Ukiah Valley Groundwater Basin Watershed Plan

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Ca. Dept of Conservation
Sustainable Groundwater Management Watershed Coordinator Program

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INTRODUCTION

The California Land Stewardship Institute (CLSI) is a non-profit organization that has had a major role in working with the agricultural community on water issues in the Ukiah Valley through a number of our programs and projects. Our Fish Friendly Farming Certification program has assessed water quality water rights and habitats on farms since 1999 and prepared and certified farm plans. CLSI administers the Russian River Frost program in the Mendocino portion of the Russian River. CLSI has implemented numerous projects with local growers and cities including building over 12 large off stream ponds to reduce direct diversion during frost events. CLSI successfully applied for grant funding for development of the infrastructure needed to distribute tertiary recycled water from the City of Ukiah wastewater plant to farmers.

In 2020 CLSI received approval of a grant from the Department of Conservation for a Sustainable Groundwater Management Watershed Coordinator for the watershed of the Ukiah Valley Groundwater Basi. This grant includes a number of tasks: working with the Ukiah Valley Groundwater Sustainability Agency (GSA) to increase community involvement in the preparation of the Groundwater Sustainability Plan (GSP), complete surface and groundwater monitoring, and completion of a watershed plan. The watershed plan evaluates: potential groundwater recharge locations, tributary creek revegetation sites, fire/fuel reduction projects, agricultural water infrastructure improvements and potential urban creek and stormwater improvements.

THE UKIAH GROUNDWATER BASIN WATERSHED

General Description

The Russian River watershed (Figure 1) is about 1,485 square miles, spanning across rugged mountainous terrain and river valleys of Mendocino and Sonoma Counties. The Russian River flows from north to south for 110 miles before it veers west, cuts through the Sonoma County coastal mountains, and drains into the Pacific Ocean. It supports a diverse agricultural, industrial, recreational, and wine tourism economy.

The "upper Russian River watershed" (Figure 1) described herein refers to the extent of the watershed affecting the Ukiah Valley groundwater basin (Figure 2). The upper Russian River watershed begins at its northernmost headwaters, drains into the West Fork Russian River, joins the East Fork Russian River north of the City of Ukiah and extends south to the confluence of McNab Creek. The Ukiah and Redwood Valleys here follow a roughly north-south orientation with rugged mountainous terrain to the east and west.

In the Potter Valley to the northeast (Figure 1) surface water is diverted from the Eel River into the East Fork of the Russian River and eventually is impounded in Lake Mendocino. However, large mountains separate Potter Valley's groundwater basin (Figure 2) from the Ukiah Valley groundwater basin. The Sanel Valley groundwater basin is located to the south of Ukiah Valley (Figure 2).

The Ukiah Valley Groundwater Basin Watershed Plan contains the following chapters:

1. Groundwater Recharge – Thie chapter includes a description of the geology and climate of the Ukiah basin, a summary of the Ukiah Valley Groundwater Sustainability Plan (GSP) and analyses of a series of potential recharge project sites, prioritization of the sites and conceptual designs for the priority sites.

2. Stream Revegetation – This chapter includes a description of the geomorphology of creeks in the watershed, the riparian ecosystem, historic conditions and changes, revegetation practices, high priority creek reaches for revegetation and conceptual designs for priority sites.

3. Fire Prevention and Fuel Load Reduction – This chapter describes the features of the watershed – rainfall, vegetation and topography, historic fires and natural fire regimes, the effects of wildfire on watershed hydrology, erosion and air quality, CalFire modeling of fire hazards and risks, modeled effects of climate change on local fire conditions and potential projects.

4. Agricultural Water Supply – This chapter describes the surface and groundwater supply for agriculture, summary of water rights, projected changes to agricultural water supply with the elimination of the Potter Valley Project (PVP) and potential projects to provide needed infrastructure.

5. Urban Stormwater – This chapter describes the potential effects of urban runoff from the City of Ukiah and rural residential areas on water quality and creeks and describes potential projects

