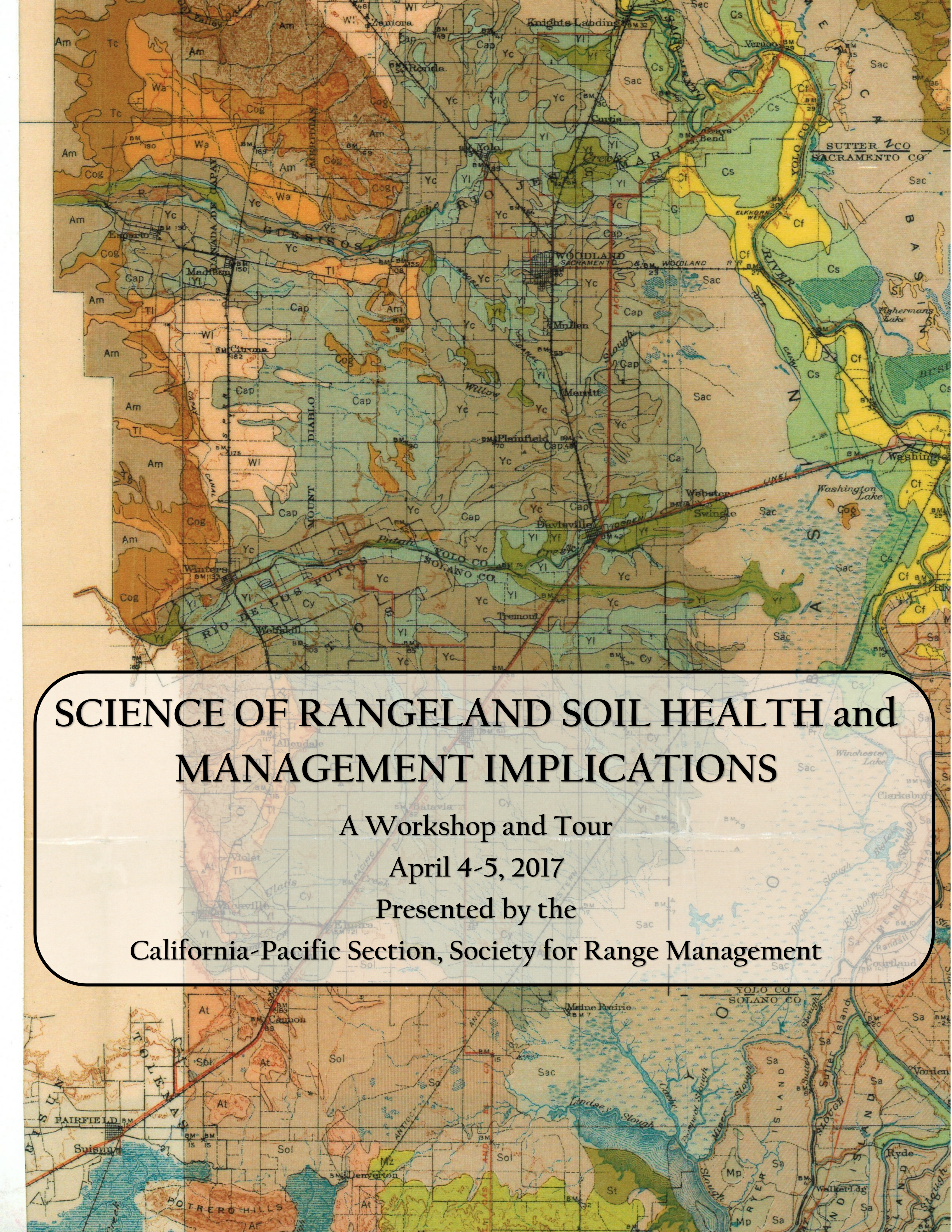

SCIENCE OF RANGELAND SOIL HEALTH and MANAGEMENT IMPLICATIONS

A Workshop and Tour

April 4-5, 2017

Presented by the

California-Pacific Section, Society for Range Management

Welcome to the Science of Rangeland Soil Health and Management Implications Workshop

and

Rangeland Soil Geomorphology of Yolo County Field Tour

David B. Kelley and Morgan Doran, eds.
Kelley & Associates Environmental Sciences, Inc. and
University of California Cooperative Extension

April 4-5, 2017

Thank you to the individuals who helped make this program possible:

Jared Lewis, Solano County Land Trust

Bruce Rominger, Rominger Brothers Farms

Dave and Diane Gilmer

Devii Rao, California-Pacific Section, SRM

And all the speakers and presenters

Cover: Soils Map, Sacramento Valley, California. 1913. Source: U.S. Department of Agriculture, Field Operations, Bureau of Soils

SCIENCE OF RANGELAND SOIL HEALTH AND MANAGEMENT IMPLICATIONS

A Workshop and Tour

And the Spring Meeting for the California-Pacific Section of the Society for Range Management

This program is a two-day event with the first day, Tuesday, April 4th, being held at the Solano Land Trust's Rush Ranch Nature Center. This first day is a mix of indoor and outdoor presentations and soil geomorphology discussions. The second day is a field tour covering four sites along a west-to-east transect of rangeland soils in Yolo County. The tour will begin at the Lake Berryessa Monticello Dam and will proceed to two private ranch sites and one public site adjacent to the Sacramento River.

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4. Kachituli Oxbow soil map

SCIENCE OF RANGELAND SOIL HEALTH AND MANAGEMENT IMPLICATIONS

A Workshop and Tour

And the Spring Meeting for the California-Pacific Section of the Society for Range Management

Workshop Agenda, Tuesday, April 4th, Moderated by David Kelley

8:00 AM	Registration
9:OO AM	Historical perspectives on rangeland soil science and conservation practices. *Leonard Jolley, USDA-NRCS, retired*
9:20 AM	Soil properties and potential for change through management. *Will Horwath, Professor, UC Davis*
10:00 AM	How rangeland soil characteristics affect our ability to change soil health properties. *Susan Marshall, Professor, Humboldt State University*
10:30 AM	Break
10:45 AM	Diagnosing soil health in California's annual rangelands: Issues of Scale. *Toby O'Geen, UCCE Specialist, UC Davis*
11:15 AM	Dynamic processes in rangeland and oak woodland soils: Water, nutrients and biology. *Randy Dahlgren, Professor, UC Davis*
11:45 AM	Lunch
12:30 PM	Field tour of soil pits and soil geomorphology. *David Kelley, Kelley & Associates* Perennial grass restoration: How soils and hydrology affect restoration outcomes. *Vic Claassen, UC Davis*
2:45 PM	Grazing management for healthy soils. *Leslie Roche, UCCE Specialist, UC Davis*
3:15 PM	A national perspective on rangeland soil health and why we should care. *Joel Brown, USDA-NRCS, Jornada Experimental Range, NM*
4:00 PM	Wrap up and tour details *Morgan Doran, UCCE Advisor*
4:30 PM	Adjourn
6:30 PM	California-Pacific Section Spring Meeting Dinner at the Cast Iron Grill & Bar, 700 Main Street, Suite 104 (entrance on Solano Street), Suisun City.

RANGELAND SOIL GEOMORPHOLOGY
OF YOLO COUNTY

Field Tour

And the Spring Meeting for the California-Pacific Section of the Society for Range Management

Rangeland Soils Tour, Wednesday, April 5th

Wednesday's tour will begin at 8:30 AM at the top of Monticello Dam, 9 miles west of Winters on Hwy. 128. The drive from Suisun City to the Dam is approximately 36 miles, 45 minutes.

8:30 AM	Coffee and assemble group
8:45 AM	History of Monticello Dam, Lake Berryessa and importance to local communities. *Morgan Doran, UC Cooperative Extension*
9:00 AM	Coast Range soil geomorphology and origin of the Putah Creek alluvial fan. *David Kelley, K&AES, Inc.*
9:30 AM	Depart for Winters In parking lot, east of Putah Creek Café, we will assemble carpools for remainder of tour. Bathroom break at public restrooms in city park.
10:00 AM	Rominger Bros. Farm, near 26982 County Road 29, Winters, CA Land use history, soil quality, soil pit and compost application on Corning soil series.
11:30 AM	Lunch (burritos) at Rominger Bros.
12:30 PM	Depart Rominger Bros.
1:00 PM	Arrive at Dave and Diane Gilmer's property, 34319 Corcoran Hill Lane, Davis, CA Spatial diversity of soil qualities and land use.
2:00 PM	Depart for Kachituli Oxbow on Sacramento River
2:30 PM	Arrive at Kachituli Oxbow, 19826 Old River Road, West Sacramento, CA Riparian soils, wetland mitigation and grassland restoration.
3:30 PM	Adjourn

Rangeland Soil Landscapes in Yolo and Solano Counties: Suisun Marsh, The Sacramento River, and The Putah Creek Fan

David B. Kelley, K&AES, Inc.

The Lower Sacramento Valley Landscape

There is no hiding the complexity of the landscapes one encounters in the region where the lower Sacramento River courses south and west toward its confluence with the San Joaquin River flowing from the south into the largest remnant tidal marsh on the West Coast, on the northern edge of the Sacramento-San Joaquin Delta, arguably the largest inland delta in the world. The complexity of the landscapes to be observed from Suisun City and Rush Ranch, where CalPac SRM will hold its workshop the first day, and those visible on the next-day tour of a portion of the Putah Creek watershed, may be subtle, in part because much of the complexity is expressed as surface features that belie the underground complexities of Yolo and Solano Counties, but it is robust. The following discussion provides some hints at these complexities of this watery region.

The City of Sacramento is situated on stream terraces and fans near the confluence of the Sacramento and American Rivers, which for the most part are streams of the Sierra Nevada rising to the east and north of the Sacramento Valley. The Sacramento Valley to the north and, to the south, the San Joaquin Valley, whose streams also originate in the Sierra but south of the Sacramento's watersheds, conjoin just south of the City of Sacramento, combining to form the Great Central Valley of California, a region of unparalleled agricultural productivity and many amiable Californians—including cattle, sheep, citizens, and politicians.

In the past few years leading up to 2017, California's normally dry climate held sway, *in extremis*. The effects of what many consider to be California's epic drought have been somewhat attenuated by fall and winter and now spring rains (and some prospect of coming rains, perhaps the week of our meeting), marking a period of abnormal adequacy. (As an example of these extremes, some places recorded no rainfall in January 2015, traditionally the middle month of our Mediterranean climate's rainy season, but 2017 brought record rainfall totals in the same seasonal timeframe.) Those of us who live in the region have experienced several "pineapple express" events, when moisture from the central and north Pacific is lifted over or through the Coast Range and dumped on our cities and rangelands and farms, but, most important, on our Sierra. Good weather in the California prior to 2017 had come to be defined as rainy days with prospects of more to come. Sometimes one can only take so many sunny, 60-degree days in the wintertime. Nowadays, we fickle lovers of rain are anxious for some weekends of sun and dry.

On our field excursions, we will have a chance to examine some of the complexities of the soil landscapes of the region. At Rush Ranch, we will see upland soils of ancient and gravelly remnant alluvial fans that reflect another set of climatic conditions (not to mention river hydraulics, sea level differences, and cultural influences) not obvious now. And we will observe soils that were, figuratively speaking, in terms of pedologic time, laid down yesterday. Similarly, on our Yolo County field trip, we will see soils of great age (200K years? 500K years?) alongside soils of the Holocene (less than 15K years old).

