes over time. Historians working for the NPS or the USFS infrequently describe this type of dynamic. However, it can be very valuable for the purposes of tracking landscape-scale dynamics to do so, because understanding how one program influenced the next can help with the integration of large survey datasets for analysis. In the case of the VTMs, the methods used were subsequently incorporated into the state of California's Soil Vegetation Survey mapping efforts. The Soil Vegetation Survey (SVS) was a collaborative program by the state, the USFS, and the University of California, which mapped much of California's natural lands and is spatially complimentary to the VTMS (Keeler-Wolf 2007). The SVS maps contain polygon-specific information about the soil types and species codes denoting dominant species in rank descending order for each polygon, which are the same as the codes used in the VTM maps. There was considerable overlap of personnel during the SVS program, including Wieslander himself, who was instrumental in developing and running the SVS program (Wieslander 1986). An important product that integrates the VTM maps with the SVS is the atlas of range maps for California's tree species (Griffin and Critchfield 1972). The digitization of the SVS is an opportunity to establish additional California reference conditions for vegetation, from the 1940's and 1950's, particularly for the northwest ecoregion, and potentially parts of the Sierra Nevada. Further investigation into how California's SVS and the National Resources Conservation Service's soil survey program (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/survey/) correspond to each other; and into the relationship between the VTM's species-specific mapping efforts and later ones using the US National Vegetation Classification System (http://usnvc.org/) or other national landcover classifications, could allow an examination of the VTM results from broader spatial and mapping perspectives, and also might permit use of the detail in the VTMs to assess the quality of the national products.

The VTM maps contain more taxonomic information than available in modern landcover maps in California. Modern vegetation mapping efforts in California fall into two general classes; efforts that are specific to California and efforts that are part of more extensive mapping endeavors. There exist currently several California-specific vegetation mapping efforts including: the Manual of California Vegetation (MCV), the State government's most intensive and detailed mapping effort; a USFS product termed 'CalVeg' (http://www.fs.fed.us/r5/rsl/projects/mapping/accuracy.shtml); and the 'FRAP' map, a rasterized state-level effort to integrate the most current, detailed, and accurate maps available. It is produced by the California Department of Forestry and Fire Protection (http://frap.fire.ca.gov/). Each of these products provides more detail than any of the national-scale map

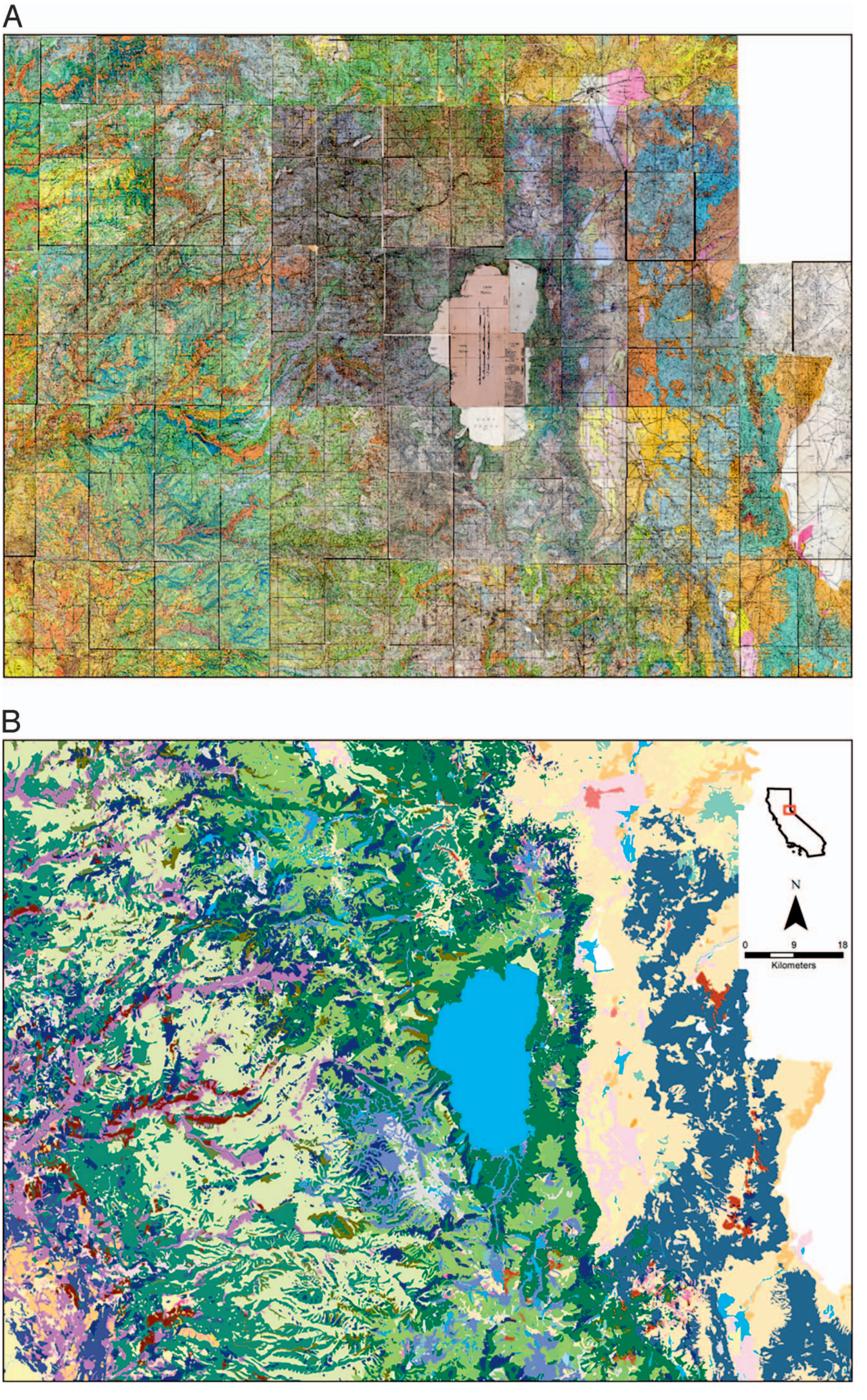

FIG. 6. A mosaic of multiple VTM quadrangles representing the Lake Tahoe and Central Sierra Nevada region. Figure 6A shows the original maps. Figure 6B shows the GIS rendered from the VTMs, using WHR landcover types as the classification (Fig. 7).

FIG. 7. The legend of the WHR types shown in the GIS portrayal of Figure 6.

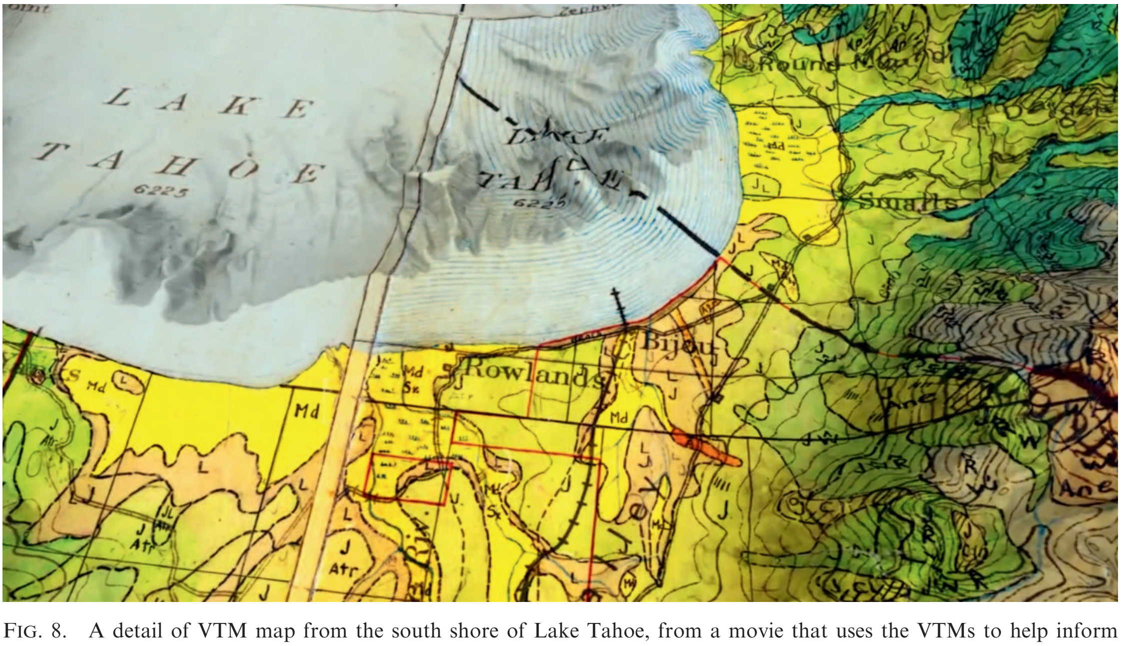

FIG. 8. A detail of VTM map from the south shore of Lake Tahoe, from a movie that uses the VTMs to help inform changes in forest lands in the Sierra Nevada (Thorne & McQuinn 2012)