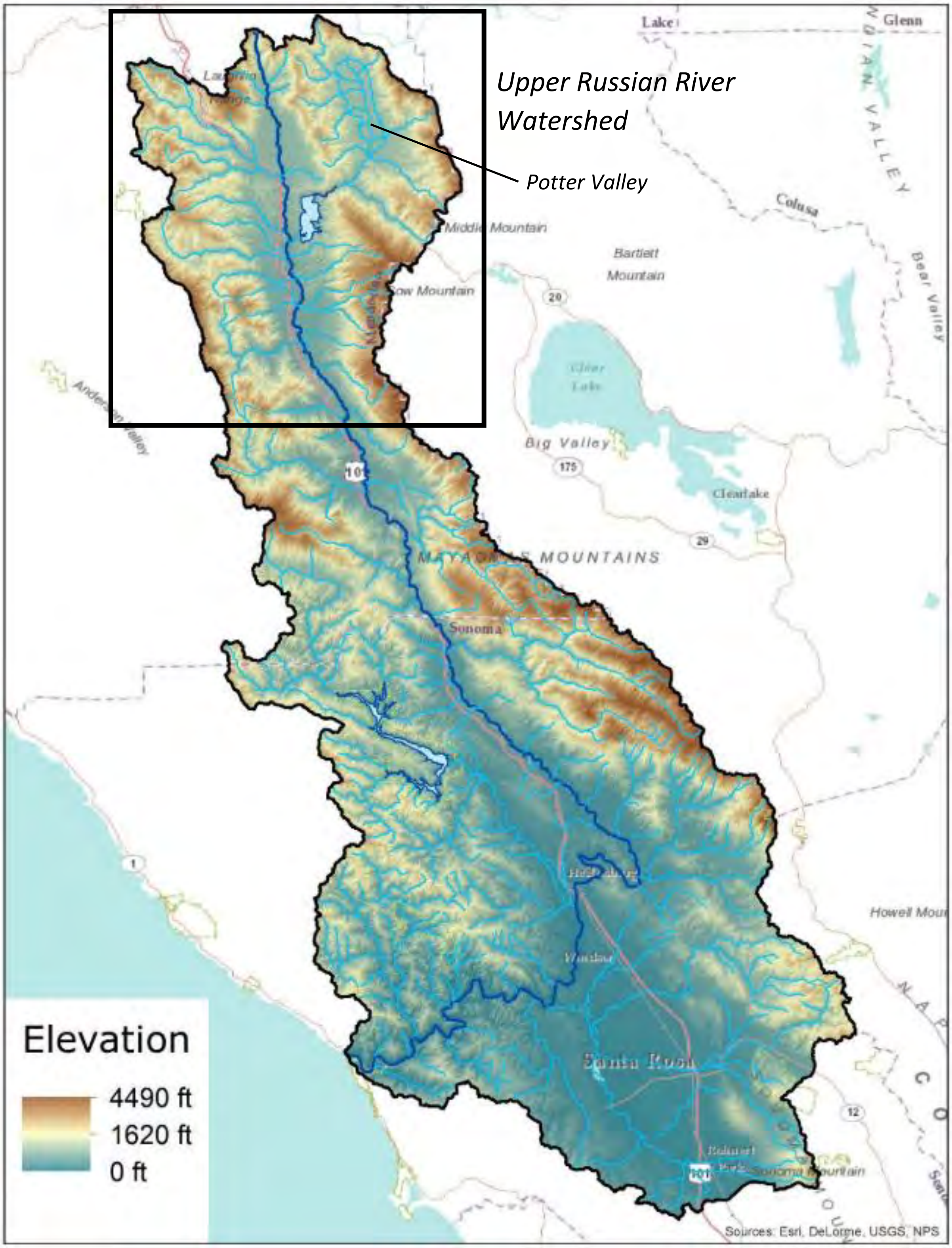


Figure 1. The Russian River Watershed (ISRP 2014).