Rush Ranch and the Suisun Marsh/Delta Wetlands

Most of the so-called annual grasslands of California might be better characterized as prairies—they support many forbs and other dicots, remnant bunchgrasses, and many native species, as well as broadleaf weeds (most likely a big part of the forage and grazing base) and many other invasive species. They are dominated, for part of the year, by annual introduced grasses that are native to Mediterranean countries and that found a sound welcome here on the California prairies. In some areas, the natives have been all but eliminated, though they find refuge in the vernal pools, small depressional wetlands associated with restricted internal drainage of the soil profile, which are productive refugia for native species of plants and animals amid a sea of introduced annual grasses and forbs. These endorheic wetlands and some areas of ground that have not been cultivated, provide classic study sites for native populations that are somewhat insular and somewhat at risk. The plants of these ecosystems, which may be characterized by their unique vegetation and faunal displays, may persist as ecological features for thousands of generations.

Vernal pools and swales in the Rush Ranch area, and other short-term wetlands of the prairie ecosystems, are associated with restricted drainage features of the clayey soil profiles—

specifically, clay lenses that don't allow ponded surface waters to permeate the subsoil. In other instances and other places that we will see on our Yolo County trip, the sub-surface restrictions may be in the form of indurated (cemented) layers, or duripans, that are pedogenic expressions of clay and mineral migrations and concentrations that result in the development of iron silicate precipitates and crystals that bridge soil particles and can form massive aquicludes (in some cases, cemented horizons two- to six-feet thick). The climate—winter rain and summer dry—allows the expression of vegetation types in landscape positions and conditions that reflect the truly harsh ecological cycles the pools undergo. The plants and the critters that have evolved in these unique systems are generally rare and passingly vulnerable to changing conditions. The pools and their biota are singularly adapted to the effects of grazing animals—sheep, cattle, and horses in contemporary California, and presumably elk and other grazers in pre-contact California—and other grassland processes such as wind erosion and deposition of aeolian sediments, fires, periods of water sufficiency and of drought, predation and herbivory, and other insults.

Rush Ranch occupies a fan terrace and some structural (underlain by bedrock) hills that have been shaped by streams and outwashes and influenced by watershed dynamics and sea level changes over the last few hundred thousand years. The system lies on the fringe of the Suisun Marsh, an inland marsh feature of the large inland Sacramento-San Joaquin Delta. We will be able to discuss the ecosystem dynamics of this wonderful complex of earth, air, fire, and water cohorts when have some field time at the afternoon soil pits.

In the vicinity of Rush Ranch, near the Sacramento River one may encounter old stabilized fan terraces in Solano and Yolo Counties and in some of the low spots in the region, the fringelands of the Suisun Marsh and the Delta, where one can encounter wet organic soils and high-productivity irrigated pasture. Throughout the region, you will notice the green annual grasslands that color the hills and provide grazing for thousands of hoofed animals. In November, those hills were gray and brown and crackly dry, and, in some cases, on fire. On our trip in Yolo County we will see the greened up hills where summer fires crisped and charred all the forage. We shall see what a little rain can do.

The Putah Creek - Cache Creek Fan

The second day of our workshop we will begin the day at Monticello Dam on Putah Creek, about 9 miles west of Winters. Most participants will come form the Suisun City/Fairfield area or from Sacramento. Heading west from those areas, one encounters the distal edges of the large coalesced fan complex of Putah Creek and Cache Creek, the major streams of Yolo and Solano Counties (with watersheds in Napa, Colusa, and Lake Counties, as well). Putah and Cache Creeks are shown on older maps of Yolo County as "Rio de los Putos" and "Rio Jesus Maria" respectively. They are creeks in name only; at certain times and under certain conditions, they could be easily characterized as rivers, filling and overbanking along their populated, intensely farmed overwash plains and occasionally reminding Yoloans of their capabilities and fluvial/geomorphic histories. Even with the modern development of dams and levee systems, canal diversions and pump intakes, roadways and byways, these streams still provide those reminders. They can still reclaim old channels, remove and replace streambanks and gravel bars, shift property boundaries, and cause property owners to reconsider established land uses. But not like they used to.

We will have the opportunity on the field exploration of this part of the Putah Fan ("the Fan", from now on in this story) to discuss some of the past events that led to the formation of the Fan landscape. We can't know it all: the geologic history, the fluvial/geomorphic history, the pedologic history, the cultural and agricultural histories—but we can examine, assess, and speculate about those histories, and we might even be able to weakly predict some of the futures the Fan will have. We will visit the Fan from top to bottom—from Monticello Dam on the west to Davis and the Sacramento River bypass and the Kachituli Oxbow and the Putah Sinks on the eastern edges. The only way to frame this trip is to recognize the natural (if ever-changing) features of the landscape. These include the Putah Creek canyon, the widening of the canyon as the stream debouches onto and through its fan and into the Sacramento Valley, the eastern edges of the uplifted or remnant sediments and soils that rim the upslope edges of the Fan, the short and numerous secondary drainages that reflect and form parts of the alluvial dynamic of the Fan, and the mother stream of the valley, the Sacramento.

From a prehistoric perspective, there is another important thing to recognize about this landscape, about the Fan: it has not always been the way it is now. In many ways, it is a classic alluvial fan. It is fan-shaped and defined by its major stream, Putah Creek; the two creeks—Putah and Cache—intercept and carry waters from their secondary and primary channels; it has deep sediment accumulations (reflected by deep and delightful agricultural soils); it is sloped from west to east ("tilted") and has discrete edges. On the other hand, it has some oddities, or maybe superlatives. The Putah Creek Fan coalesces with its sister, the Cache Creek Fan, to form what is arguably one of the largest alluvial fans in the country, certainly in the Great Central Valley of California. Its streams don't make their way into the Sacramento River channel—that mother stream has massive and robust levees that turn the Fan's streams aside and force them to yazoo their way into the basin-mingling waters of the Sacramento-San Joaquin Delta. Thus, the distal, eastern edge of the fan is not so much truncated by the Sacramento (at least in its current form), but drowned by its sediment deposits, and Putah Creek's waters are drowned somewhere in the spreading fringes of the Sacramento (in the large and remarkable Delta). The lowest landscape position on the Fan may be characterized as a trough that more-or-less parallels the Sacramento, running along the Sacramento's distal western levees and marked by salty undrained basin soils and moribund wetlands. And there is an older fan here, or at least a memory of one—a fan that we will see remnants of but that no longer exists.

Imagine a landscape where the Sacramento River, its base level reflecting sea level, runs in a channel that is from 100 to 300 feet lower than it is now. We don't need to go too far back in time to find that possibility: that was the situation at the end of the Pleistocene and the beginning of the Holocene, before the catastrophic, cataclysmic global warming of the late Pleistocene returned glacial waters to the sea. Imagine San Francisco's gap in the Coast Range—we call it the Golden Gate today—as a river valley 200 to 400 feet lower than sea level today, with the comingled waters of the Sacramento and San Joaquin Rivers coursing through the valley and entering the sea a mile or more west, toward Japan, from the Golden Gate Bridge. If we encountered the Fan in those days, what would the landscape look like? We can suggest that Putah Creek may have had its own canyon, cut through an ancient, massive ancestral (pre-Holocene) alluvial fan, and a completely different gradient dynamic—a fast stream, carrying more water and more (and larger) sediment, doing more work on the landscape, maybe breaching the broad Sacramento River levees, moving through an alluvial plain that looks much different from the one we see now. Further, imagine that this was the landscape that the first people to invade this continent encountered. We can ask where they might have camped twelve to fifteen thousand years ago, what fish they might have eaten, what critters they may have encountered, what their trade routes and seasonal migration patterns might have been. Not only would the flora and fauna have been different (and maybe terrifying), but the ground that lay beneath their hide-covered feet and their villages and campsites and hunting grounds have been covered up by successive sediment inundations as the Fan built.

Coda

This is the framework for our field days. We will see and discuss some remnants of this new landscape (Holocene-new), as well as remnants of an older, maybe more unfathomable landscape. (If we can perceive the differences in the landscape that existed ten thousand years ago, can we do the same for a million-year-old landscape? A ten million-year-old landscape?) Be prepared to feel and discuss our way through our fieldwork. We have designed the field days to introduce the fans and terraces and basins as organic, dynamic, and intriguing landscapes, even to folks who know them already. We hope that participants will see this landscape differently today from the way they might have seen it yesterday.

A Note about the Sacramento and Davisville and Winters Landscapes

These landscapes grow great trees. The arboretum at the State Capitol and the Arboretum at UC Davis have beautiful and very large examples of most of the native trees of the region, as well as many of the important horticultural species that are grown (and may have naturalized) in the region. These plants (and many agricultural/horticultural plantings) benefit from deep terrace soils and a benign climate along the Sacramento River and Putah Creek, and down into the Suisun Marsh. Similarly the cities of Woodland and Davis, and the campus of the University of California at Davis that occupy the central sector of the large, gently sloping alluvial fans of Putah and Cache Creeks, across the river west of Sacramento, and which drain a portion of the uplifted (to >3000 feet in some places) Coast Range lying to the west, grow great trees and crops and grasslands. The parent materials of the soils of these modern fans are derived chiefly from uplifted marine sediments transported down onto and overlapping the fluvial terraces or levees of the Sacramento River, the dominant drainage of the valley. The soils around Davisville, the archaic name of the modern, ever-so-cosmopolitan City of Davis (find Davisville on this guidebook's front cover, a reproduction of a 1913 soils map of the area), and Woodland (on Cache Creek) and Winters, the other Putah Creek city, are young, deep, and fertile, for the most part. They began forming in the late Holocene (within the last 4,000 years or so) and may have been inhabited, if not farmed, for most of their young lives. These modern soils overlie in many places the older soils (paleosols) of landscapes (on the order of ten thousand to a hundred thousand years old or more) that no longer exist and, in certain places, the bones and habitations of aboriginal Yoloans.

As you might notice in an examination of soils of these fans and terraces, tree roots find little impedance in these deep soils—until some neo-Californian has come along and mucked things up by, for example, farming or building homes or constructing sidewalks, curbs, or parking lots, or by building universities on these Class I soils. The soils (at least, the soils nearest the active channels of the Fan) are generally loamy, well drained, and deep. They may be stratified and poorly developed (that is, they infrequently have accumulations of clays or toxic ions or indurations in horizons at depths to which tree and vine roots can reach), and they were subject to sediment replenishment from out-of-bank creeks until those creeks were leveed and damned.

It is difficult to find a gravel in some of these profiles. Older soils of the region (some exhumed in modern, large-scale landscape insults, others naturally outcropping in hills, streambeds, or terraces to the west) may have pedogenic clay accumulations, gravel lenses, or iron- and silica-indurated horizons (duripans). Older soils are now being farmed to tree and vine crops, but the soils for which the region is (agriculturally speaking) famous are the younger Yolo and Brentwood loams and similar soils of the Fan. These soils, when disturbed by urban or agricultural manipulations, are subject to the development of compaction zones, clay pans, traffic pans, and exposure of low-fertility subsoils, all of which may be constraints to healthy root development. These constraints may be augmented by construction activities, which seal the surface of the soils with concrete or asphalt, or by irrigation systems, which can cause soil moisture to exceed field capacity of the soils. Tree and plant roots absorbing nutrients and water and releasing or taking up gasses in these disturbed and built-over soils may have a hard go of it. Welcome to our deep landscape.