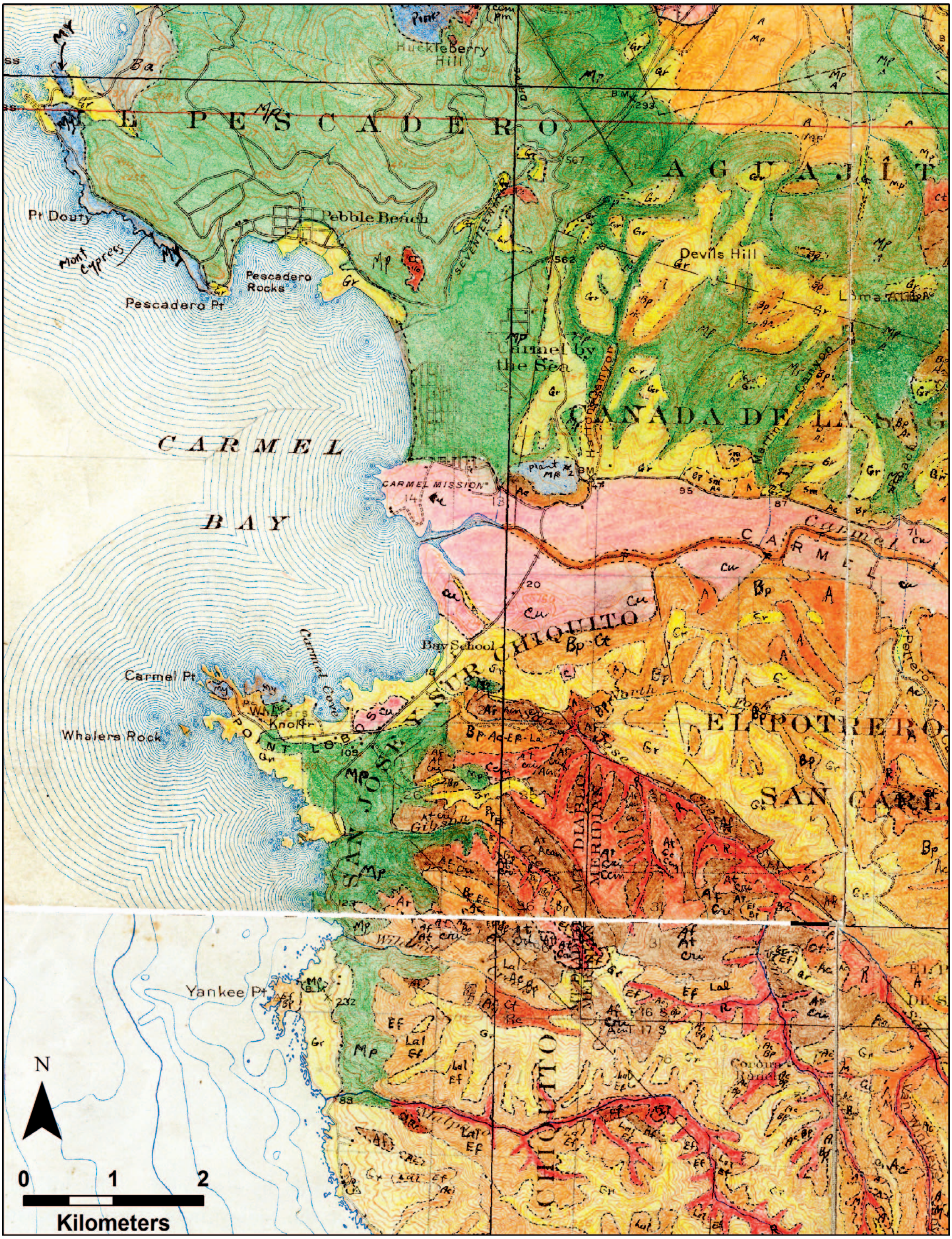

FIG. 9. A detail from mosaicked VTM tiles from the Monterey Bay Area.

efforts. The first edition of the US GAP analysis program map for California (Davis et al 1995, 1998) has more species-specific information in it than other national products, which include a second edition National GAP Analysis effort (http://gapanalysis.usgs.gov/), Landfire (http://landfire.cr.usgs.gov/viewer/), and NatureServe's (http://www.natureserve.org/) maps. However, even the state's MCV maps, which contain by far the most species-specific information among contemporary maps, do not retain at the polygon level the number of species recorded by the VTMs. In addition, while the MCV classification of landscapes has been adopted by the National Park Service, which has funded such mapping for all NPS lands in California, the methods are intensive, and despite a long-term dedicated effort, less than ½ the state has been mapped using this approach. The MCV rate of mapping is not dissimilar to the rate the VTM project accomplished, of about one half of the state in about 14 years. By recording the dominant species in each polygon, the VTMs have greater flexibility to be classed according to various classifications, for comparison to modern maps. Inclusion of this level of taxonomic detail could become a goal for contemporary mapping efforts.

Use of national-scale map classifications for assessment of landcover change in California may be problematic, because of the lack of recognition of endemic dominant tree species, and also due to widespread mis-identification or mis-classification of vegetation types, particularly of the second edition US GAP analysis survey map, and also of early versions of NatureServe's map for the region. While a formal comparative analysis of all contemporary map products available has not yet been done, the high levels of plant species diversity in California require some engagement of local botanists to develop maps sufficiently accurate for use in assessment of landcover change (Thorne et al 2008). It should be noted that the groups engaged with the different state-level mapping approaches are aware of each other's work, and are collaborating in an attempt to improve the quality of statewide maps.

The VTM maps can be used for several types of analysis. First, as shown by Griffin and Critchfield (1972), the ranges and locations of individual species can be developed. Second, assessment of change in the location of habitats can be determined (Thorne et al. 2008). However, the VTM polygons are generally too large to permit direct comparison with the more detailed maps produced using the MCV methodology, and for practical purposes, landcover change has so far been done using the state's more general classification system, the WHR.

Finally, several quadrangles that we suspect were surveyed are missing from the overall collection. Historically, it was permitted that originals were removed for use by various research and agency personnel. During the efforts to digitize the collection, several repositories of maps were recovered. However, two 15' quadrangles are missing from the Central Coast ecoregion, which if recovered would improve representation for that region: quads 86B (west of Orestimba Peak) and 85D (south of the Mt. Doug and west of the Gilroy Hot Springs quadrangles). Additionally the 30' Cuyama quadrangle is missing a portion (156D tiles 3 and 4), and three 7.5' quadrangles south of Pacifico Mountain and San Fernando (162q, r, and w) were not in the collection. It may be possible that these quadrangles are still in existence, and the authors request agency and research personnel to search their archives. The VTM maps and corresponding GIS are posted on the VTM website at UC Berkeley (http://vtm.berkeley.edu), which can be used for further detail about the missing quadrangles and to obtain the data for other purposes. Additionally, two 30' quadrangles representing the locations of VTM plots around northern Lake Tahoe and to the west of it (the Colfax and Truckee quadrangles) would greatly improve the collection if they are found and returned.

Acknowledgments

This study was a joint effort supported financially by many agencies including the U.S. Forest Service, National Science Foundation, California Energy Commission, Sequoia and Kings Canyon National Parks, Lassen National Park, Tahoe National Forest, Sierra National Forest, Klamath National Forest, Los Padres National Forest, the Keck Foundation and the Tejon Ranch Conservancy. It would not have been possible without the aid of Mary Larsgaard and Greg Hajic at the Alexandria Digital Library (University of California, Santa Barbara), the Chico Map Library, and the UC Berkeley Geology Map Library, who provided scanned base maps. Financial and intellectual support were unstintingly provided by Professors Barbara Allen-Diaz, Craig Moritz, Maggi Kelly, and David Ackerly, UC Berkeley, Dr. Todd Keeler-Wolf, CA Department of Fish and Wildlife, and Dr. Hugh Safford, U.S. Forest Service.

We thank our colleagues who also worked on organizing the project and the digitizing the maps, Ryan M. Boynton, Jackie Bjorkman, Andrew Holguin, Jeff Kennedy, and Sarah Thrasher. We thank Aaron Fulton, Camille Kustin, Alexa Callison-Burch, Noriyuki Nawata, Joyce Hsu, Clay Delong, Trevor Cleak, Simmy Pattar, Myra Kim, Joseph A. Stewart, Brian Morgan, Rodd Kelsey, Kyle Shipley, Michael Louie, Trevor Cleak, and many other students for their patient work digitizing and attributing the original maps. We thank Dr. Jim Quinn, UC Davis, for providing the space to house computers and host the work.

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APPENDIX 1

A brief list of plot-based publications that make use of the Wieslander VTM plots for historical change studies.

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APPENDIX 2

The data fields in the VTM GIS. This Appendix provides a definition for each field found in the attribute tables of GIS developed from the VTMs. They are presented in descending order, which follows the column headings from left to right.

FID = internal GIS ID
VTM ID = unique polygon ID
VTM Quad ID = ?
Area HA = calculated polygon area in hectares
Area M^2 = calculated area in square meters

WHR1 = California Wildlife Habitat Relationship Code for primary vegetation type, derived from cross walking the Manual of California Vegetation (1995) classification to the WHR system.