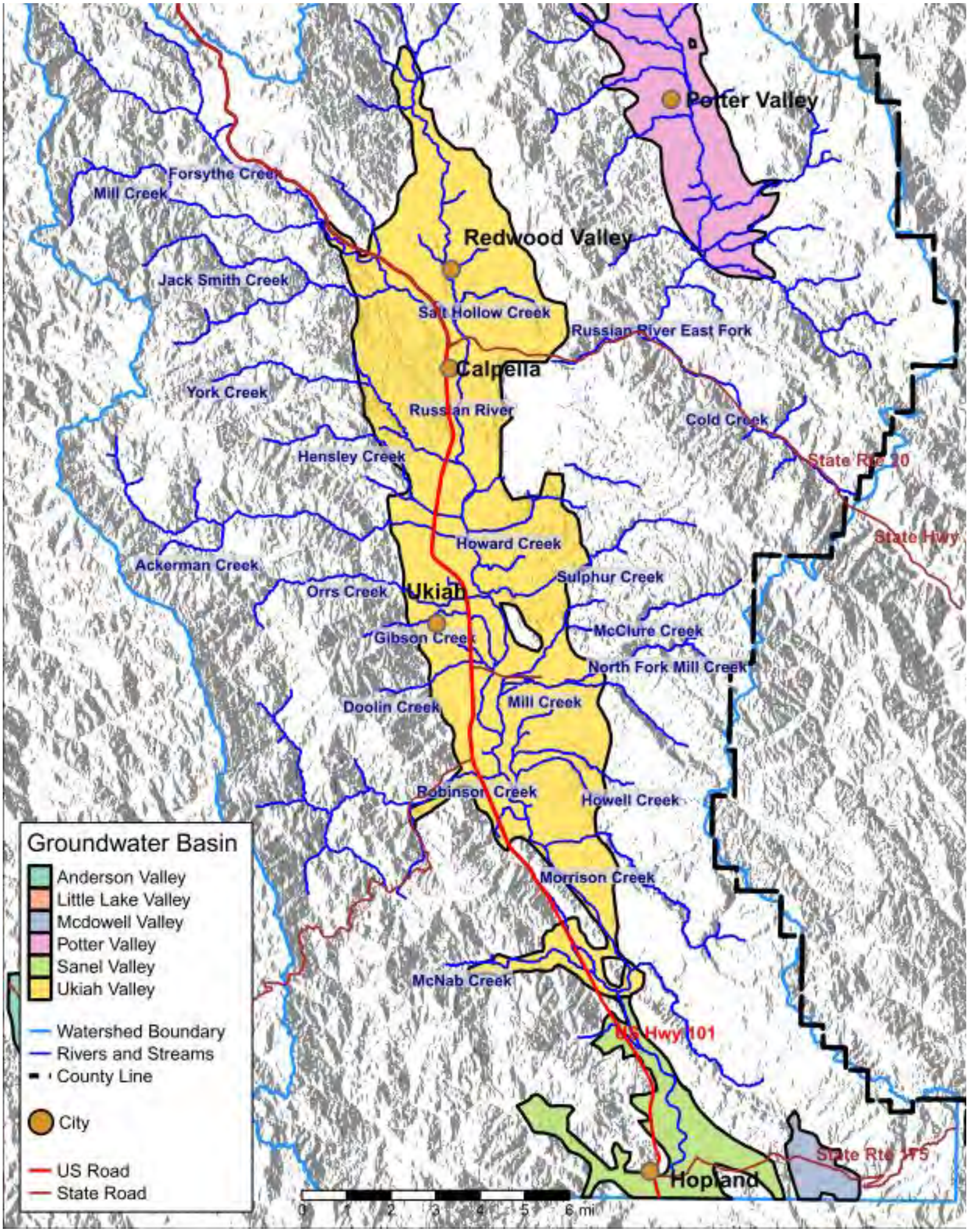


Figure 2. The Ukiah Valley groundwater basin (Ukiah Valley Basin Groundwater Sustainability Agency, 2021).

I. GROUNDWATER RECHARGE

Geology

Geology is a primary determinant of where groundwater basins will occur. The Ukiah and Redwood Valleys were formed by fault blocks of the San Andreas system moving at different rates relative to each other and forming pull-apart basins (Figures 3 and 4). Sediment eroded from the surrounding mountains and transported by streams and debris flows filled the pull-apart basins and created alluvial deposits that store groundwater. The active Maacama Fault dissects the region from the western mountains in the north, crosses the Russian River south of the East and West Fork confluence, then extends down the east side of the valley (ISRP 2014).

Figure 5 depicts the surface rock types of the watershed. Franciscan Complex (Jurassic and Cretaceous) makes up the mountains that surround the Ukiah Valley and form the underlying basement/bedrock of the groundwater basin. Franciscan Complex is highly erodible with low permeability, and is considered non-water bearing. Franciscan Complex is an assemblage of sandstone, greywacke, shale, mélange, conglomerate, chert, greenstone and serpentinite that accumulated between 200 to 50 million years ago along the subduction trench between the Pacific and North American tectonic plates. The Franciscan Complex compressed along the boundary between the two plates, then folded, faulted, mixed and finally uplifted to create mountains. This watershed is steep and highly erodible producing large quantities of sediment ranging from small clay particles to large boulders.

The Continental Basin Deposits (Pliocene and Pleistocene) lie atop the Franciscan Complex in the valley, and represent the oldest sedimentary layer that filled the valley. They are composed of poorly consolidated, poorly sorted alluvium with high clay content.

Uplifted terraces to the east and west of the river valley (Pleistocene) are made up of loosely consolidated deposits of gravel, sand, silt, and clay. This layer lies over the Continental Basin Deposits and contains less clay and silt.

Quaternary Alluvium consists of unconsolidated gravel, sand, silt, and small amounts of clay. It is the youngest of the major geologic units and is primarily concentrated in narrow bands along river and creek channels.

Hydrology

Figure 6 and Table 1 depict the hydrologic cycle and the processes of groundwater recharge and infiltration of surface runoff into the ground.

Rainfall in this region occurs between October and April most years. Normal year precipitation averages 45 inches in the north and 35 inches in the south of this watershed. Dry years can have as little as 8 inches of rain while wet years can have up to 76 inches of rain (Figure 7). These figures represent the total rainfall at the location where a rainfall gage is located. However, the volume and timing of rainfall varies greatly from the west to the east side of the watershed and varies by tributary creek basin due to differences in topography.

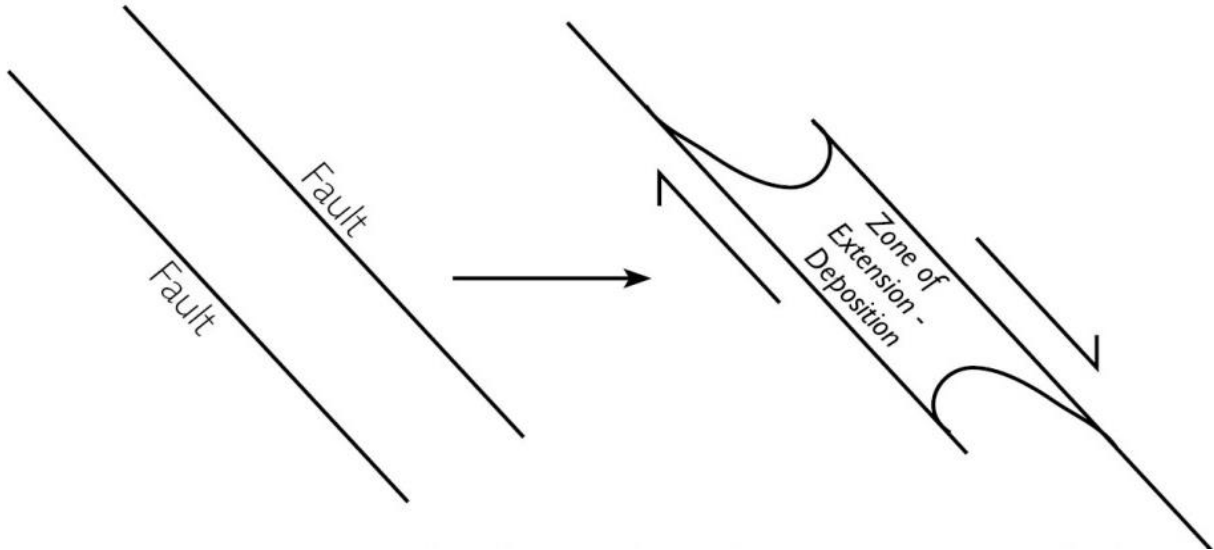


Figure 3. Diagram of pull-apart basin formation along right-lateral slip faults.