David B. Kelley
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Rush Ranch

Provided by Jared Lewis, Solano Land Trust

Welcome to Rush Ranch, introduce ….

- Rush Ranch est. 1850's, working ranch until 1988 when SLT acquired Rush Ranch with the support of the California Coastal Conservancy (Conservancy).
- Grazing protected the largest remnant tidal marsh on the west coast (1,070 acres)
- Continues to be a working ranch (uplands only): two-herd rotational grazing (Dec-June; 100 Mother cows and 150 heifers & steers). Livestock improvements (water system, fences).

Three legged Stool

- Recreation (trails, rentals, hunting, birdwatching,scenic resources)
- Education (partner ships with RCD, RREC, AA) – educational programs In 2007, SLT completed construction of a Nature Center, with support from the National Oceanic and Atmospheric Administration (NOAA) and the Conservancy, to educate the public and provide an on-site research station for visiting scientists.
- Science: In 2003, San Francisco Bay National Estuarine Research Reserve (NERR) officially designated Rush Ranch as a component site in a nationwide network of research reserves.

Science at Rush Ranch:

- Marsh studies NERR and others water quality, USDA Invasive weeds (lepidium), UCDavis fish studies (1st mallard Slough), Ecosystem and marsh accretion (sea level rise), carbon dynamics (methane flux tower), Accoustic Bird monitoring (USGS), Nutrient dynamics, ecosystem transgression (ecotone)
- T&E species: CTS, TCB, Ridgway Rail, Black rail
- Restoration: large landscape level restoration projects ongoing
- Carbon Farming
- UAS mapping research

Carbon Farming:

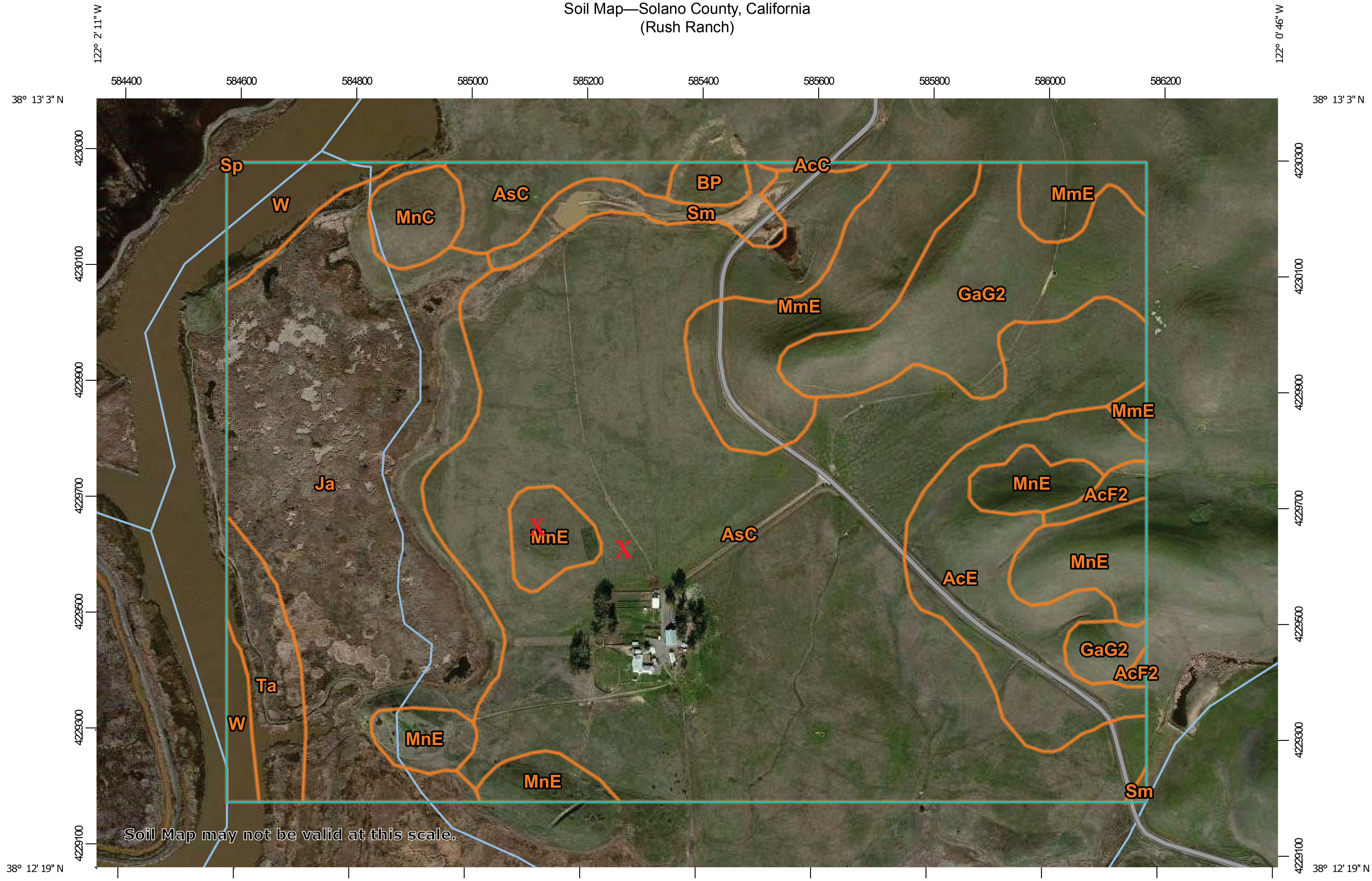
- Definition: Land management that reduces Greenhouse Gas emissions and/or holds carbon in vegetation and soils.
- Compost addition: single 1 inch application of greenwaste compost amendments increased forage production (50%) and soil carbon sequestration (on average 1 ton/hectare) over three years.
- Net ecosystem carbon storage increased by 25–70% without including the direct addition of compost carbon
- The addition of compost led to increased water-holding capacity in soils.

- Less greenhouse gas emissions than either the application of manure slurries or the application of inorganic N fertilizer across a broad range of environmental and management conditions.
- Compost amendments could result in significant offsets to greenhouse gas emissions, amounting to over 28 Million metric tonnes CO_2e when scaled to 5% of California rangelands, while sustaining productive lands and reducing waste loads.

SLT Carbon project:

- 24 plots (1 acre in size, 3 soil types, 3 slope categories)
- 4 treament combinations for each plot (1/4 acre) Burn, burn+Compost, Compost, control.
- Grazing exclosures in each plot
- Monitor soil moisture, soil C, vegetation composition, Biomass, Crude protein
- Purpose: is soil carbon amendment via green-waste compost a feasible rangeland management action? Is it cost effective? Can it be used for Carbon credits on a larger scale?
- Funding: NRCS (Regional Conservation Partnership Program), carbon aggregators, others????

Soil Map—Solano County, California
(Rush Ranch)



Map Scale: 1:9,360 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0, 100, 200, 400, 600

Feet: 0, 450, 900, 1800, 2700

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

Map Unit Legend

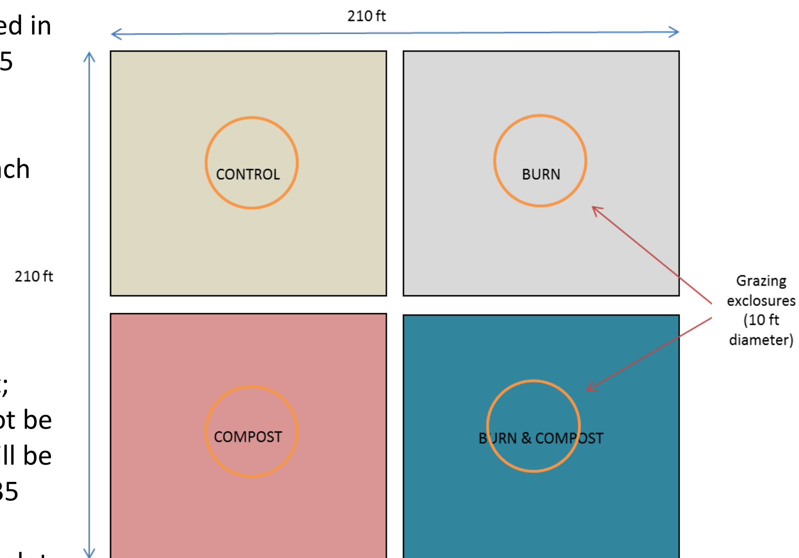
Solano County, California (CA095)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
AcC	Altamont clay, 2 to 9 percent slopes	0.6	0.1%
AcE	Altamont clay, 9 to 30 percent slopes	27.6	6.3%
AcF2	Altamont clay, 30 to 50 percent slopes eroded	2.6	0.6%
AsC	Antioch-San Ysidro complex, thick surface, 2 to 9 perce nt slopes	199.6	45.7%
BP	Borrow pit	2.3	0.5%
GaG2	Gaviota sandy loam, 30 to 75 percent slopes, eroded	31.6	7.2%
Ja	Joice muck	84.1	19.3%
MmE	Millsholm loam, 15 to 30 percent slopes, MLRA 15	29.0	6.6%
MnC	Millsholm loam, moderately deep variant, 2 to 9 percent slopes	5.5	1.3%
MnE	Millsholm loam, moderately deep variant, 9 to 30 percent slopes	25.8	5.9%
Sm	Solano loam, dark surface variant	7.3	1.7%
Sp	Suisun peaty muck, MLRA 16	0.0	0.0%
Ta	Tamba mucky clay, MLRA 16	10.0	2.3%
W	Water	10.5	2.4%
Totals for Area of Interest		**436.6**	**100.0%**

SOLANO LAND TRUST

Experimental Carbon Sequestration at Rush Ranch

Overview: The Rush Ranch Carbon Sequestration Project seeks to develop a methodology for carbon sequestration and avoided greenhouse gas (GHG) emissions related to compost additions to grazed grasslands. In December of 2015, land trust staff applied greenwaste compost to the study site in order to evaluate short scale and long-term soil carbon storage, changes in soil characteristics, nutrient content and plant productivity. Compost was trucked to the study site by commercial dump truck and dispersed mechanically across each of the application areas. Compost was applied to half of each 1-acre plot.

Design: Four 1-acre plots located on the perimeter of previously burned grasslands were established in October of 2015. Each plot consists of 4 (0.25 acre) cells with the following treatments: compost only, compost +burn, burn only, control. Four cattle exclusion cages within each treatment combination were constructed in October 2015, to examine the effect of grazing on plant composition, soil chemistry and carbon storage. Soil samples (cores) will be collected in November, 2016 within each treatment cell of each study plot; soil core depth will be 40 cm. Samples will not be composited. The following measurements will be conducted on the soil samples at 5, 20, and 35 cm depth increments: total soil carbon, soil texture, soil bulk density, soil pH. Thus each plot will yield 24 soil samples (8 cores with 3 stratum samples each), resulting in 96 samples. Soil sampling will be repeated annually.