WHR1 Type = Full name of the California Wildlife Habitat Relationship type for primary vegetation type, derived from cross walking the Manual of California Vegetation (1995) classification to the WHR system.

WHR2 = California Wildlife Habitat Relationship Code for secondary vegetation type, derived from cross walking the Manual of California Vegetation (1995) classification to the WHR system.

WHR2 Type = Full name of the California Wildlife Habitat Relationship type for secondary vegetation type, derived from cross walking the Manual of California Vegetation (1995) classification to the WHR system.

MCV1 1995 = Alliance name from 1995 edition of the Manual of California Vegetation. This is for the primary vegetation type in a polygon.

MCV2 1995 = Alliance name from 1995 edition of the Manual of California Vegetation. This is for the secondary vegetation type in a polygon.

MCV1 2009 = Alliance name from 2009 edition of the Manual of California Vegetation. This is for the primary vegetation type in a polygon.

MCV2 2009 = Alliance name from 2009 edition of the Manual of California Vegetation. This is for the secondary vegetation type in a polygon.

SP1–Sp9 = VTM codes listing the species, or occasionally the vegetation or land cover type, recorded in each polygon

SP1 Name–SP9 Name = Latin binomial for the species codes from previous column, from the first edition Jepson Manual (Hickman 1993).

CH Angle = Angle of cross-hatching in polygons that show cross-hatching. These lines refer to sparse vegetation or recent disturbance for the polygon in question. The disturbance can be either due to fire or to logging. If the cross-hatching is in black ink it refers to sparse vegetation, in red to brown ink (refer to scanned images, not completely recorded in GIS) it refers to fire, if in blue ink it refers to logging.

Note that for burned areas, the field instructions (Wieslander et al. 1934) indicate that crews were to get fire maps from local rangers and then to adjust the fire perimeters when in the field. Therefore, early fires recorded in the VTMs may represent more accurate fire boundaries than early fire boundaries derived from other sources. These fire boundaries may portrayed in a compiled form in the Weeks et al. (1943) publication for the central and northern Sierra Nevada, but they could also be extracted from the GIS of the VTMs to compare with other maps of fire perimeters from the 1930's, and comparison to contemporary fire perimeters.

We interpret the cross-hatching angles to mean the following (as per the field manual by Coffman (1934):

Burns

//: 45° angle. Recent burns are indicated by a cross-hatching of diagonal lines running from left to right in red to brown ink.

=: 90° angle. Brushfields and woodland areas which have resulted from fire within the virgin stands that are not restocking to coniferous timber. The timber species are present as reproduction, rather than as mature trees. (no visible reproduction). Indicated by cross-hatching of horizontal lines.

0 = no cross-hatching.

\\:135° angle. Brushfields and woodland areas which have resulted from fire within the virgin stands that are restocking to coniferous timber. The timber species are present as reproduction, rather than as mature trees. Numbers on top of the cross hatching refer to 1 = well stocked; 2 = medium stocked, and 3 = poorly stocked.

||: 360° angle. Areas recently deforested by burns, which have not yet developed into brushfields or other non-coniferous fire types. Indicated by cross-hatching of vertical lines.

Logging

//: 45° angle. Selectively logged areas with residual stand sufficient to justify a second cut prior to maturity of reproduction. Indicated by a cross-hatching of diagonal lines running from left to right;

=: 90° angle. Clean cut or burned logged over areas which are not restocking (no visible reproduction). Indicated by cross-hatching of horizontal lines.

\\:135° angle. Clean cut areas, which are restocked to seedlings, saplings, or trees. Numbers on top of the cross hatching refer to 1 = well stocked; 2 = medium stocked, and 3 = poorly stocked.

CH Color = the colors of cross-hatching were sometimes recorded during digitization, but could be added for all cross-hatching, using the scheme for cross-hatching above.

Vegstring = A compilation of the species names from the polygon and the crosshatching. This was used to determine the MCV type, from which WHR types were derived. Early seral stage from cross-hatching was taken into account at this point.

Comments = Comments relating to species that may be out of the known range, uncertain codes, or other details related to that polygon.

CalVeg1 = A placeholder column in case the US Forest Service desires to translate the MCV types to CalVeg codes. This is for the primary type in the polygon.

CV1 Name = A placeholder column in case the US Forest Service desires to translate the MCV types to CalVeg names. This is for the primary type in the polygon.

CalVeg2 = A placeholder column in case the US Forest Service desires to translate the MCV types to CalVeg codes. This is for the secondary type in the polygon.

CV2 Name = A placeholder column in case the US Forest Service desires to translate the MCV types to CalVeg names. This is for the secondary type in the polygon.

VTM color = The colors in the VTMs are tied to a classification scheme that relied on Dixon colored pencils (Dixon Ticonderoga Company, Lake Mary, FL) of different numbers. The colors refer to categories of land cover and vegetation. There are extensive notes about the composition of species related to the colors in the field manuals. We did not determine a way to process the colors (which may or may not be consistently applied to all maps, there are certain maps such as the southern-most quads in north coast ecoregion which have different coloring). Remote sensing techniques might be applied to the scans if review of the field manuals suggests that better vegetation types could be defined using the colors than the approach we used. We used the actual species recorded, in addition to any cross-hatching to assign a MCV alliance name. We checked to see if the color of the polygon indicated a landcover type in agreement to the one we assigned. The color in some cases caused us to change a hardwood woodland type to a chaparral type.

VTM type = This is associated the color discussion above, and could be filled out later if found useful.

Vetting = This indicates if species listed in the polygon were checked in one of the several levels of vetting, and if so for what region of the state.

APPENDIX 3. The root mean square error (RMSE), and notes for each VTM quadrangle that was digitized. These values represent the degree to which the basemaps that the vegetation polygons are drawn on differ from the current measure of topography, and are obtained by registering the old topography to a modern topographic surface. In essence, these measurements provide an estimate of potential spatial error in the location of vegetation introduced by the maps it was recorded upon. Note that some 15' and 7.5' quadrangles that either were not used in the final GIS or were not registered are listed, in order to provide a full set of VTM quadrangle codes. Where RMSE rows are marked with a "—" indicates that the value was not recorded. Generally single numbers identify a 30' quadrangle, a number followed by a capital letter indicate a 15' quadrangle, and a number followed by a lowercase letter signifies a 7.5' quadrangle. Many of the 7.5' quadrangles are also represented in 15' or 30' maps, in which case the 7.5' were not included in the GIS, and RMSE was not tested because we assumed the 7.5' versions were copied from the coarser scale maps. However, those 7.5' quadrangles were scanned.

VTM quadrangle number	Quadrangle name	Root mean square error (m)	Quadrangle size, in minutes	Extent of quadrangle surveyed — 100 percent if blank	Notes made during digitization
7	SEIAD VALLEY	131.6	30		
8	PRESTON PEAK	116.5	30		
12	SAWYERS BAR	86.1	30		
22	BURNEY	114.2	30		
23	REDDING	80.4	30		
24	WEAVERVILLE	119.1	30		
25	BIG BAR	127.8	30	approx. 50%	lower left section missing
30	SPORTSHAVEN	80.4	30	approx. 50%	C&D apparently missing
33	SHINGLETOWN	77.7	30	approx. less than 50%	quads only partially mapped
37	SIERRAVILLE	118.7	30		
38	DOWNIEVILLE	129.5	30		
39	KIMSHEW POINT	189.6	30		
40	CHICO	139.3	30		
49	BUTTE CITY	31.0	30		
50	SMARTVILLE	180.3	30		
51	COLFAX	115.8	30		
52	TRUCKEE	106.2	30	over 50%	lower right quad missing
53	WELLINGTON	94.4	30		
54	MARKLEEVILLE	127.7	30		
55	PYRAMID PEAK	83.7	30		
56	PLACERVILLE	119.7	30		
57	SACRAMENTO EAST	137.4	30		
65	NAPA	78.8	30		
68	JACKSON	73.5	30		
69	DEVILS NOSE	106.6	30	fully mapped. I think it its fine	Note on quad — topography in fairly large error in section B5
70	DARDANELLE	85.6	30		
71	BRIDGEPORT	48.1	30		
76	MT. LYELL	72.7	30		
77	YOSEMITE FALLS	83.1	30		
78	SONORA	160.9	30		
84	HALF MOON BAY	63.3	30		
89	MARIPOSA	71.3	30	approx. less than 50%	The northwest corner of this set is missing
90	KAISER PEAK	108.1	30	approx. less than 50%	Upper right and lower right quads missing. Partial veg polys.
91	MT. GODDARD	50.8	30	approx. less than 50%	partial VM polys
98	MOUNT WHITNEY	75.5	30	approx. less than 50%	partial polys on the lower left quad; scale is suspect
99	TEHIPITE DOME	59.3	30	approx. 50%	Upper left & right quads on same canvas backing.
100	PATTERSON MTN.	48.4	30		
103	PANOCHE	68.6	30	approx. 50%	legends in margins, partial VTM polys