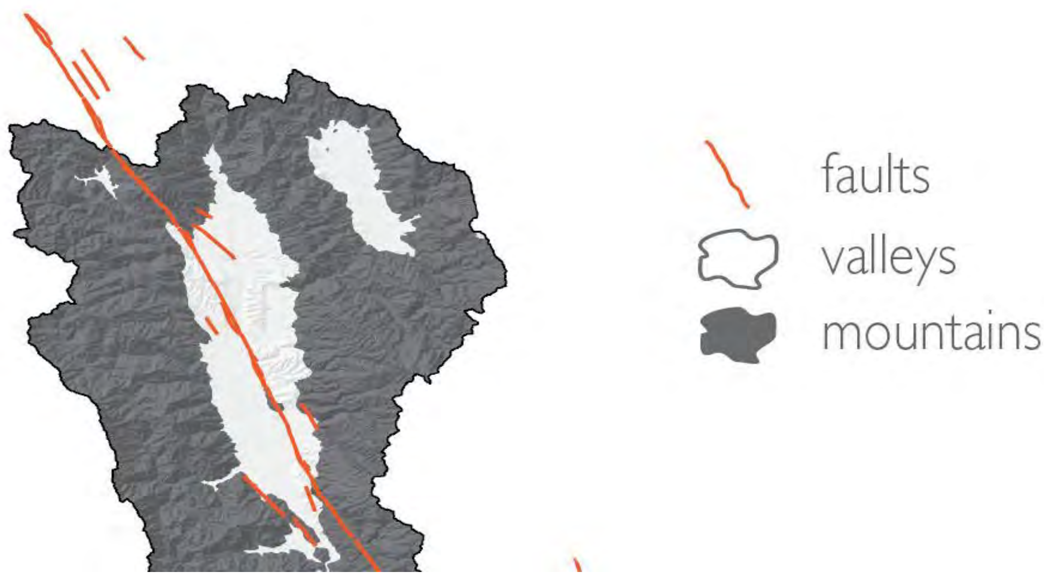


Figure 4. Faults in the Ukiah Valley Groundwater Basin watershed.