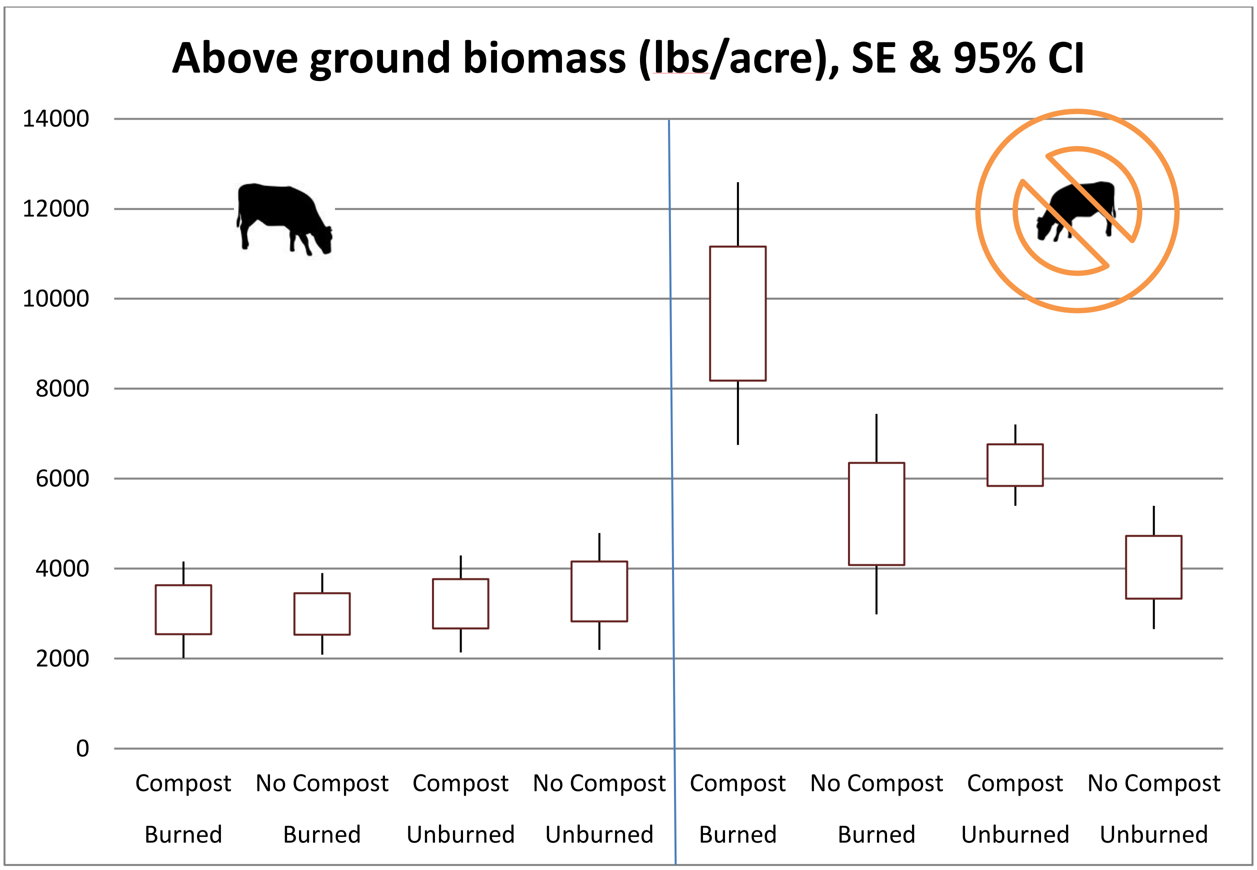
Monitoring: Plant productivity was evaluated on April 15th, 2016 within the grazed and ungrazed portions of each study plot and cell. To measure total above ground biomass, 6 samples were collected in each cell: two samples in exclosures; and four samples in grazed cells (each cell sampled). 24 samples were collected for each macroplot. A total of 96 samples were collected across the four plots. A circular .96 ft^2 clipping frame was used in all cases. All plant material roted within the sampling frame was clipped within 1 cm of ground level, air-dried to a constant weight, and weighed in the lab.

Future research: A significant expansion of the current project will be initiated in August 2016. Specifically, the proposed research seeks to (1) identify and quantify the ecological factors that drive ecosystem carbon storage in the context of a sustainable agricultural enterprise, and (2) to evaluate the management, socio-economic, and ecological implications of enhancing carbon stocks and improving ecosystem services through compost addition. The economics component will also include an analysis of private and social transactions costs with respect to participating in carbon markets. Further to these goals, the proposed research will evaluate these factors across a suite of representative ecological, site and cultural variables in order to capture and account for environmental and agricultural (production level) variability.

These objectives will be accomplished through a large landscape-scale experiment, involving up to 30 1-acre plots in rotationally grazed rangelands in northern California, to which completely cured, locally sourced green-waste compost is spread about 0.5 in thick in a single application (about 33 cy/ac). Each experimental plot is paired with an adjacent control plot on the same soil type. We will stratify samples by up to 3 slope categories and by soil type to ensure that appropriate environmental and management-relevant variances are addressed. Grazing exclosures are also nested within study plots to allow assessment of grazing impacts and productivity. Soil carbon and water content, along with other physical and chemical metrics, will be sampled up to 3 times per year in treatment and control sites. Monitoring and evaluating the bio-physical impacts of compost addition also include native plant communities, weeds, rare or endangered species, and native pollinator guilds.

Additionally, the proposed research will establish performance metrics and financial/economic indicators at a sample of representative sites that will track the market and nonmarket costs and benefits of implementation. A multi-tiered economic analysis will quantify associated economic benefits and constraints that pertain directly to proposed methodologies, and provide an analysis of co-benefits related to improvements in selected ecosystem services.

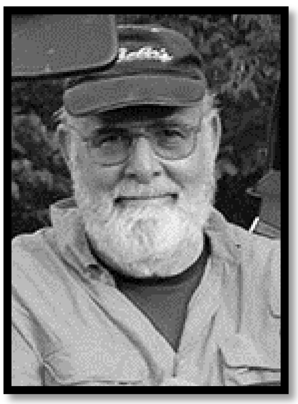
Preliminary Biomass Data:



Project Partners: Solano Land Trust (Steve Kohlmann, steve@solanolandtrust.org; Jared Lewis, jared@solanolandtrust.org), National Estuarine Research Reserve (Mike Vasey, mvasey@sfsu.edu), San Francisco State University (Tom Parker, parker@sfsu.edu), USGS (Frank Casey, ccasey@usgs.gov) Carbon Cycle Institute (Jeff Creque, jcreque@carboncycle.org; Pelayo Alvarez, palvarez@carboncycle.org), UC Davis Coop Extension (Elise Gornish, egornish@ucdavis.edu)

Speakers at the Science of Rangeland Soil Health and Management Implications Workshop and Tour

Leonard Jolley



Leonard Jolley held the position of the California NRCS State Range Conservationist before he went to Beltsville, Maryland where he finished his NRCS career as a Rangeland and Pastureland Ecologist. At the national level Leonard worked on a team that directed the Conservation Effects Assessment Project, which was a significant endeavor to evaluate the effects of NRCS practices on the nation's farms and ranches. Leonard returned to California where he enjoys his retirement and continues to fulfill his passion for rangelands and range management.

Presentation title: "Historical perspectives on rangeland soil science and conservation practices."

Outline of Talk

- Historical context of soil health and implications for the future
- Thread I will follow:
- Range health – soil quality – soil health
- Elements of galvanizing support from scientists, practitioners, and general public
- NRCS embrace of each of these in advance of supporting science
- Example of USDA CEAP Program
- Move beyond the seeming "fad" and customize for California

MY OPINION ONLY:

- UC Davis grad 1975 BS, 1976 MS Rangeland Management
- Colorado State University, 2006 PhD Riparian Ecology
- Nearly 40 years with USDA
- Lakeport CA, Santa Maria CA, Bishop CA, South Lake Tahoe CA/NV, Davis CA, Fort Collins CO, Lakewood CO, Portland OR, Washington DC (Beltsville MD), Petaluma CA

- Soil Scientist, Rangeland Management Specialist,
- District Conservationist
- Writing Scientist, UC Davis
- Lecturer, Humboldt State University
- Research Associate Professor, University of Nevada Reno (Part Time) Consultant
- Retiree (Currently)
    - Closed my USDA career by shepherding two separate literature syntheses publications to completion – one for Rangeland the other for Pastureland Hayland

RANGE HEALTH

In general, pre rangeland health approaches to rangeland condition relied on comparisons of species composition (relative biomass) of present vegetation compared to the "climax" or "potential natural" vegetation for the site.

The approaches used were founded on the same basic model of Clementsian succession proposed by Sampson (1919), and this remained the basis for evaluating "ecological status" by all three agencies until superseded by rangeland health.

Range condition date (e.g., SRM 1989) indicated that trend in range condition was up or static on about 85% of U.S. rangelands, public and private.

Critics pointed out that the same data showed that most public rangelands are in "poor" or "fair" condition and conclude that this situation indicates a failure of current management and a need for drastic action as proposed, for example, in Rangeland Reform '94 (USDI/USDA 1994).

RANGE HEALTH - TYPICAL RECOMMENDATIONS

Identify an appropriate set of attributes and the techniques for monitoring these attributes for key ecological sites, including those in riparian areas, and evaluate these attributes in relationship to the site conservation threshold.

Identify major plan community types that typify ecological sites and describe the ecological processes and management actions associated with transitions among these types.

Characterize the soils, particularly the upper soil layers, and determine the relationship of soil characteristics to plan community stability and the site conservation threshold.

(Desired plant communities and site conservation thresholds became states and transitions a la Westoby)

Suggested references:

National Research Council. 1994. Rangeland health: new methods to classify, inventory, and monitor rangelands. National Academy Press, Washington, D.C. National Research Council. 180p.

Task Group on Unity in Concepts and Terminology. 1995. New concepts for assessment of rangeland condition. Journal of Range Management 48:271-282.

West, N.E., K. McDaniel, E.L. Smith, P.T. Tueller, and S. Leonard. 1994. Monitoring and interpreting ecological integrity on arid and semi-arid lands of the western United States. Report 37. New Mexico State University, New Mexico Range Improvement Task Force.

Westoby, M., B. Walker, and I. Noy-Meir. 1989. Opportunistic management of rangelands not at equilibrium. J. Range Manage. 42:266-274.

George, M.R., J.R. Brown, and W.J. Clawson. 1992. Application of nonequilibrium ecology to management of Mediterranean grasslands. Journal of Range Management 45:436-438.

But see also. . . . Smith, E.L. 1999. The myth of range/watershed health. Pp. 6-11, In Riparian and watershed management in the interior northwest: an interdisciplinary perspective. Oregon State University Extension Service Special Report 1001, Corvallis, Oregon.

Briske, D. D. [ed.]. 2011. Conservation benefits of rangeland practices: assessment, recommendations, and knowledge gaps .Washington, DC, USA: USDA-NRCS. 429 p. Available at: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?&cid=stelprdb1045811. Accessed 2 April 2017.

William Horwath

Professor Horwath has a distinguished career at UC Davis. He was appointed as an Assistant Professor of Soil Biogeochemistry in the Department of Land, Air and Water Resources in July'96 and was promoted to Professor of Soil Biogeochemistry in July, 2004. Professor Horwath was appointed the James G. Boswell Endowed Chair in Soil Science in 2008. Professor Horwath received the Soil Science Society of America Fellow award in 2009. The Fellow award is the highest recognition given by the society.