APPENDIX 3. CONTINUED

VTM quadrangle number	Quadrangle name	Root mean square error (m)	Quadrangle size, in minutes	Extent of quadrangle surveyed — 100 percent if blank	Notes made during digitization
108	PRIEST VALLEY	51.7	30		
109	COALINGA	73.9	30	approx. 75%	upper right quad missing, legends in margins
112	KAWEAH	72.7	30	approx. 50%	lower right missing, partial polys, no legends
113	OLANCHA	77.2	30	approx. less than 50%	partial polys, no legend
125	KERNVILLE	52.2	30		
128	LOST HILLS	83.5	30		
129	CHOLAME	81.5	30		
134	MCKITTRICK SUMMIT	74.2	30		
135	BUENA VISTA LAKE BED	97.6	30		only a few polys
136	BRECKENRIDGE MTN.	124.2	30		
137	MOJAVE	82.8	30	a little over 50	partial polys, legends in margins and on maps, some edges cut
153	BISSELL	76.1	30		
154	LIEBRE TWINS	94.1	30		
155	PLEITO HILLS	65.1	30		
156	CUYAMA	100.9	30		D—3,4 missing
157	LOMPOC	77.2	30		
158	GUADALUPE	78.5	30	over 50%	only 2 quads for this coastal area, no legend
165	SAN GORGONIO MTN.	110.8	30		
174	INDIO	173.8	30	approx. less than 50%	only lower L&R quads available, mislabeled according to labeling scheme
175	SAN JACINTO	81.3	30		
176	LAKE ELSINORE	77.9	30		
177	CORONA NORTH	80.3	30		
180	SAN LUIS REY	70.6	30		
181	RAMONA	101.6	30		
182	RABBIT PEAK	101.3	30		
190	CARRIZO MTN.	175.8	30		
191	CUYAMACA PEAK	46.4	30		
179A	SAN CLEMENTE	70.6	30		
N59B	WADSWORTH	98.2	30	approx. less than 50%	upper and lower right quads missing, small amount of veg data. no data on B tiles, so not registered
N60	RENO	113.3	30		
N61	CARSON	128.9	30	over 50%	only lower right quad in collection got the others from Zinke 3/07
N62C	WABUSKA	92.6	30	approx. less than 50%	only lower left quad present, partial veg data in CA.
43A	COVELO EAST	46.8	15	over 50%	lower left cut out
43D	JAMISON RIDGE	51.3	15	approx. 50%	upper right cut off
46A	FOSTER MTN.	27.5	15	approx. less than 50%	US Army Corps Engineers basemap
46B	WILLITS	32.0	15	approx. less than 50%	only partial topo and veg coverage
46D	UKIAH	27.6	15		
47C	LAKEPORT	24.4	15		
47D	BARTLETT SPRINGS	24.4	15	approx. less than 50%	partial veg information

APPENDIX 3. CONTINUED

VTM quadrangle number	Quadrangle name	Root mean square error (m)	Quadrangle size, in minutes	Extent of quadrangle surveyed — 100 percent if blank	Notes made during digitization
59d	—	—	15		US Army Corps Engineers basemap, not used
60a	LOWER LAKE	9.5	15		
60b	KELSEYVILLE	224.5	15		US Army Corps Engineers basemap
61A	HOPLAND	29.9	15		
64A	SANTA ROSA	30.0	15	approx. less than 50%	veg map partial
64D	PETALUMA	31.3	15	over 50%	partial veg map
65C	MARE ISLAND	78.8	15		
65D	CORDELIA	78.8	15		
66B	ALLENDALE	20.6	15	over 50%	lower left edge cut off
66C	ANTIOCH NORTH	23.8	15		
72	—	—	15		
79A	COPPEROPOLIS	42.5	15		
80C	TRACY	34.0	15		
81A	BRENTWOOD	22.6	15		
81B	DIABLO	35.6	15		
81C	DUBLIN	31.3	15	over 50%	corners cut off
81D	ALTAMONT	30.7	15	over 50%	legends in margin, some edges cut
82A	OAKLAND EAST	34.6	15	over 50%	partial edges cut off
82B	SAN FRANCISCO NORTH	36.5	15		
82C	SAN MATEO	35.2	15		
82D	HAYWARD	67.9	15	over 50 fine	partial veg mapped, edges partially cut off
84A	PALO ALTO	63.3	15		
85A	MT. DAY	57.2	15		
85B	SAN JOSE EAST	57.2	15		
85C	—	57.2	15		
86A	ORESTIMBA PEAK	30.6	15		
86C	GILROY HOT SPRINGS	30.6	15	over 50%	edges cut
86D	PACHECO PASS	30.6	15	over 50%	edges cut
88A	INDIAN GULCH	22.2	15		
104A	QUIEN SABE VALLEY	23.3	15		
104B	—	23.0	15		
104C	—	27.9	15		
104D	SAN BENITO	27.8	15		
105A	—	46.7	15		
105B	SOQUEL	33.4	15		
105C	MONTEREY	45.5	15		
105D	SALINAS	40.2	15		
106A	CARMEL VALLEY	24.7	15		
106B	POINT SUR	21.7	15		
106D	PARTINGTON RIDGE	30.1	15		
107A	NORTH CHALONE PEAK	48.3	15		
107B	SOLEDAD	48.3	15		
107C	JUNIPERO SERRA PEAK	48.3	15	over 50%	2 maps this one edition of 1930, partial polys
107D	THOMPSON CANYON	48.3	15		
130A	SAN MIGUEL	91.3	15		
130B	BRADLEY	57.7	15		
130C	ADELAIDA	41.0	15		
130D	PASO ROBLES	46.7	15		
131A	BRYSON	44.0	15		
131B	CAPE SAN MARTIN	33.9	15		
131C	PIEDRAS BLANCAS	30.0	15	over 50%	mostly water quad
131D	SAN SIMEON	30.3	15	over 50%	mostly water quad
132A	SAN LUIS OBISPO	65.8	15		
132B	CAYUCOS	37.4	15		
132C	PORT SAN LUIS	49.4	15		
132D	ARROYO GRANDE NE	54.0	15		

APPENDIX 3. CONTINUED

VTM quadrangle number	Quadrangle name	Root mean square error (m)	Quadrangle size, in minutes	Extent of quadrangle surveyed — 100 percent if blank	Notes made during digitization
133A	LA PANZA	30.2	15		
133B	POZO SUMMIT	32.1	15		
133C	NIPOMO	29.9	15		
133D	LOS MACHOS HILLS	30.6	15		
159A	SANTA BARBARA	58.2	15	over 50%	only part of lands around SB are mapped on this quad
159B	GOLETA	58.2	15	over 50%	only part of lands around Goleta are mapped on this quad
160A	SANTA PAULA	61.7	15		
160B	VENTURA	61.7	15		
160D	CAMARILLO	61.7	15		
161A	NEWHALL	37.8	15		
161B	PIRU	74.8	15		
161C	TRIUNFO PASS	Not tested	15		
161D	CALABASAS	59.9	15		
162A	PACIFICO MOUNTAIN	141.5	15		
162B	SAN FERNANDO	141.5	15		
162D	PASADENA	141.5	15		
163A	MOUNT SAN ANTONIO	157.1	15	over 50%	there are 2 maps, each with 1/2 the veg polys
163B	VALYERMO	157.1	15		
163C	GLENDORA	157.1	15		
163D	CUCAMONGA PEAK	157.1	15		
164C	SAN BERNARDINO NORTH	60.3	15		
164D	REDLANDS	60.3	15		
178A	LONG BEACH	52.0	15	approx. less than 50%	small area mapped, legend in margin
178B	REDONDO BEACH	52.0	15	approx. 50%	partial veg polys
178C	SAN PEDRO	52.0	15		
178D	SEAL BEACH	52.0	15		
192A	LA JOLLA	30.9	15		
192D	NATIONAL CITY	30.9	15	over 50%	map extends beyond box, edges cut, good condition
40d	RICHARDSON SPRINGS NW	—	n/a		
40f	RICHARDSON SPRINGS	—	n/a		
40k	CHICO	—	n/a		
40l	ORD FERRY	—	n/a		
40m	LLANO SECO	—	n/a		
40p	OROVILLE	—	n/a	over 50%	upper left cut off
49a	PALERMO	—	7.5		Upper right and lower left cut off
49b	BIGGS	—	7.5		
49c	WEST OF BIGGS	—	7.5		
49d	BUTTE CITY	—	7.5		
49E	MARYSVILLE BUTTES	—	n/a		This quad may have high RMSE.
49f	PENNINGTON	—	7.5		
49g	GRIDLEY	—	7.5		
49h	HONCUT	—	7.5		
49i	YUBA CITY	—	7.5		
49j	SUTTER	—	7.5		
49k	SUTTER BUTTES	—	7.5	approx. 50%	Contour level 5 feet, between broken contours 500 feet.
49l	MERIDIAN	—	7.5		
49m	GRIMES	—	7.5		
49n	TISDALE WEIR	—	7.5		
49o	GILSIZER SLOUGH	—	7.5		