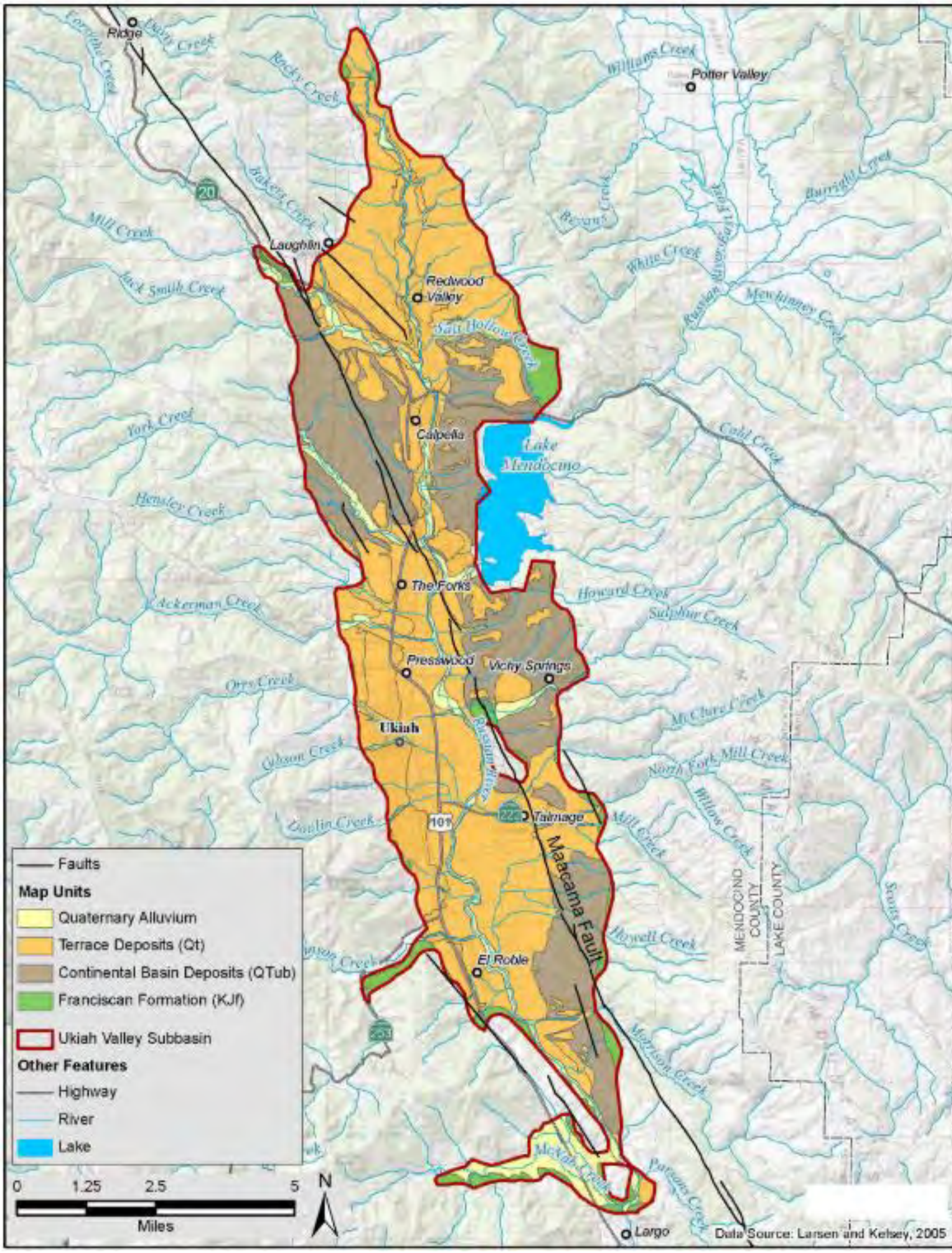


Figure 5. Surficial geology (Ukiah Valley Basin Groundwater Sustainability Agency, 2021).

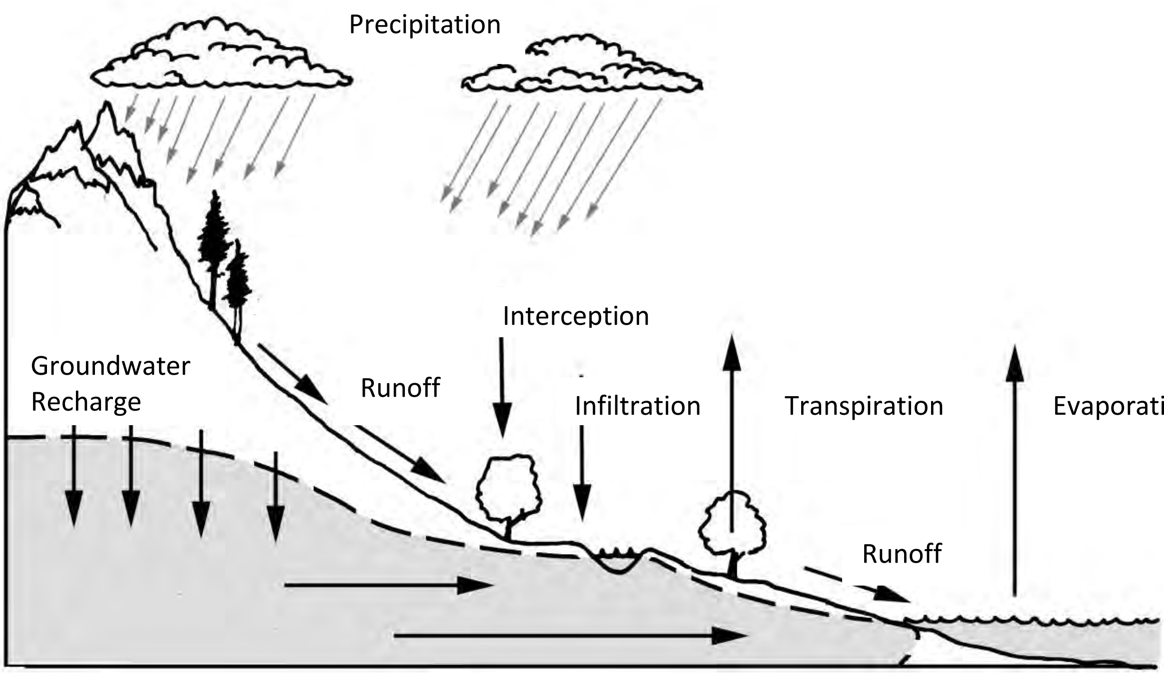


Figure 6. Hydrologic cycle.

Table 1. Hydrologic cycle.

Process	**Watershed Features Affecting Hydrologic Processes**
Precipitation	Topography, proximity to coast, orthographic effect in which rainfall amounts are higher over coastal mountains than the adjacent inland valley
Interception	Vegetative density and type - forests have high interception of rainfall, grassland has low interception
Transpiration	Extent and type of vegetation, temperature and season. For example, riparian vegetation transpires large amounts of water in the summer, but is largely deciduous and leafless in the fall/winter. Native evergreen vegetation such as oaks or conifers is drought tolerant transpiring in the winter and spring and largely shutting down in summer to conserve water.
Evaporation	Temperature, wind, humidity
Infiltration	Geology - rock types with low permeability (Franciscan Complex) have lower infiltration rates than more permeable rocks (alluvium, Sonoma Volcanics). Slope and topography are major factors as is land use and areas of impervious pavement.
Groundwater Recharge	Extent and location of alluvial deposits, cracks and faults in certain rock types determine where water will infiltrate and recharge aquifers. The extent and location of impervious surfaces (urban areas), roads and highly compacted soils are locations where infiltration and groundwater recharge will be reduced.
Runoff	Geology, groundwater storage, surface water storage, vegetative cover, topography and slope, extent and location of impervious surfaces, modification of stream channels - all affect runoff processes.