Professor Horwath's research record includes over 100 peer-reviewed papers and book chapters and over 15 million dollars in research grants from highly competitive State and Federal funding sources. Many of these funds have been used to advance the sustainable agriculture, natural resource management, climate change mitigation and environmental stewardship. He has been a leader in sustainable agriculture research at UC Davis, including the Sustainable Agriculture Farming Systems project for which he has been director since 2003.

Presentation title: "Soil properties and potential for change through management."

Susan Marshall

Since 1996 Susan Marshall has been a Professor of Rangeland Resources & Wildland Soils in the Department of Forestry and Wildland Resources at Humboldt State University in Arcata, California. Susan maintains a heavy teaching load at HSU whose courses include Wildland Resource Principles, Intro. to Soil Science, Origin & Classification of Soils, Forest & Range Soils, Soil Physics, Soil Microbiology, Soil Fertility, Vegetation Analysis & Health, Wildland Plant Communities, Wildland Restoration & Developments, Public Land Policy & Management. Susan's research interests include small-scale surface processes in soils, infiltration, crusts, seed banks, competition between different plant species in their roots zones, soil physical properties and implications for plant production and survival.

Presentation title: "How rangeland soil characteristics affect our ability to change soil health properties."

Suggested references:

Task Group on Unity in Concepts and Terminology. 1995. New Concepts for Assessment of Rangeland Condition. J. Range Manage, 48:271-282.

California NRCS Soil Health Webpage https://www.nrcs.usda.gov/wps/portal/nrcs/main/ca/soils/health/

Anthony "Toby" O'Geen

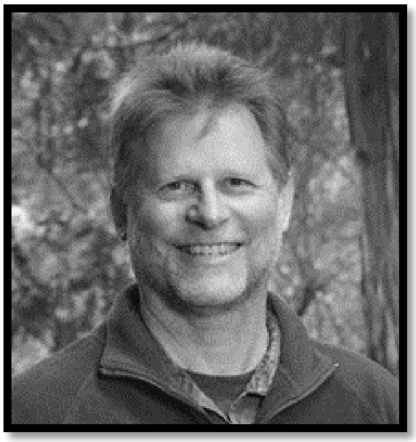
Toby has been a Soil Resource Specialist in Cooperative Extension at UC Davis since 2002 where he leads the California Soil Resources Lab. Toby and his lab have developed many web-based application tools including the SoilWeb, SoilWeb Earth, Soil Series Extent Explorer, Soil Properties App and the Soil Agricultural Groundwater Banking Index. Toby's research interests include soil genesis and morphology, rangeland soils, hydropedology, water quality and constructed wetlands, soil-landscape relationships and modeling, watershed-scale digital soil mapping and quantitative pedology and repackaging soil survey into interactive decision support tools.

Presentation title: "Diagnosing soil health in California's annual rangelands: Issues of Scale."

Suggested references:

Tate, K.W., D.M. Dudley, N.K. McDougald and M.R. George. 2004. Effect of Canopy and Grazing on Soil Bulk Density. Journal of Range Management, Vol. 57, No. 4: pages 411-417.

Randy Dahlgren



Randy is a professor of Soil Science and is a Pedologist / Soil Mineralogist. Randy also holds the prestigious Russell L. Rustici Endowed Chair in Rangeland Watershed Sciences. Randy's biogeochemistry research team studies interactions of hydrological, geochemical, and biological processes in regulating surface and ground water chemistry. This research provides information to help guide the management of agricultural and wildland ecosystems in a sustainable and environmentally responsible manner.

Presentation title: "Dynamic processes in rangeland and oak woodland soils: Water, nutrients and biology."

Suggested references:

Dahlgren, R.A., M.J. Singer and X. Huang. 1997. Oak tree and grazing impacts on soil properties and nutrients in a California oak woodland. Biogeochemistry, 39: pages 45-64.

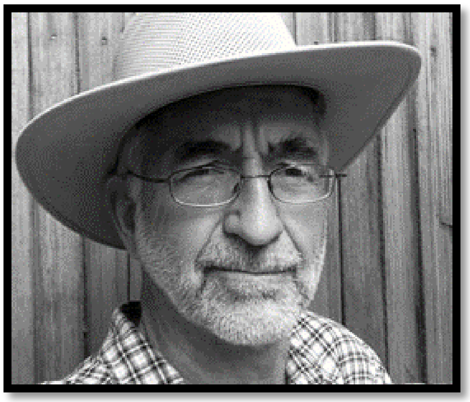
Schnabel, S., R. A. Dahlgren and G. Moreno-Marcos. 2013. Soil and Water Dynamics. In: P. Campos et al. [eds.]. Mediterranean Oak Woodland Working Landscapes, Landscape Series 16, DOI: 10.1007/9 978-94-007-6707-2_4, Springer Science+Business Media Dordrecht.

O'Geen, A.T., R.A. Dahlgren, A. Swarowsky, K.W. Tate D.J. Lewis and M.J. Singer. 2010. Research connects soil hydrology and stream water chemistry in California oak woodlands. California Agriculture, 64(2): pages 78-84.

Dahlgren, R.A., W.R. Horwath, K.W. Tate and T.J. Camping. 2003. Blue oak enhance soil quality in California oak woodlands. California Agriculture, 57(2): pages 42-47.

Dahlgren, R.A., K.W. Tate, D.J. Lewis, E.R. Atwill, J.M. Harper and B.H. Allen-Diaz. 2001. Watershed research examines rangeland management effects on water quality. California Agriculture, 55(6): pages 64-71.

Victor "Vic" Claassen

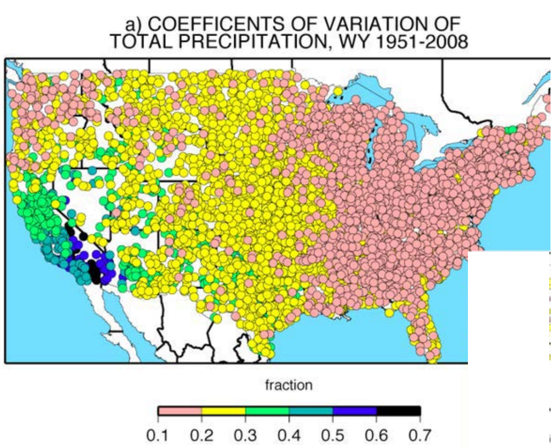


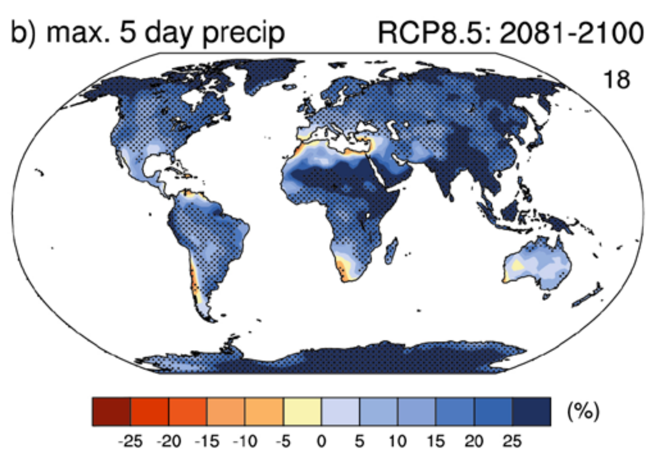
Vic Claassen is an Assistant Research Soil Scientist in the Department of Land, Air and Water Resources at UC Davis. Much of Vic's research has specialized in the restoration and revegetation of highly degraded soil, often resulting from construction excavation. Specific research interests include soil fertility in wildlands systems, endomycorrhizae, soil organic matter, hydropedology and root growth.

Presentation title: "Perennial grass restoration: How soils and hydrology affect restoration outcomes."

Abstract: Perennials require access to soil moisture throughout the summer. In upland Mediterranean environments, adequate plant-available moisture depends on the soil's ability to capture winter rainfall and retain it in the subsoil until late summer. Revegetation sites with engineered fill, compacted soils or areas that have been impacted by decades of annual grass cover may not have the deep rooting and moisture storage capacity needed to support resilient perennial grass communities.

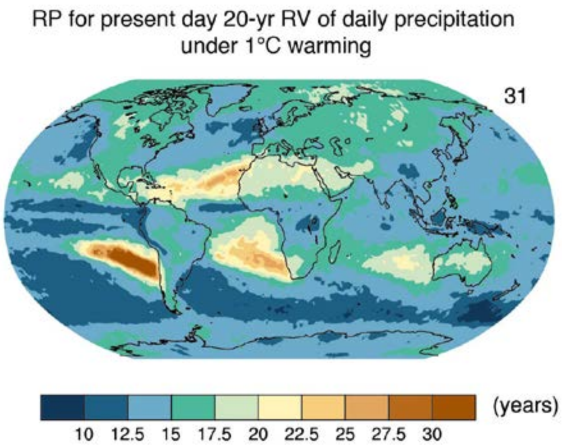
Soils are biological systems that consume fixed carbon as an energy source for function and maintenance. Since annual grasses fix less carbon than perennials (Koteen et al, 2011) and root less deeply (Holmes and Rice, 1996), replacement of deep-rooted perennial grass and forb communities with shallow-rooted annual grasses can be expected to also result in a long-term reduction in subsoil organic content, structure and porosity. Widespread stream entrenchment, increased overland flow during moderate storm events and increasingly flashy hydrographs in watersheds throughout the state may partly be a result of a decrease in subsoil capacity for stormwater capture. How can we evaluate the effects of soil hydrologic characteristics for revegetation projects on degraded sites, or for climate change projections of increased storm severity, so that these sites can adequate capture rainfall, be erosion resistant and sustain perennial grass communities or forage production?



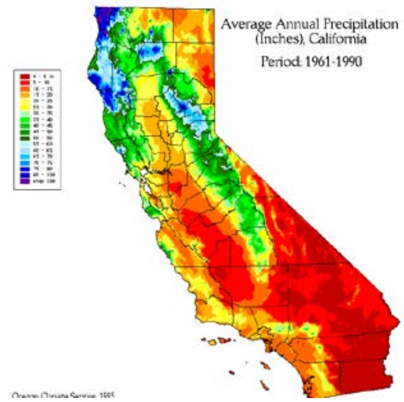


California's hydroclimate is unusually variable. Most of the rainfall comes on just 5 to 15 days per year.

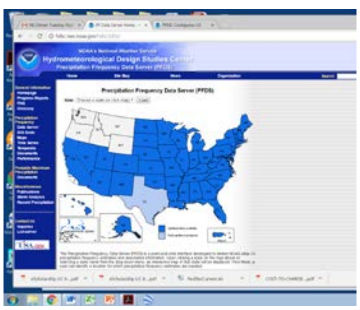
(Dettingeret al., 2011). Future climate projections suggest that storms on these wettest storms will deliver about 20 % more rainfall (Hall, 2016). Viewed another way, the Return Period for a 20 year intensity event will start to occur, on average at 12 to 15 year intervals with minimal warming and more frequently under warmer conditions.

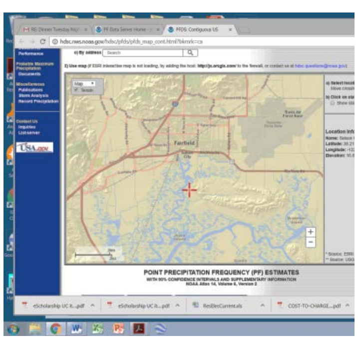


The problem for field practitioners is that climate change models are at a large scale, approximately 100 – 200 km in resolution. This doesn't help in a heterogeneous environment like California.