Appendix 3. Continued

VTM quadrangle number	Quadrangle name	Root mean square error (m)	Quadrangle size, in minutes	Extent of quadrangle surveyed — 100 percent if blank	Notes made during digitization
49p	OLIVEHURST	—	7.5		
50e	LOMA RICA	—	7.5	over 50%	upper right corner cut off, but present, incomplete topo and veg work
50m	WHEATLAND	—	7.5		
57c	LINCOLN	137.4	n/a		Values for this series from the 30′ quad.
57d	SHERIDAN	137.4	7.5		
57e	PLEASANT GROVE	137.4	7.5		
57f	ROSEVILLE	137.4	7.5		
57j	FOLSOM	137.4	7.5	over 50%	map not glued to canvas, entire. Only partial topo and veg coverage
57k	CITRUS HEIGHTS	137.4	7.5		
57l	RIO LINDA	137.4	7.5		
57n	CARMICHAEL	137.4	7.5		
67a	CARBONDALE	40.5	7.5		
67h	GOOSE CREEK	—	7.5		
67i	CLEMENTS	—	7.5		
67p	LINDEN	—	7.5		
78l	LA GRANGE	—	7.5	over 50%	only partial topo and veg map
78m	SNELLING	—	7.5		
78n	MERCED FALLS	—	7.5	over 50%	only partial topo and veg map
80o	WESTLEY	37.8	7.5	approx. less than 50%	partial veg mapped, legends in margin
79c	BACHELOR VALLEY	42.5	7.5	approx. less than 50%	only partial veg
79d	FARMINGTON	42.5	7.5	approx. less than 50%	very small amount of veg
79f	OAKDALE	42.5	7.5		
79i	COOPERSTOWN	42.5	7.5	approx. less than 50%	partial veg mapped
79p	TURLOCK LAKE	42.5	7.5	approx. less than 50%	partial veg mapped
80o	WESTLEY	37.8	n/a	approx. less than 50%	partial veg mapped, legends in margin
87a	WINTON	22.2	7.5		Old Quadrangle name
88c	HAYSTACK MOUNTAIN	22.2	7.5		Old Quadrangle name
88d	YOSEMITE LAKE	22.2	7.5	approx. less than 50%	very small amount of veg mapped
88f	PLANADA	22.2	7.5	approx. less than 50%	partial veg mapped, legend
88i	RAYNOR CREEK	22.2	7.5	approx. less than 50%	very small amount of veg mapped
88j	LE GRAND	22.2	7.5	approx. less than 50%	very small amount of veg mapped
101a	—	31.4	7.5		
111a	—	—	7.5		
111h	ROCKY HILL	56.2	7.5	approx. 50%	no polys in the flats
162m	LA CRESENTA	141.5	7.5		Old Quadrangle name
162n	SUNLAND	141.5	7.5		Old Quadrangle name
162o	PACOIMA	141.5	7.5		Old Quadrangle name
162p	VAN NUYS	141.5	7.5	approx. 50%	about 1/2 of map has veg polys; old quadrangle name
162s	ALTADENA	141.5	7.5		Old Quadrangle name
162t	SIERRA MADRE	—	7.5	approx. 50%	a few veg polys
162u	EL MONTE	—	7.5	approx. less than 50%	legend in map, partial polys; old quadrangle name

APPENDIX 3. CONTINUED

VTM quadrangle number	Quadrangle name	Root mean square error (m)	Quadrangle size, in minutes	Extent of quadrangle surveyed — 100 percent if blank	Notes made during digitization
162v	ALHAMBRA	—	7.5	approx. 50%	partial polys, legend on margin; old quadrangle name
162x	HOLLYWOOD	141.5	7.5	approx. less than 50%	mostly city; old quadrangle name
162y	SAWTELLE	141.5	7.5		Old Quadrangle name
163p	AZUSA	—	7.5		Old Quadrangle name
163q	GLENDORA	—	7.5	approx. 75%	about 1/2 of map has veg polys and topo lines; ; old quadrangle name
163r	LA VERNE	—	7.5	approx. 75%	partial polys; old quadrangle name
163w	CLAREMONT	—	7.5	approx. less than 50%	partial polys, legend on map; ; old quadrangle name
163x	COVINA	—	7.5		Old Quadrangle name
163y	PUENTE	—	7.5		Old Quadrangle name
177d	LA BREA	—	n/a	approx. 50%	1/2 of map has polys
177e	LA HABRA	52.0	7.5	approx. less than 50%	bounding box coordinates cut off, check against other maps. Partial polys; old quadrangle name
178d	INGLEWOOD	—	n/a	approx. less than 50%	partial veg polys; old quadrangle name

APPENDIX 4. The list of all codes and the names assigned to them in the VTM map data. Codes with parentheses around the species name indicate the entity was dead.

Species code	Species and land cover name used
***	No data
A	*Quercus agrifolia*
A2	*Alnus rhombifolia*
A3	*Populus tremuloides*
Aa	*Amelanchier alnifolia*
Aaa	*Arctostaphylos auriculata*
Aan	*Arctostaphylos andersonii*
Aap	*Arctostaphylos pechoensis*
Aar	*Artemisia arbuscula*
Ab	*Xylococcus bicolor*
Abm	*Abronia maritima*
Ac	*Artemisia californica*
Aca	*Amorpha californica*
Acg	*Acer glabrum*
Acl	*Acleisanthes longiflora*
Acm	*Achyrachaena mollis*
Acn	*Arctostaphylos canescens*
Aco	*Arctostaphylos columbiana*
Acp	*Acaena pinnatifida californica*
Acs	*Acamptopappus sphaerocephalus*
Ad	*Arctostaphylos pringlei drupacea*
Ado	*Adolphia californica*
Adr	*Artemisia dracunculus*
Ae	*Arctostaphylos manzanita elegans*
Aec	*Aesculus californica*
Af	*Adenostoma fasciculatum*
Aff	*Atriplex confertifolia*
Afr	*Amorpha fruticosa*
Ag	*Arctostaphylos glauca*
Agc2	*Elymus caninus*
Agl	*Arctostaphylos glandulosa*
Agr	*Acacia greggii*
Ags2	*Pseudoroegneria spicata spicata*
Ah	*Arctostaphylos hookeri*
Airpt	Airport
Alo	*Allenrolfea occidentalis*
Am	*Arctostaphylos manzanita*
Ama	*Arctostaphylos viscida mariposa*
Ame	*Aster chilensis*
Amr	*Arctostaphylos morroensis*
Amy	*Arctostaphylos myrtifolia*
An	*Arctostaphylos nevadensis*
Ane	*Arctostaphylos nevadensis*
Ang	*Antirrhinum multiflorum*
Ani	*Arctostaphylos nissenana*
Ann	Annuals
Ao	*Arctostaphylos otayensis*
Aob	*Arctostaphylos obispoensis*
Ap	*Arctostaphylos patula*
Apa	*Artemisia tridentata parishii*
Apc	*Apocynum cannabinum*
Apc2	*Aira caryophyllea*
Ape	*Arctostaphylos pechoensis*
Api	*Arctostaphylos pilosula*
Apm	*Arctostaphylos pumila*
App	*Arctostaphylos patula*
Aps	*Arctostaphylos mewukka mewukka*
Apu	*Arctostaphylos pungens*
Apy	*Arctostaphylos parryana*
Ar	*Arctostaphylos rudis*
Ar2	*Agrostis variabilis*

APPENDIX 4. CONTINUED

Species code	Species and land cover name used
Arc	*Artemisia cana bolanderi*
Are	*Arctostaphylos regismontana*
Arr	*Artemisia rothrockii*
Arsp	*Artemisia spinescens*
As	*Adenostoma sparsifolium*
Asa	*Actaea rubra*
Asbo	*Astragalus bolanderi*
Asc	*Asclepias cordifolia*
Ase	*Arctostaphylos nummularia*
Asi	*Arctostaphylos silvicola*
Asl	*Aster chilensis*
Aso2	*Aristida oligantha*
Asp	*Atriplex spinifera*
Ast	*Arctostaphylos stanfordiana*
At	*Arctostaphylos tomentosa*
Atb	*Atriplex lentiformis breweri*
Atc	*Atriplex canescens*
Ate	*Alnus incana tenuifolia*
Atem	*Artemisia* sp.
Atex	*Atriplex argentea mohavensis*
Atl	*Atriplex lentiformis*
Ato	*Artemisia nova*
Atp	*Atriplex polycarpa*
Atr	*Artemisia tridentata*
Atri	*Artemisia tridentata*
Att	*Atriplex lentiformis torreyi*
Atx	*Atriplex* sp.
Aty	*Artemisia pycnocephala*
Av	*Arctostaphylos viscida*
Avb	*Avena barbata*
Avb2	*Avena barbata*
Avf2	*Avena fatua*
Avh	*Artemisia douglasiana*
Avh2	*Artemisia vulgaris heterophylla*
Avx2	*Avena* sp.
Aw	*Arctostaphylos wieslanderi*
Ax	*Astragalus* sp.
Axp	*Arctostaphylos* sp.
Ay	*Arctostaphylos* sp.
B	*Quercus kelloggii*
B1	*Abies bracteata*
B3	*Populus balsamifera trichocarpa*
Ba	Barren
Bas2	*Bassia hyssopifolia*
Bc	*Brickellia californica*
Bd	*Baccharis douglasii*
Be	*Baccharis emoryi*
Beach	Beach
Ber	*Berberis aquifolium repens*
Bf	*Berberis fremontii*
Bg	*Brickellia grandiflora*
Bg2	*Bromus grandis*
Bh	*Bromus hordeaceus*
Bh2	*Bromus hordeaceus*
Bi	*Triteleia ixioides*
Bm2	*Bromus carinatus carinatus*
Bma2	*Bromus madritensis*
Bn	*Berberis nervosa*
Bp	*Baccharis pilularis*
Br2	*Bromus diandrus*
Bra2	*Bromus hordeaceus*
Brm	*Brickellia microphylla*
Brm2	*Briza minor*