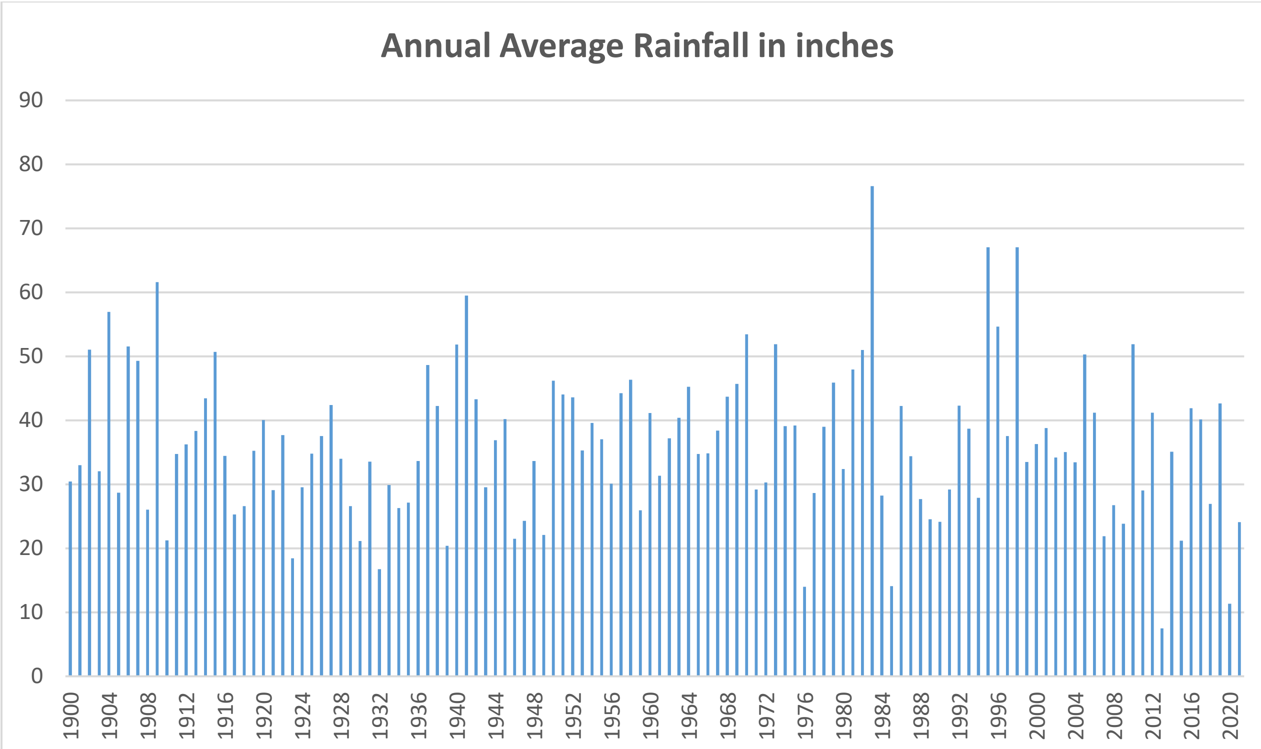


Figure 7. Average annual rainfall 1900-2020 as measured at Weather Station 00023275, Ukiah Municipal Airport.

<u>Ukiah Valley Groundwater Basin</u>

The Ukiah Valley groundwater basin consists of two principal aquifers with a combined holding capacity of 444,000 acre-feet, and covers approximately 59 square miles beneath Redwood Valley and Ukiah Valley. A general characterization of the upper Russian River watershed and its surface/groundwater interactions follows as summarized from the Russian River Independent Science Review Panel Final Report (ISRP 2014).

Surface-Groundwater Interactions

The groundwater basin is recharged in the fall and early winter each year by infiltration of precipitation and runoff from hillslopes and creeks. When groundwater elevation rises higher than the elevation of streambeds, flow occurs in the stream, which continues after storm events have ended as groundwater drains from the alluvium into the channel. As groundwater levels recede below the bottom of the stream channels in the summer, streams dry up

Pre-development, the Russian River had a wide, shallow, possibly braided channel; riparian forest and wetlands covered the floodplain. In the mid 1800s the Russian River was known to run dry during summer months, and likely maintained isolated pools connected by subsurface flow. Historically groundwater likely filled pools in the Russian River and some of the unconfined alluvial portions of its tributaries in the summer during years of average or above average rainfall—however many reaches likely went dry on a regular basis. Bedrock channels on the western slopes likely flowed all year due to cooler foggy conditions, which supports the redwood forest there. Eastern channels may have dried up in the summer.

Most of the West Fork Russian River has an unconfined alluvial channel, and downstream portions of York and Forsythe creek channels also become unconfined alluvial as they cross the valley to meet the main stem. Upstream of the unconfined alluvial portions of Forsythe and York Creeks, the stream networks are primarily confined by bedrock. Bakers Creek, Salt Hollow Creek, Mariposa Creek, and upstream portions of the West Fork Russian River have channels made of dissected alluvium composed of the continental basin deposits. Main stem Russian River is a low slope unconfined alluvial channel (<1%) flowing north to south with occasional meanders for 12 miles through the Ukiah Valley.

Tributaries start as bedrock-confined channels in the mountains and occasionally flow through alluvium where openings and lower gradients occur (Morrison and Robinson are examples of this morphology). McClure and Mill Creeks also have dissected alluvial reaches as they cross the Terrace Deposits. Many streams form alluvial fans as they enter the lower-gradient valley from their steep bedrock channels in the mountains, and all creeks have unconfined alluvial channels as they cross the valley floor to reach the main stem. Much of McNab Creek flows through dissected alluvium, and often has summer pools that sustain during dry years, connected by subsurface flow (ISRP 2014).

The U.S. Geological Survey gage on the West Fork (11461000 Russian River near Ukiah) shows very low flow conditions (0.2-2.5 cfs) from July to October for the 1912 and 1913 records. Rainfall was normal in both of these years.