Capture of rainfall depends on surface infiltration during intense storms as well as an ability to retain larger rainfall volumes during multi-day events without surface saturation. How can revegetation design on degraded sites be made more robust and erosion resistant relative to climate change projections?





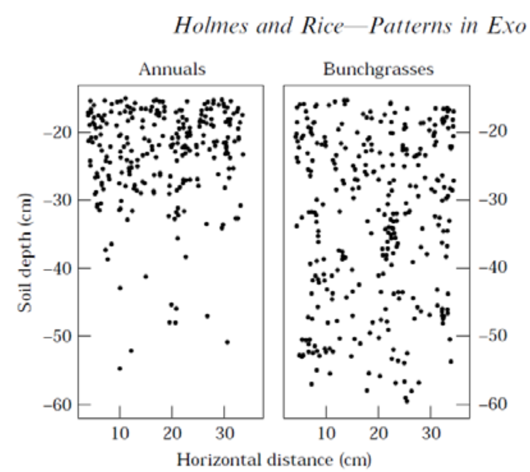


FIG. 3. Root maps for a stand of exotic annuals (*B. distachyon* and *T. hirtum*) and a stand of the native perennial bunchgrass, *N. pulchra*, at SFREC. Each point represents the cut surface of an individual root.

NOAA PFDS web site: http://hdsc.nws.noaa.gov/hdsc/pfds/

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
15-min	**0.198**	**0.249**	**0.317**	**0.374**	**0.454**	**0.517**	**0.583**	**0.651**	**0.747**	**0.822**
60-min	**0.382**	**0.481**	**0.613**	**0.724**	**0.878**	**0.999**	**1.13**	**1.26**	**1.44**	**1.59**
6-hr	**1.01**	**1.27**	**1.63**	**1.91**	**2.31**	**2.61**	**2.93**	**3.25**	**3.69**	**4.04**
24-hr	**1.84**	**2.37**	**3.08**	**3.65**	**4.44**	**5.05**	**5.67**	**6.31**	**7.19**	**7.87**
2-day	**2.32**	**3.00**	**3.89**	**4.62**	**5.61**	**6.37**	**7.14**	**7.93**	**9.01**	**9.84**
7-day	**3.63**	**4.72**	**6.12**	**7.26**	**8.78**	**9.93**	**11.1**	**12.3**	**13.9**	**15.1**

NOTE: Rainfall capture and retention are supply-side effects. Also critical are the demand-side effects of increased air, leaf and soil temperatures on evapotranspirative losses and physiological stresses.

Suggested references:

Dettinger, M.D., F.M. Ralph, T. Das, P.J. Neiman, and D.R. Cayan. 2011. Atmospheric rivers, floods and the water resources of California. Water, 3(2), 445–478. DOI: 10.3390/w3020445.

Hall, A. 2016. “How California’s Climate Shapes Water Resources. Rationalizing the Allocation of California Water Workshop” Presentation at The Keck Center, California Institute of Technology. Pasadena CA. April 19 – 21, 2016. Accessed February 28, 2017. http://workshop.caltech.edu/caH2O/presentations.html

Holmes, T.H. and K.J. Rice. 1996. Patterns of growth and soil-water utilization in some exotic annuals and native perennial bunchgrasses of California. Annals of Botany. 78:233-243.

Koteen, L.E., D.D. Baldocchi, and J. Harte. 2011. “Invasion of non-native grasses causes a drop in soil carbon storage in California grasslands.” Environmental Research Letters 6:0044001. Online at stacks.iop.org/ERL/6/044001

Leslie Roche

Leslie Roche is an assistant Cooperative Extension specialist in the Department of Plant Sciences. Her research and extension program is at the intersection of agricultural, environmental, economic, and social aspects of ranching and livestock production on California's rangelands and pastures. She completed her Ph.D. in ecology at UC Davis and was a USDA-NIFA Postdoctoral Fellow in the Department of Plant Sciences before joining the faculty in 2015. Leslie's research pursuits include rangeland and pasture management, ecology of grazing lands, grazing systems, drought and climate change adaptation and participatory research methodologies.

Presentation title: "Grazing management for healthy soils."

Suggested references:

Briske D. D., J. D. Derner, D. G. Milchunas, and K. W. Tate 2011. An evidence-based assessment of prescribed grazing practices. In: D. D. Briske [ed.]. Conservation benefits of rangeland practices: assessment, recommendations, and knowledge gaps. Washington, DC, USA: USDA-NRCS. p. 21–74.

George, M.R., R.D. Jackson, C.S. Boyd and K.W. Tate. 2011. A scientific assessment of riparian management practices. In: D. D. Briske [ed.]. Conservation benefits of rangeland practices: assessment, recommendations, and knowledge gaps. Washington, DC, USA: USDA-NRCS. p. 21–74.

Eastburn, D.J., A.T. O'Geen, K.W. Tate and L.M. Roche. 2017. Multiple ecosystem services in working landscape. PLoS ONE 12(3): e0166595.

Roche, L.M., A.T. O'Geen, A.M. Latimer, D.J. Eastburn. 2014. Montane meadow hydropedology, plant community, and herbivore dynamics. Ecosphere 5:art150.

Joel Brown

Since 1998 Joel Brown has been a Cooperating Scientist and Rangeland Ecologist with the NRCS at the Jornada Experimental Range, Las Cruces, New Mexico. He is also an Adjunct Professor in the Department of Animal and Range Sciences, New Mexico State University, Las Cruces. Joel too held the position of the California NRCS State Range Conservationist before moving on to international rangeland research in Australia and then was assigned as the Special Assistant to the Chief for Global Change with NRCS. Joel's research interests include Rangeland ecology, application of state and transition models to rangelands, rangeland soil carbon dynamics, shrub invasion, grazing systems, effects of climate change on rangelands and adoption of management practices on rangelands.

Presentation title: "A national perspective on rangeland soil health and why we should care."

Suggested references:

Briske, D.D., L.A. Joyce, H.W. Polley, J.R. Brown, K. Wolter, J.A. Morgan, B.A. McCarl and D.W. Bailey. 2015. Climate-change adaptation on rangelands: Linking regional exposure with diverse adaptive capacity. Frontiers in Ecology and the Environment. Volume 13, Issue 5, p.249-256.

MacLeod, N. and J.R. Brown. 2014. Valuing and rewarding ecosystem services from rangelands Rangelands. Volume 36, Issue 2, p.12-19.

Herrick, J.E., J.R. Brown, B. Bestelmeyer, S.S. Andrews, G. Baldi, J. Davies, M.C. Duniway, K.M. Havstad, J.W. Karl, D.L. Karlen, D. Peters, J.N. Quinton, C. Riginos, P.L. Shaver, D. Steinaker and S. Twomlow. 2012. Revolutionary land use change in the 21st century: Is (rangeland) science relevant? Rangeland Ecology and Management. Volume 65, p.590-598.

David Kelley

David Kelley has been a consultant on soil and plant science, rangeland ecology and management, land use and environmental resource issues, and arboricultural and agricultural matters for over 35 years. He is a registered professional soil scientist and a certified arborist. As president and founder (1981) of Kelley & Associates Environmental Sciences, Inc., a private consulting firm, and as president of Tuscan, Inc., a non-profit foundation formed (in 1991) to hold grazing land and wildland conservation easements and to manage and protect wildlands for educational and research purposes, he has had the opportunity to oversee the implementation and completion of many large agricultural and development projects and the development of agricultural and rangeland preserves in California. He has worked on many projects in the Great Central Valley, the Salinas and Napa Valleys, the California Coast, and the Sacramento-San Joaquin Delta and adjacent counties, on projects ranging from rangeland management issues and large-scale wildlife habitat restoration, to agricultural development and analyses of damages and claims on rangeland sites. His work has included agricultural development, wetlands, and rangeland projects in Peru, Mexico, Belize, Venezuela, Hong Kong, and other countries. He has taught plant physiology and rangeland ecology at the university level (the University of California-Davis and Humboldt State University), and frequently lectures at universities and colleges throughout the state. He teaches professional short courses on soils, ecology, and arboriculture on a regular basis.

Morgan Doran

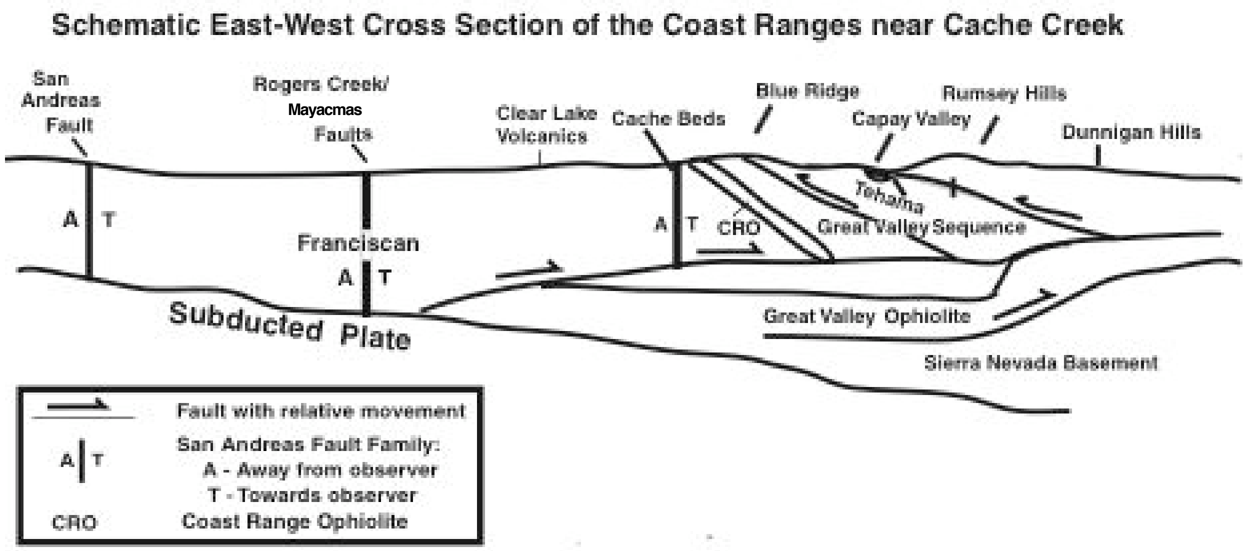
Since 2001 Morgan has been a Livestock & Natural Resources Advisor for UC Cooperative Extension covering Napa, Solano, Yolo and Sacramento counties. Much of his work in Cooperative Extension has focused on rangeland management and the use of livestock for specific vegetation management objectives in range and croplands. Other work includes invasive weed control, oak recruitment strategies, water quality, niche meat marketing, and grazing management systems. Morgan is the current past-president for the California-Pacific Section of Society for Range Management and has co-organized this workshop and tour with David Kelley.

On the Geology of Cache Creek

Eldridge Moores

Cache Creek lies within the southeastern part of the northern California Coast Ranges, a region internationally famous among geologists for its spectacular exposures of rocks formed at a tectonic plate margin. While much Cache Creek geology is observable from the hillsides or roads, some dramatic aspects are best seen from a raft floating down the creek.