APPENDIX 4. CONTINUED

Species code	Species and land cover name used
Bru	*Bromus madritensis rubens*
Bru2	*Bromus madritensis rubens*
Brx	Unknown Code
Bs	*Pseudotsuga macrocarpa*
Bsg	*Balsamorhiza sagittata*
Bsp2	*Bromus* sp.
BT	*Sequoia gigantea*
Bt2	*Bromus tectorum*
Burn	Burn
Bv	*Baccharis salicifolia*
Bv2	*Bromus vulgaris*
Bx2	*Bromus* sp.
C	*Quercus chrysolepis*
C.Nev	*Cupressus nevadensis*
Ca	*Ceanothus foliosus foliosus*
Ca1	*Opuntia* sp.
CAG	Unknown Code
Cax	*Carex* sp.
Cb	*Cercocarpus betuloides*
Cc	*Ceanothus cuneatus*
Ccl	*Carpenteria californica*
Ccm	*Chrysolepis chrysophylla minor*
Cco	*Ceanothus cordulatus*
Ccr	*Ceanothus crassifolius*
Ccu	*Ceanothus cuneatus*
Ccx	Unknown Code
Cd	*Ceanothus leucodermis*
Cde	*Ceanothus dentatus*
Cdi	*Ceanothus diversifolius*
Cdu	*Cneoridium dumosum*
Ce	*Echinocereus engelmannii*
Cec	*Cercis occidentalis*
Cem	*Centaurea melitensis*
Ceme	Cemetary
Ceo	*Cephalanthus occidentalis californicu*
Cf	*Chamaebatia foliolosa*
Cfa	*Chamaebatia australis*
Cfo	*Ceanothus foliosus*
Cg	*Ceanothus greggii*
Cgp	*Ceanothus greggii perplexans*
Cgr	*Collomia grandiflora*
Chb	*Ericameria bloomeri*
Chc	*Chaenactis carphoclinia*
Chn	*Chrysothamnus nauseosus*
Chp	*Chrysothamnus parryi*
Chr	*Chrysothamnus* sp.
Chv	*Chrysothamnus viscidiflorus*
Chx	Unknown Code
Ci	*Ceanothus integerrimus*
Cim	*Ceanothus impressus*
Cin	*Ceanothus incanus*
Cj	*Ceanothus jepsonii*
Cl	*Cercocarpus ledifolius*
Cle	*Ceanothus lemmonii*
Clo	*Ceanothus* sp.
Cm	*Ceanothus megacarpus megacarpus*
Cn	*Cornus nuttallii*
Cnc	*Chrysothamnus nauseosus consimilis*
Cng	*Chrysothamnus nauseosus gnaphalodes*
Cno	*Chrysothamnus nauseosus albicaulis*
Co	*Ceanothus oliganthus*
Coa	*Convolvulus arvensis*
Cof	*Lessingia filaginifolia*

APPENDIX 4. CONTINUED

Species code	Species and land cover name used
Cog	*Coreopsis gigantea*
Col	*Calystegia occidentalis s.l.*
Coo	*Calystegia occidentalis*
Cp	*Pinus coulteri*
Cpa	*Ceanothus palmeri*
Cpl	*Ceanothus papillosus*
Cpo	*Ceanothus prostratus*
Cpr	*Ceanothus parryi*
Cpu	*Calochortus pulchellus*
Cpv	*Ceanothus parvifolius*
Cr	*Corylus cornuta californica*
Cra	*Coleogyne ramosissima*
Crc	*Croton californicus*
Crf	*Ceanothus fresnensis*
Cri	*Ceanothus cuneatus rigidus*
Crn	*Cryptantha intermedia*
Cs	*Chrysolepis sempervirens*
Csa	*Ceanothus sanguineus*
Cse	*Ceanothus prostratus*
Cso	*Ceanothus oliganthus sorediatus*
Csp	*Ceanothus spinosus*
Ct	*Ceanothus thyrsiflorus*
Ctc	*Ceanothus thyrsiflorus*
Ctl	*Ceanothus tomentosus olivaceus*
Cto	*Ceanothus tomentosus*
Cu	Cultivated
Cv	*Ceanothus velutinus*
Cve	*Ceanothus verrucosus*
Cvp	*Chrysothamnus viscidiflorus puberulus*
Cx	*Ceanothus* sp.
Cxb	*Carex barbarae*
Cy	*Cycladenia humilis*
D	*Pseudotsuga menziesii menziesii*
D'	*Quercus douglasii*
D3	*Fraxinus anomala*
Da	*Mimulus aurantiacus*
Dam	*Datura wrightii*
Dc	*Dicentra chrysantha*
De	Desert
Deser	Desert
Dis2	*Distichlis spicata*
DIt2	*Distichlis spicata*
DLake	Dry Lake
Dp	*Pinus sabiniana*
Dpu	*Mimulus aurantiacus puniceus*
Dr	*Dendromecon rigida*
Dump	Dump
Dy	*Cupressus sargentii*
E	*Quercus engelmannii*
Ea	*Encelia actoni*
Ear	*Ericameria arborescens*
Eb	*Ericameria brachylepis*
Eba	*Eriogonum baileyi*
Ec	*Eriodictyon californicum*
Eca	*Ephedra californica*
Ech	*Eucrypta chrysanthemifolia chrysanthemifolia*
Ech2	*Ellisia chrysanthemifolia*
Eci	*Erodium cicutarium*
Eci2	*Erodium cicutarium*
Eco	*Eriophyllum confertiflorum*
Eco2	*Elymus condensatus*
Ecr	*Eriodictyon crassifolium*
Ecs	*Ericameria cuneata spathulata*

APPENDIX 4. CONTINUED

Species code	Species and land cover name used
Ecu	*Ericameria cuneata*
Ed	*Eriogonum deflexum*
Ee	*Ericameria ericoides*
Eel	*Eriogonum elatum*
Ef	*Eriogonum fasciculatum*
Efa	*Marah fabacea*
Efc	*Eriogonum cinereum*
Eff	*Eriogonum fasciculatum foliolosum*
Efp	*Eriogonum fasciculatum polifolium*
Ehe	*Eriogonum heermannii*
Em	*Euphorbia misera*
Em2	*Elymus* X trachycaulus
Emi	*Eriogonum microthecum*
Eml	*Eriogonum microthecum*
Emo	*Ericameria cooperi cooperi*
Emp	*Emmenanthe penduliflora*
En	*Eriogonum nudum*
Enc	*Encelia californica*
Ene	*Ephedra nevadensis*
Enf	*Encelia farinosa*
Ep	*Eriogonum parvifolium*
Epa	*Ericameria palmeri*
Epc	*Epilobium ciliatum*
Epi	*Ericameria pinifolia*
Epv	*Ephedra viridis*
Era	*Eriogonum arborescens*
Erc	*Ericameria cooperi cooperi*
Erd	*Eriogonum douglasii douglasii*
Ere	*Eriogonum elongatum elongatum*
Ero	*Erodium botrys*
Es	*Picea engelmannii*
Esa	*Eriophyllum staechadifolium*
Esc	*Eschscholzia californica*
Ese	*Eremocarpus setigerus*
Esp	*Erodium* sp.
Et	*Eriodictyon trichocalyx*
Etl	*Eriodictyon trichocalyx lanatum*
Eto	*Eriodictyon tomentosum*
Eu	*Eucalyptus* sp.
Euc	*Camissonia californica*
Eul	*Krascheninnikovia lanata*
Eum	*Eriogonum umbellatum*
Ev	*Eriogonum roseum*
Evm	*Eriogonum luteolum*
Ew	*Eriogonum wrightii*
Ex	*Eriogonum* sp.
F3	*Populus fremontii fremontii*
Far2	*Festuca* sp.
Fbi	*Ambrosia chamissonis*
Fc	*Fremontodendron californicum*
Fca	*Fragaria vesca*
Fch	*Ambrosia chenopodiifolia*
Fco	*Festuca* sp. *viridula*
Fd	*Fraxinus dipetala*
Fg	*Frankenia salina*
Fm2	*Vulpia myuros hirsuta*
Fmv2	*Vulpia myuros myuros*
Fnm	*Forestiera pubescens*
Fp	*Pinus balfouriana*
Fr2	*Festuca* sp. *rubra*
Fra	*Ambrosia acanthicarpa*
Fx2	*Festuca* sp.
G	*Quercus garryana*