A 1913 report summarizing water resources in California (USGS 1913) reports gage heights and discharge measurements for the Russian River near Ukiah gage (11461000) on the West Fork. Discharge on 8/8/1911 was 0.5 cfs with a stage reading of 3.12 ft. in the gage pool. These readings represent very low flow with the gage likely located in a pool just over three feet deep. The November 1911 readings were 0.2 cfs and 3.10 ft. stage on 11/2/1911; 0.5 cfs and 3.25 ft. stage on 11/20/1911. The 1912 readings were 510 cfs with a stage of 5.6 feet on 3/6/1912; 3,390 cfs with a stage of 10.35 feet on 3/15/1912; 1,090 cfs with a stage of 6.78 feet on 3/16/1912; 60 cfs with a stage of 4.13 feet on 3/28/1912 and 32 cfs with a stage of 3.85 feet on 4/5/1912. These measurements on the West Fork indicate isolated pools connected by a low level of surface flow.

Discharge measurements made in the East Fork Russian River prior to the Potter Valley Project on 9/21/1905 recorded a 2.2 cfs flow. A discharge measurement on the West Fork on the same day recorded a 1.2 cfs flow. These measurements indicate very low flows (USGS 1913). Discharge measurements on creeks in the Ukiah Valley were done on Ackerman Creek on 11/2/1911 and it was dry near the confluence with the river and on Orr Creek on 11/2/1911 and it was also dry near the mouth. The Ukiah rainfall gage (049122) shows a total of 34.72 inches for 1911. This is slightly below the average annual rainfall of 37.27 inches at this station.

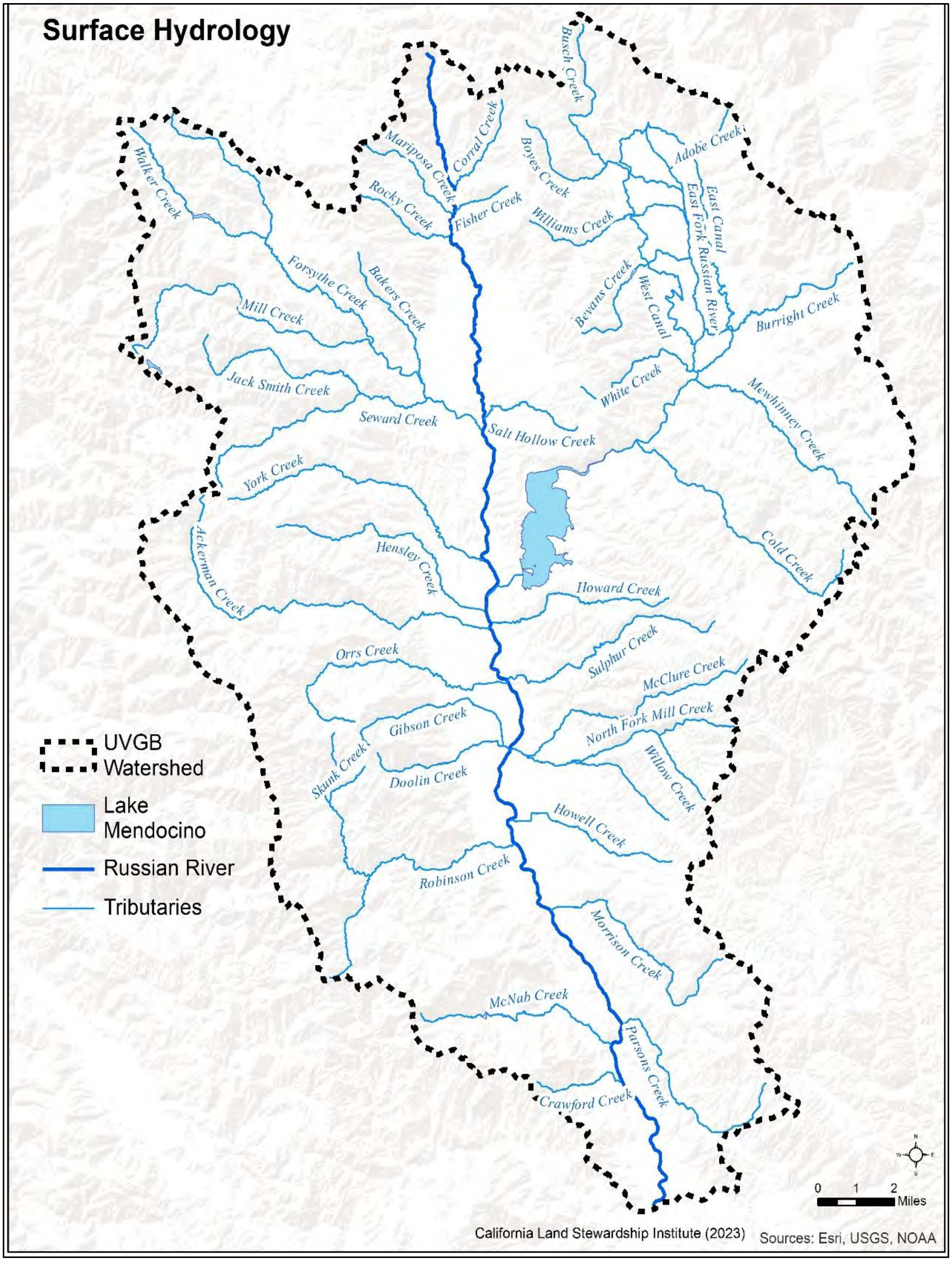


Figure 8. The Watershed of the Ukiah Valley Groundwater Basin (UVGBW).