Some 200 million years ago, nothing existed in the Cache Creek region except deep ocean water. The edge of North America was a convergent plate margin (subduction zone) located somewhere in the central Sierra Nevada. Some distance to the west was a chain of islands, which migrated into and collided with North America about 160–175 million years ago, forming the rocks now present in the western Sierra foothills and also deep beneath the Great Valley itself. The western margin of North America shifted to the present Coast Ranges, where a new subduction zone developed. As various oceanic plates descended beneath North America, material was scraped off to form the assemblage of diverse rocks called the "Franciscan Complex," approximately 15–150 million years old. Subduction caused the development of magma deep within the Earth, which rose to form the Sierra Nevada granites. Between the Franciscan and the Sierra Nevada, a deep basin developed, in which a very thick sequence of sediments, called the Great Valley Sequence, some 50–150 million years old, were laid down on top of older oceanic crust, called the Coast Range or Great Valley Ophiolite. Ophiolites are thought to represent oceanic crust and mantle formed at oceanic spreading centers. (Peridotites, or silicate rocks rich in magnesium and iron, form the lower part of ophiolites, and volcanic rocks the top. Add water to peridotite and it becomes serpentine, the California State Rock.



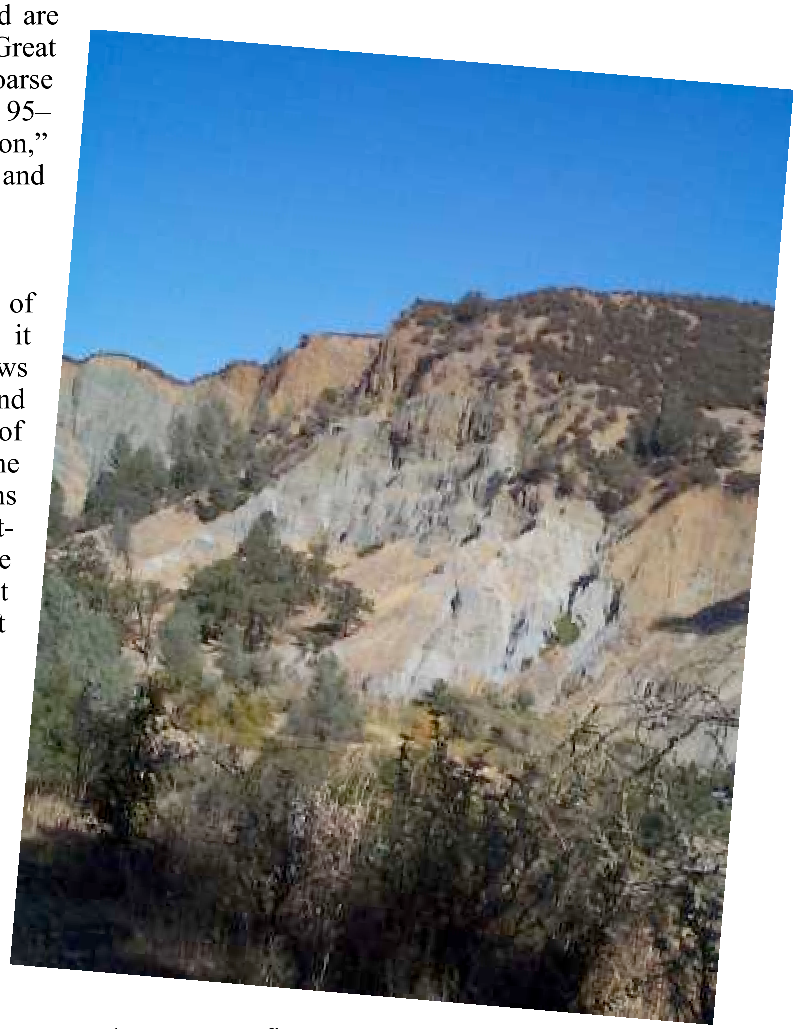
In central California, the present plate boundary comprises the San Andreas "transform fault" boundary, along which the Pacific Plate moves northwest with respect to the North American plate. This family of active faults includes the San Andreas fault itself, the Hayward fault in the East Bay, the Rogers Creek/ Mayacmas faults west of Napa Valley, the Bartlett Springs fault extending from just north of Clear Lake to near Cape Mendocino, and several smaller potentially active faults in the Cache Creek region—called the Wilson, Kennedy, and Dunsfield faults. Activity on the San Andreas fault system began about 30 million years ago and continues today.

In the Cache Creek watershed, the Franciscan complex is visible in roadcuts on Highway 20 along the north shore of Clear Lake and south of Indian Valley Dam. The Coast Range ophiolite is represented by serpentine along Highway 20 a mile or so west of Highway 16 and around the northern part of Indian Valley Reservoir. The northern end of a large area of exposed Coast Range Ophiolite crosses Cache Creek about a mile upstream from the North Fork mouth. The Great Valley Sequence comprises most of the rocks in Cache Creek Canyon, forming spectacular exposures of nearly vertical beds of the originally horizontal sediments. These sedimentary rocks are steeply tilted up along the entire length of the western side of the Sacramento Valley, and near Cache Creek they are folded, highly deformed, and cut by several subhorizontal potentially active faults.

Lying over these older rocks are the 1–3 million year old Cache Beds and the 10,000–2.5 million year old Clear Lake volcanic rocks. The Cache Beds, poorly cemented deposits of streams and lakes, are present along Highway 20 near the North Fork of Cache Creek. Clear Lake volcanic rocks are present along the eastern and southern sides of Clear Lake. Conical Mount Konocti just southwest of Clear Lake last erupted about 10,000 years ago.

The age of uplift of the eastern Coast Ranges—culminating in the Blue Ridge—is quite recent, and continues today. The Coast Ranges are moving slowly eastward towards the Great Valley, with active or potentially active faults producing ridges such as the Rumsey Hills, the Dunnigan Hills, and Blue Ridge itself. Cache Creek itself, with its pronounced bends or meanders in its steep gorge, is older than the uplift of Blue Ridge.

For rafting fans the "Wild Stretch" of the North Fork of Cache Creek and Cache Creek immediately downstream, first runs through tilted strata of the Cache Creek Beds and then highly deformed, generally steeply tilted rocks of the Great Valley Sequence near the potentially active Wilson, Kennedy, and Dunfield faults. These faults intersect a mile or so west of the rafter's put-in known as "Buck Island." The Wilson fault runs along Cache Creek on the north side of Wilson Valley, and the Kennedy fault runs through Kennedy Flats, a wide area along the Creek. Exposures from "Buck Island" downstream to the Low Water Bridge on Rayhouse Road are in mostly steeply tilted rocks of the Great Valley sequence. A thick, resistant, coarse sandstone and conglomerate unit, the 95–100 million year old "Venado formation," overlies a potentially active fault and forms the high Blue Ridge.

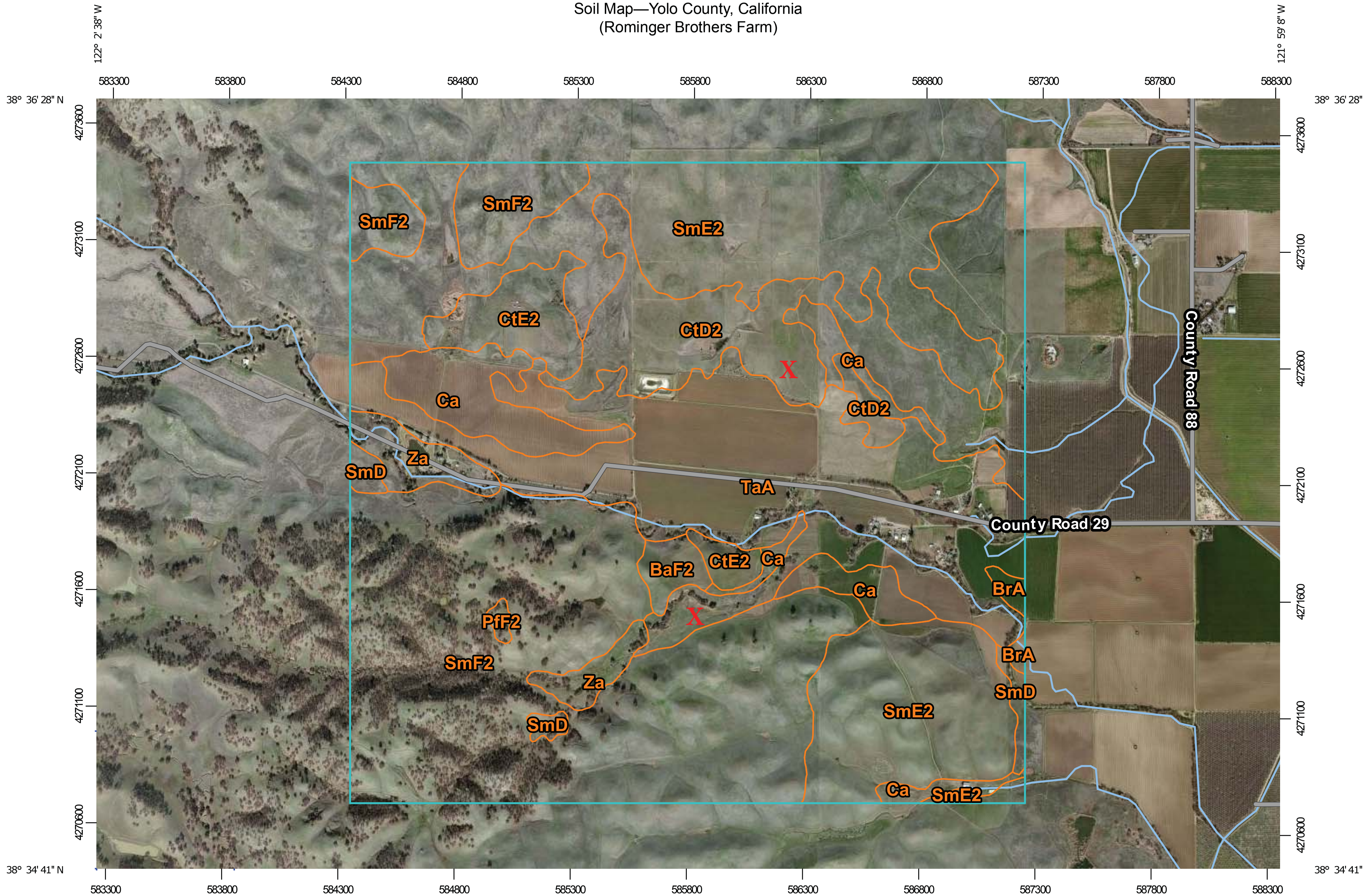


Cache Creek continues through rocks of the Great Valley Sequence until it reaches Capay Valley. There it flows over both Great Valley rocks and 100,000 to 2 million-year-old gravels of the Tehama formation (including the "Blue Cliffs" near Rumsey). Streams depositing these gravels flowed eastward from the Coast Ranges toward the Great Valley; they herald the first geologic evidence of widespread uplift of the Coast Ranges.

Landslides are abundant on the steep slopes along Cache Creek Canyon. A 1990 map by Michael Manson of the California Geological Survey shows nearly 100 landslides between Clear Lake and Capay Valley. Landslides form nearly half the canyon slope just west of Blue Ridge. One landslide occurred about two weeks after the 1906 earthquake, dammed the stream, and gave way five days later, flooding and badly damaging the town of Rumsey.