APPENDIX 4. CONTINUED

Species code	Species and land cover name used
G1	*Abies grandis*
Gb	*Gnaphalium canescens beneolens*
Gd	*Gayophytum diffusum*
Ge	*Garrya elliptica*
Gf	*Garrya fremontii*
Gfb	*Garrya buxifolia*
Gfl	*Garrya flavescens*
Gfv	*Garrya congdonii*
Gh	*Gaultheria humifusa*
Gl	*Gutierrezia microcephala*
Glaci	Glacier
Gls	*Glossopetalon spinescens*
Gr	Grass sp.
Gr2	Grass sp.
Grs	*Grayia spinosa*
Gs	*Gaultheria shallon*
Gsa	*Gutierrezia sarothrae*
Gv	*Garrya veatchii*
Gy	*Cupressus goveniana*
H	*Tsuga heterophylla*
H'	Unknown Code
H2	*Aesculus californica*
Hb	Herbs
Hb2	Herbs
Hd	*Holodiscus discolor*
Hdd	*Holodiscus discolor*
Hdg	*Holodiscus microphyllus glabrescens*
Hg	*Heterotheca grandiflora*
Hg2	*Hordeum marinum gussoneanum*
Hgr	*Helianthus gracilentus*
Hgu2	*Hordeum marinum gussoneanum*
Hj2	*Hordeum jubatum*
Hm	*Tsuga mertensiana*
Hm2	*Hordeum murinum*
Hp	*Hypericum perforatum*
Hp2	*Hypericum perforatum*
Hpe	*Helianthus petiolaris petiolaris*
Hs	*Hazardia squarrosa*
Hsc	*Helianthemum scoparium*
Hsv	*Helianthemum scoparium*
Hys	*Hymenoclea salsola*
I	*Calocedrus decurrens*
Ia	*Isomeris arborea*
Iax	*Iva axillaris robustior*
Imi	*Iris missouriensis*
Iv	*Isocoma acradenia acradenia*
Ivv	*Isocoma menziesii vernonioides*
J	*Pinus jeffreyi*
J3	*Juncus* sp.
Jc	*Juniperus californica*
Jm	*Juniperus communis*
Jo	*Juniperus occidentalis*
Ju	*Juniperus osteosperma*
Jue	*Juncus effusus*
Jx	*Juncus* sp.
K	*Pinus attenuata*
Kc2	*Koeleria macrantha*
Koa	*Kochia americana*
L	*Pinus contorta murrayana*
L'	*Umbellularia californica*
La	*Lupinus albifrons*
Laf	*Lithophragma affine*
Lake	Water

APPENDIX 4. CONTINUED

Species code	Species and land cover name used
Lal	*Lupinus albicaulis*
Lar	*Lupinus arboreus*
Lc	*Pinus contorta*
Lcf	*Leptodactylon californicum*
Lch	*Lupinus chamissonis*
Lde	*Lithocarpus densiflorus echinoides*
Lg	*Ledum glandulosum*
Lig	*Ligusticum grayi*
Lm2	*Lolium multiflorum*
Ln	*Lepidium nitidum*
Lp	*Pinus flexilis*
Lpu	*Leptodactylon pungens*
Lpx	*Lupinus* sp.
Ls	*Lotus scoparius*
Lsa	*Lotus salsuginosus*
Lsp	*Lathyrus splendens*
Lsq	*Lepidospartum squamatum*
Lsu	*Lonicera subspicata*
Lt	*Larrea tridentata*
Luca	*Lupinus argenteus heteranthus*
Lul	*Lupinus lepidus lobbii*
Lup	*Lupinus* sp.
Lux	*Lupinus excubitus*
Lx	*Lotus* sp.
Lys	*Stephanomeria spinosa*
M	*Arbutus menziesii*
M2	*Acer macrophyllum*
M3	*Alnus incana tenuifolia*
Ma	*Carpobrotus chilensis*
Mad	*Ericameria discoidea*
Marsh	Marsh
Mas	*Ericameria suffruticosa*
Mbu2	*Melica bulbosa*
Mc	*Myrica californica*
Md	Meadow
Md2	Meadow
Mdw	Meadow
Mh	*Myrica hartwegii*
Mhi	*Medicago polymorpha*
Mic	*Micropus californicus*
Mill	Mill
Ml	*Mirabilis californica*
Mm	*Mimulus moschatus*
Mo	*Monardella odoratissima*
Moss	Moss
Mp	*Pinus radiata*
Mpa	*Malva parviflora*
Mpe	*Claytonia perfoliata*
Mv	*Marrubium vulgare*
Mya	*Cupressus abramsiana*
My	*Cupressus macrocarpa*
Mz	*Manzanita* sp.
N	*Torreya californica*
N2	*Acer negundo californicum*
Nav2	*Navarretia* sp.
Ng	*Nicotiana glauca*
Np	*Turricula parryi*
Npa	*Nolina parryi*
Ny	*Cupressus macnabiana*
O	*Cupressus lawsoniana*
O3	*Fraxinus latifolia*
Ob	*Opuntia bigelovii*
Oc	*Oemleria cerasiformis*

APPENDIX 4. CONTINUED

Species code	Species and land cover name used
Ok	*Quercus kelloggii*
Olive	*Olive orchard*
Oo	*Opuntia X occidentalis*
Ool	*Opuntia littoralis*
Ot	*Opuntia treleasei*
Ox	*Opuntia* sp.
P	*Pinus monophylla*
P3	*Washingtonia filifera*
Pa	*Heteromeles arbutifolia*
Pad	*Prunus andersonii*
Pal	*Palafoxia arida*
Pan	*Keckiella antirrhinoides*
Pb	*Keckiella breviflora*
Pba	*Phacelia brachyloba*
Pbc	*Ptelea crenulata*
Pbs	*Polygonum bistortoides*
Pc	*Keckiella cordifolia*
Pci	*Plectritis ciliosa*
Pcm	*Penstemon* sp.
Pct	*Horkelia tridentata tridentata*
Pd	*Prunus virginiana demissa*
Pda	*Polygonum davisiae*
Pe	*Prunus emarginata*
Pf	*Prunus fasciculata*
Pfr	*Prunus fremontii*
Pg	*Purshia tridentata glandulosa*
Phb	*Phyllodoce breweri*
Phd	*Phlox cespitosa*
Phh	*Phacelia heterophylla virgata*
Pht	*Phacelia thermalis*
Pi	*Prunus ilicifolia*
Pj	*Prosopis glandulosa torreyana*
Pl	*Philadelphus lewisii*
Plb	*Horkelia cuneata puberula*
Pln	*Plagiobothrys nothofulvus*
Pm	*Pickeringia montana*
Po	*Pellaea mucronata*
Pos	*Ivesia santolinoides*
Pot	*Populus tremuloides*
Pp	*Pinus quadrifolia*
Ppo	*Psorothamnus polydenius*
Ps	*Penstemon spectabilis*
Ps2	*Poa secunda secunda*
Psc2	*Poa secunda secunda*
Pse	*Pluchea sericea*
Psp2	*Poa secunda secunda*
Psu	*Prunus subcordata*
Pt	*Purshia tridentata*
Pta	*Pteridium aquilinum pubescens*
Pur	*Arctostaphylos purissima*
Px2	*Poa* sp.
Q	*Chrysolepis chrysophylla*
Qa	*Quercus agrifolia agrifolia*
Qc	*Quercus chrysolepis nana*
Qd	*Quercus berberidifolia*
Qdo	*Quercus douglasii*
Qdu	*Quercus durata*
Qe	*Quercus engelmannii*
Qg	*Quercus garryana*
Qgb	*Quercus garryana*
Qgs	*Quercus garryana*
Qk	*Quercus kelloggii*
Qp	*Quercus palmeri*

APPENDIX 4. CONTINUED

Species code	Species and land cover name used
Qs	*Quercus sadleriana*
Qv	*Quercus vaccinifolia*
Qw	*Quercus wislizeni frutescens*
R	*Sequoia sempervirens*
R1	*Abies magnifica*
R2	*Alnus rubra*
Ra	*Ribes aureum*
Rb	*Ribes bracteosum*
Rc	*Rhamnus californica*
Rca	*Ribes californicum*
Rce	*Ribes cereum*
Rci	*Rhamnus ilicifolia*
Rcl	*Rosa californica*
Rcr	*Rhamnus crocea*
Rct	*Rhamnus tomentella tomentella*
Rd	*Toxicodendron diversilobum*
Rep	Reproduction
Res	Residence
Rha	*Rhamnus* sp.
Ri	*Rhus integrifolia*
Ris	*Ribes* sp.
River	Water
Rl	*Malosma laurina*
Rm	*Ribes malvaceum*
Ro	*Rhus ovata*
Rock	Rock
Ros	Unknown Code
Rp	*Rubus parviflorus*
Rr	*Ribes roezlii*
Rt	*Rhus trilobata*
Rv	*Rubus ursinus*
Rve	*Ribes velutinum*
Rvg	*Ribes velutinum*
S	*Pinus lambertiana*
S1	*Abies magnifica shastensis*
S3	*Platanus racemosa*
Sa	*Salvia apiana*
Saa	*Salicornia virginica*
Sab	*Sarcobatus vermiculatus*
Sad	*Salvia dorrii*
Sal	*Symphoricarpos albus laevigatus*
Salsp	*Salvia* sp.
Sand	Sand
Sar	*Symphoricarpos rotundifolius*
Sas	*Salicornia subterminalis*
Sav	*Sarcobatus vermiculatus*
Sc	*Lepechinia calycina*
Sca	*Simmondsia chinensis*
Sci	*Scirpus acutus*
Scl	*Salvia clevelandii*
Sco2	*Achnatherum coronatum*
Scr	*Salvia dorrii*
Sd	*Senecio flaccidus douglasii*
Sf	*Malacothamnus fasciculatus*
Sg	*Sambucus mexicana*
Sha	*Shepherdia argentea*
Sia	*Sisymbrium altissimum*
Sih	*Malvella leprosa*
Sil	*Silene lemmonii*
Skt	*Salsola tragus*
Sl	*Salvia leucophylla*
Sli	*Ericameria linearifolia*
Sm	*Salvia mellifera*