Thus Cache Creek captures the history of the northern California Coast ranges in its rocks and faults. To drive the canyon or float down the creek is to witness the drama of 150 million years of Earth's history and continuing activity.

Soil Map—Yolo County, California
(Rominger Brothers Farm)



Map Scale: 1:23,300 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 300, 600, 1200, 1800

Feet: 0, 1000, 2000, 4000, 6000

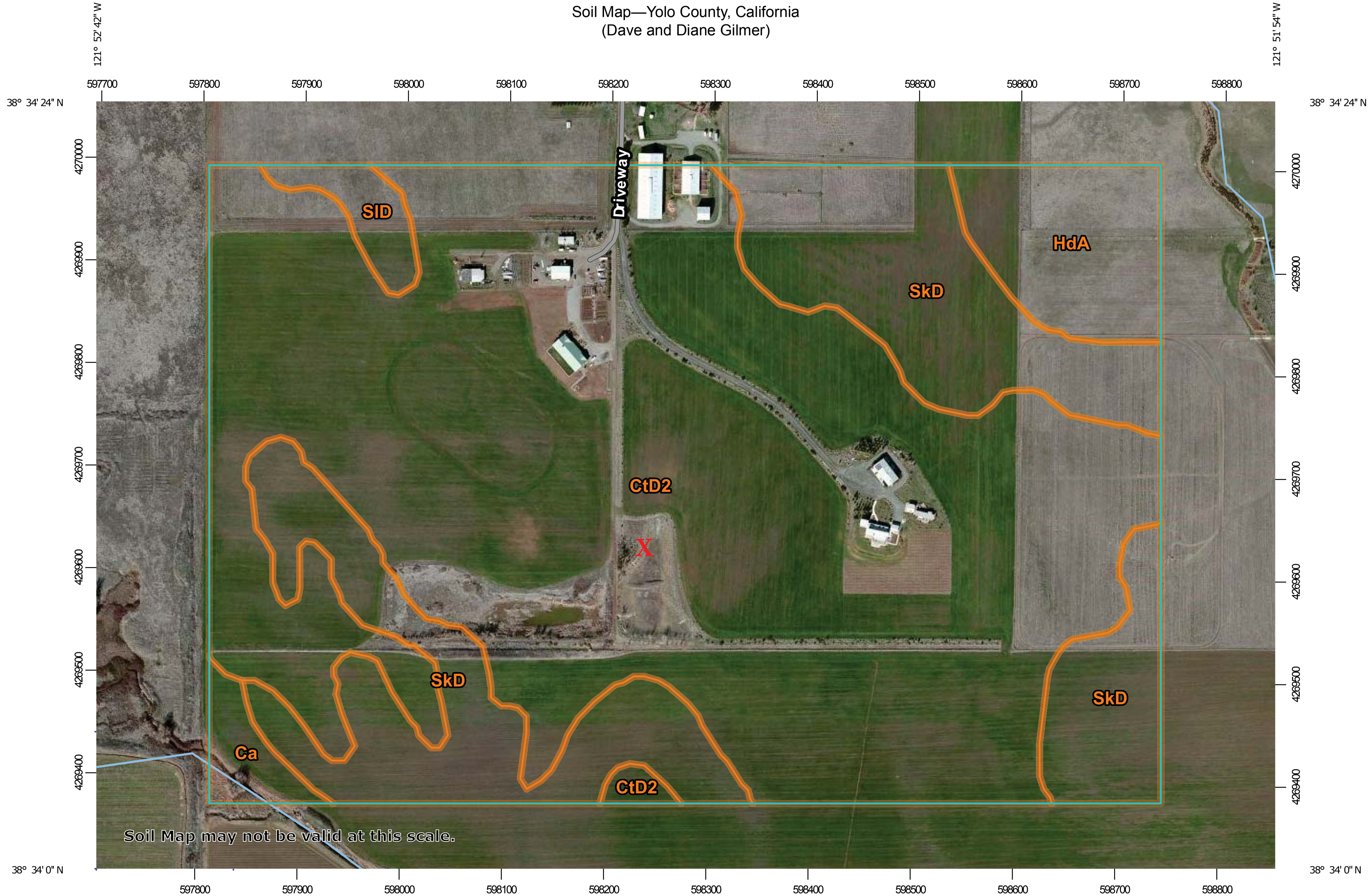
N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

Map Unit Legend

Yolo County, California (CA113)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
BaF2	Balcom silty clay loam, 30 to 50 percent slopes, eroded	15.8	0.8%
BrA	Brentwood silty clay loam, 0 to 2 percent slopes	7.0	0.4%
Ca	Capay silty clay	113.7	5.7%
CtD2	Corning gravelly loam, 2 to 15 percent slopes, eroded	247.5	12.5%
CtE2	Corning gravelly loam, 15 to 30 percent slopes, eroded	60.3	3.0%
PfF2	Positas gravelly loam, 30 to 50 percent slopes, eroded	3.3	0.2%
SmD	Sehorn-Balcom complex, 2 to 15 percent slopes	17.1	0.9%
SmE2	Sehorn-Balcom complex, 15 to 30 percent slopes, eroded	485.4	24.5%
SmF2	Sehorn-Balcom complex, 30 to 50 percent slopes, eroded	606.5	30.6%
TaA	Tehama loam, 0 to 2 percent slopes, loamy substratum, MLRA 17	376.2	19.0%
Za	Zamora loam	46.2	2.3%
Totals for Area of Interest		**1,979.2**	**100.0%**

Soil Map—Yolo County, California
(Dave and Diane Gilmer)



Map Scale: 1:5,270 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 50, 100, 200, 300

Feet: 0, 250, 500, 1000, 1500

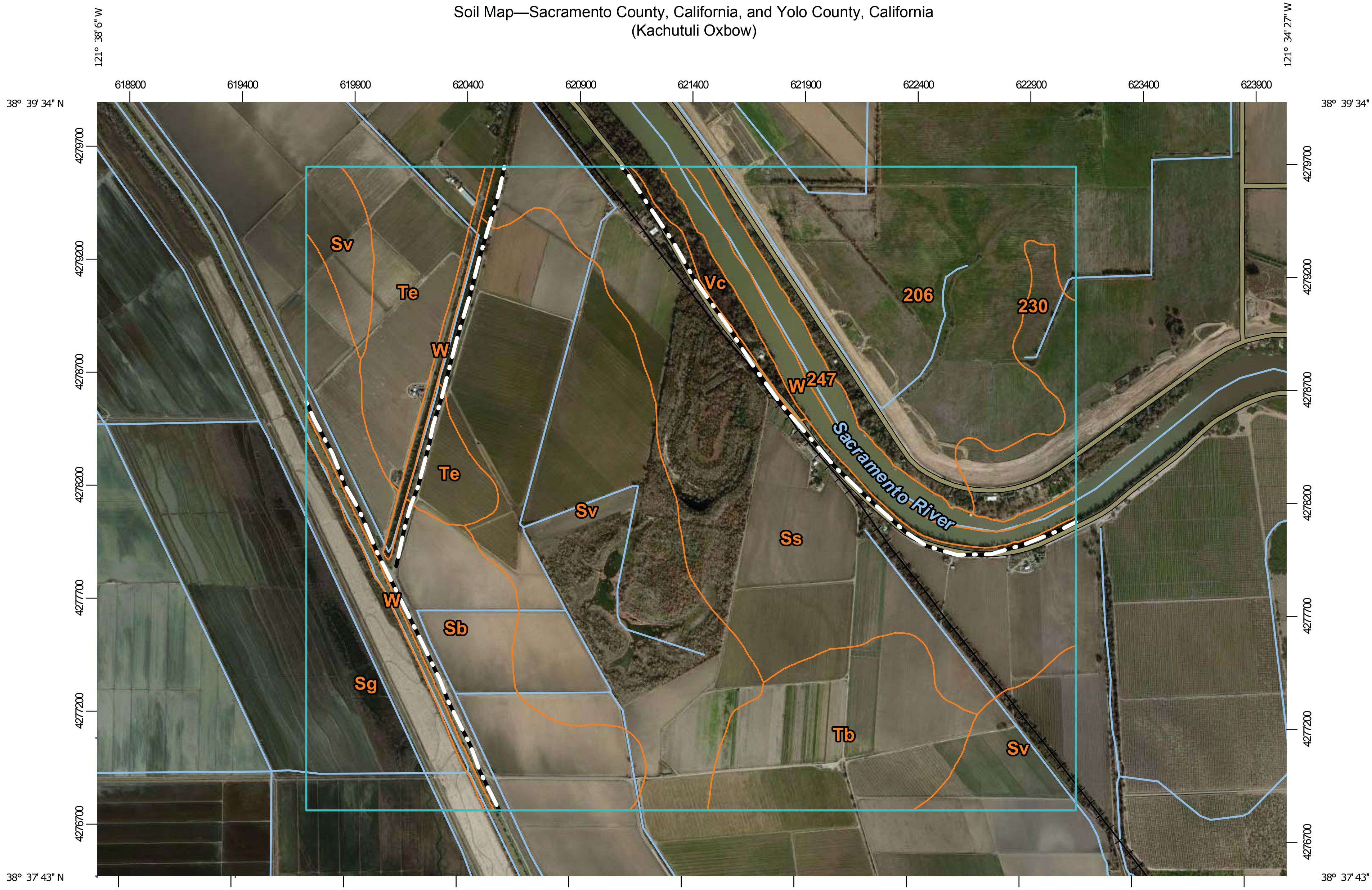
N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

Map Unit Legend

Yolo County, California (CA113)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Ca	Capay silty clay	1.9	1.4%
CtD2	Corning gravelly loam, 2 to 15 percent slopes, eroded	99.4	69.2%
HdA	Hillgate loam, moderately deep, 0 to 2 percent slopes	7.2	5.0%
SkD	Sehorn clay, 2 to 15 percent slopes	33.2	23.1%
SlD	Sehorn cobbly clay, 2 to 15 percent slopes	2.0	1.4%
Totals for Area of Interest		**143.7**	**100.0%**

Soil Map—Sacramento County, California, and Yolo County, California
(Kachutuli Oxbow)



Map Scale: 1:24,200 if printed on A landscape (11" x 8.5") sheet.

N

0 350 700 1400 2100 Meters

0 1000 2000 4000 6000 Feet

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

Map Unit Legend

Sacramento County, California (CA067)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
206	Sailboat silt loam, partially drained, 0 to 2 percent slopes	364.9	15.1%
230	Valpac loam, partially drained, 0 to 2 percent slopes	72.5	3.0%
247	Water	53.4	2.2%
Subtotals for Soil Survey Area		**490.9**	**20.3%**
Totals for Area of Interest		**2,415.8**	**100.0%**

Yolo County, California (CA113)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Sb	Sacramento silty clay loam, drained	230.3	9.5%
Sg	Sacramento soils, flooded	166.5	6.9%
Ss	Sycamore silty clay loam	486.9	20.2%
Sv	Sycamore complex, drained	606.2	25.1%
Tb	Tyndall very fine sandy loam	167.9	6.9%
Te	Tyndall very fine sandy loam, deep	150.8	6.2%
Vc	Valdez complex, flooded	26.6	1.1%
W	Water	89.8	3.7%
Subtotals for Soil Survey Area		**1,924.9**	**79.7%**
Totals for Area of Interest		**2,415.8**	**100.0%**