APPENDIX 4. CONTINUED

Species code	Species and land cover name used
Smo	*Symphoricarpos mollis*
So	*Styrax officinalis redivivus*
Sol	*Sonchus oleraceus*
Sos	*Sorbus scopulina*
Sp2	*Nassella pulchra*
Sr	*Sambucus racemosa*
Ss	*Salvia spathacea*
Ss2	*Achnatherum speciosum*
Sso	*Salvia sonomensis*
Stn	*Stellaria nitens*
Str	*Stephanomeria pauciflora*
Su	*Solanum umbelliferum*
Sum	*Suaeda moquinii*
Sv	*Sambucus mexicana*
Sx	*Salix* sp.
Sy	*Cupressus sargentii*
T	*Lithocarpus densiflorus*
Tar2	*Taraxacum* sp.
Tc	*Tetradymia canescens*
Te	*Trientalis latifolia*
Teg	*Tetradymia glabrata*
Tet	*Tetradymia* sp.
Ti	*Trichostema lanatum*
Tla	*Trichostema lanceolatum*
Tm2	Unknown Code
Tp	*Pinus torreyana*
Tri2	*Trifolium variegatum*
Ts	*Tetradymia* sp.
Tule	Tule
Ty	*Cupressus forbesii*
Tyl	*Typha latifolia*
Uc	*Umbellularia californica*
Ue	*Ulex europaeus*
V	*Quercus lobata*
V3	*Fraxinus velutina*
Vc	*Vitis californica*
Vec	*Veratrum californicum californicum*
Vg	*Vitis girdiana*
Vl	*Viguiera laciniata*
Vo	*Vaccinium ovatum*
W	*Quercus wislizeni*
W'	*Pinus monticola*
W1	*Abies concolor*
Wash	Wash
Wat	Water
Water	Water
Resr	Reservoir
Wc	*Juglans californica*
WildH	Wild hay
Wm	*Wyethia mollis*
Wmo	*Wyethia mollis*
Wp	*Pinus albicaulis*
Ws	*Picea breweriana*
Xa	*Salix lasiolepis*
Xcr	*Salix* sp.
Xe	*Salix exigua*
Xr	*Salix laevigata*
Xt	*Xerophyllum tenax*
Y	*Pinus ponderosa*
Yb	*Yucca brevifolia*
Ym	*Yucca schidigera*
Yw	*Yucca whipplei*
#2	desert composite

APPENDIX 4. CONTINUED

Species code	Species and land cover name used
(A)	(*Quercus agrifolia*)
(Atr)	(*Artemisia tridentata*)
(Cb)	(*Cercocarpus betuloides*)
(Cd)	(*Ceanothus leucodermis*)
(Chr)	(*Chrysothamnus* sp.)
(Cnc)	(*Chrysothamnus nauseosus consimilis*)
(Cu)	(Cultivated)
(D')	(*Quercus douglasii*)
(Dp)	(*Pinus sabiniana*)
(Ef)	(*Eriogonum fasciculatum*)
(Gr)	(Grass sp.)
(I)	(*Calocedrus decurrens*)
(J)	(*Pinus jeffreyi*)
(Jc)	(*Juniperus californica*)
(Jo)	(*Juniperus occidentalis*)
(L)	(*Pinus contorta murrayana*)
(Ps2)	(*Poa secunda secunda*)
(Qc)	(*Quercus chrysolepis nana*)
(Qd)	(*Quercus berberidifolia*)
(Qdu)	(*Quercus durata*)
(Qw)	(*Quercus wislizeni frutescens*)
(Res)	(Residence)
(W)	(*Quercus wislizeni*)
(W1)	(*Abies concolor*)
(Wp)	(*Pinus albicaulis*)
(Y)	(*Pinus ponderosa*)
(Yw)	(*Yucca whipplei*)

APPENDIX 5. Summary information about the number of polygons and extent of landcover types in the VTM dataset. This table reports the extents by WHR type. If there is no entry in the WHR2 column, this indicates that this type never appears as the lesser landcover type in a mosaic polygon.

WHR type	# Polygons	Area (ha)	Area (km^2)	WHR1 (km^2)	WHR2 (km^2)
Alkali Desert Scrub	183	181,386.72	1813.87	1215.29	598.58
Alpine Dwarf-Scrub	1	11.07	0.11	0.11	
Annual Grassland	26,361	2,493,051.93	24,930.52	16,703.45	8227.07
Aspen	1397	16,621.51	166.22	111.36	54.85
Barren	5084	984,838.82	9848.39	9848.39	
Bigcone Douglas-Fir	2485	40,590.86	405.91	271.96	133.95
Bitterbrush	554	40,665.5	406.65	272.46	134.2
Blue Oak Woodland	7872	575,031.04	5750.31	3852.71	1897.6
Blue Oak-Foothill Pine	6208	584,171.64	5841.72	3913.95	1927.77
Chamise-Redshank Chaparral	24,594	1,482,483.19	14,824.83	9932.64	4892.19
Closed-Cone Pine-Cypress	1775	42,577.3	425.77	285.27	140.51
Coastal Oak Woodland	16,400	413,077.2	4130.77	2767.62	1363.15
Coastal Scrub	20,787	719,598.95	7195.99	4821.31	2374.68
Cropland	10,953	2,287,121.92	22,871.22	15,323.72	7547.5
Desert Riparian	41	13,766.08	137.66	92.23	45.43
Desert Scrub	848	82,198.27	821.98	550.73	271.25
Desert Succulent Scrub	2	88.86	0.89	0.89	
Desert Wash	77	16,065.61	160.66	107.64	53.02
Douglas Fir	3165	463,911.64	46,39.12	3108.21	1530.91
Dryland Grain Crops	3	78.29	0.78	0.78	
Eastside Pine	1043	55,391.95	553.92	371.13	182.79
Eucalyptus	483	8559.26	85.59	57.35	28.25
Evergreen Orchard	1	10.07	0.1	0.1	
Fresh Emergent Wetland	152	7536.81	75.37	50.5	24.87
Glacier	6	83.19	0.83	0.83	
Jeffrey Pine	6824	423,717.62	4237.18	2838.91	1398.27
Joshua Tree	48	4101.13	41.01	41.01	
Juniper	2207	200,936.8	2009.37	1346.28	663.09
Klamath Mixed Conifer	1786	246,565.04	2465.65	2465.65	
Lacustrine	1874	328,093	3280.93	3280.93	
Lodgepole Pine	2858	187,690.68	1876.91	1257.53	619.38
Low Sage	248	13,059.2	130.59	87.5	43.1
Mixed Chaparral	25,067	955,059.69	9550.6	6398.9	3151.7
Montane Chaparral	12,274	379,163.82	3791.64	2540.4	1251.24
Montane Hardwood	18,983	664,821.89	6648.22	4454.31	2193.91
Montane Hardwood-Conifer	1093	45,000.08	450	301.5	148.5
Montane Riparian	1211	25,536.53	255.37	171.09	84.27
Pasture	18	216.42	2.16	1.45	0.71
Perennial Grassland	677	71,471.24	714.71	714.71	
Pinyon-Juniper	2765	427,897.64	4278.98	2866.91	1412.06
Ponderosa Pine	7728	661,092.49	6610.92	4429.32	2181.61
Red Fir	3886	362,675.06	3626.75	2429.92	1196.83
Redwood	1038	71,584.58	715.85	479.62	236.23
Sagebrush	5547	569,785.19	5697.85	3817.56	1880.29
Saline Emergent Wetland	322	60,783.72	607.84	407.25	200.59
Sierran Mixed Conifer	6667	618,111.45	6181.11	4141.35	2039.77
Subalpine Conifer	4140	191,573.34	1915.73	1283.54	632.19
Unknown	4561	168,449.76	1684.5	1684.5	
Urban	389	151,272.98	1512.73	1013.53	499.2
Valley Foothill Riparian	1454	54,608.97	546.09	365.88	180.21
Valley Oak Woodland	1746	80,122.67	801.23	536.82	264.4
Wet Meadow	3985	96,410.32	964.1	645.95	318.15
White Fir	1675	121,434.12	1214.34	813.61	400.73