Land Use, Development, and Major Changes to the Landscape

The Potter Valley Project built in 1908 diverted water from the Eel River into East Fork Russian River via a tunnel to produce hydropower. This significantly increased summer inflows to the Russian River. It also created connected flow where previously isolated pools and dry riverbed occurred. Coyote Dam was constructed by the Army Corps of Engineers in the 1950s to aid in both flood control and water supply, creating Lake Mendocino with a storage capacity of 122,500 acre-feet.

In the 1960s, the Army Corps of Engineers dredged and straightened several reaches of the river, removing vegetation and other barriers stabilized the banks in an attempt to prevent meandering. Gravel mining has occurred in several locations in the Russian River channel, as well as in Forsythe Creek, depleting the river's sediment load.

Currently the City of Ukiah takes up about 4% of the upper Russian River valley with urban land cover. Irrigated farmland makes up about 9%, primarily clustered in the valley. The overwhelming majority of the land area is grazing or forest land, taking up about 85%.

Effects of Major Changes

Channel incision refers to the downcutting of a river channel into alluvium of its bed and banks. The significant alterations to the landscape and hydrology in the upper Russian River watershed has created streamflows that are carrying less sediment, resulting in "sediment-starved" water. The construction of Lake Mendocino cut off the transport of sediment from the East Fork Russian River into the mainstem and is the primary cause of channel incision in the mainstem Russian River.

By 1985 Mendocino County observed that the channel had incised at least 18 feet in the main stem and 10 feet in the West Fork, resulting in a deeply entrenched riverbed absent of critical bedform habitats (riffles, pools, gravel bars) or riparian canopy cover. By 1995 the main stem had entrenched over 20 feet. This creates a disconnect between the river channel and its former floodplain (the valley floor), and a drop in the base level of the river bed that migrates upstream to similarly affect every alluvial tributary and lower the surrounding water table. The mainstem, West Fork, and their tributaries will likely continue to deepen due to inadequate sediment supply. This change will create difficulties for infrastructure, erode private land, erode riparian and aquatic habitats and lower summer groundwater elevations (ISRP 2014). Rapid drops in main stem flow in the onset of the dry season can also cause tributary flow to go subterranean interrupting normal surface flows and stranding fish.

Incision also makes off-stream groundwater recharge options more difficult: the steep banks can necessitate expensive pumping operations, and the channel's lowered base in conjunction with the highly conductive Quaternary Alluvium could drain any off-stream recharge projects as surface flow rather than contribute to the aquifer.

Ukiah Valley Groundwater Sustainability Plan

The Ukiah Valley Groundwater Sustainability Plan (GSP), drafted by the Ukiah Valley Basin Groundwater Sustainability Agency (GSA) draws from a diversity of land and water management agencies to "ensure that sustainable groundwater management in the basin by the GSA is achieved by 2042," (UVBGSA 2021). The following section is excerpted from the GSP.

Sustainable Management Criteria and Undesirable Results

Sustainable management criteria are measurable steps toward a sustainability goal that avoid undesirable results. Undesirable results are defined in the Sustainable Groundwater Management Act

(SGMA)include (1) chronic lowering of groundwater levels, (2) reduction of groundwater storage, (3) seawater intrusion, (4) degraded water quality, (5) land subsidence, (6) depletions of interconnected surface water and (7) effects on groundwater dependent ecosystems. The GSP describes the features of Ukiah Valley groundwater basin including: setting, soils, geology, aquifers, aquitards groundwater recharge and discharge, surface water and data gaps.

Ukiah Valley Aquifers

The Ukiah Valley groundwater basin is split into two aquifers. Aquifer I is the main source and used for all purposes. Aquifer II serves only domestic water supply due to its limited yield.

Aquifer I, the primary production aquifer, has about 60,000 – 120,000 acre-feet of storage capacity in portions of the Quaternary Alluvium that consists of highly permeable unconsolidated sands and gravels. The Quaternary Alluvium is mostly constrained to small bands along river channels, with a depth and thickness increases from north to south, and high hydraulic conductivity that decreases with distance from river channels into older deposits. Its lack of cementation and low clay content keeps it hydraulically connected with adjacent rivers, and groundwater elevations fluctuate seasonally but fully recharge each year. Aquifer I is unconfined, and overlies or is adjacent to the less conductive Aquifer II.

Aquifer II has a capacity of 324,000 acre-feet, and is composed of Terrace Deposits and Continental Basin Deposits consisting of moderately cemented sand and gravels interspersed with thick clay layers. It generally has low conductivity, low permeability, and low well yields, but slowly recharges from precipitation at surface outcrops, basin margins, and through bedrock fractures in the Franciscan Complex.

The two aquifers are hydraulically connected, but are considered distinct due to their significantly differing hydraulic conductivities. The groundwater basin is fully replenished each year from precipitation recharge and stream flow. No significant aquitards are known, but sporadic clay layers interspersed in the Continental Basin Deposits cause some perched water and restrict flow. Primary groundwater uses are irrigation, domestic, and municipal use.

Regional geologic trends observed from cross sections (Figures 9–12) include a slight increase in depth to bedrock from north to south, and the area of quaternary alluvium increasing from north to south.

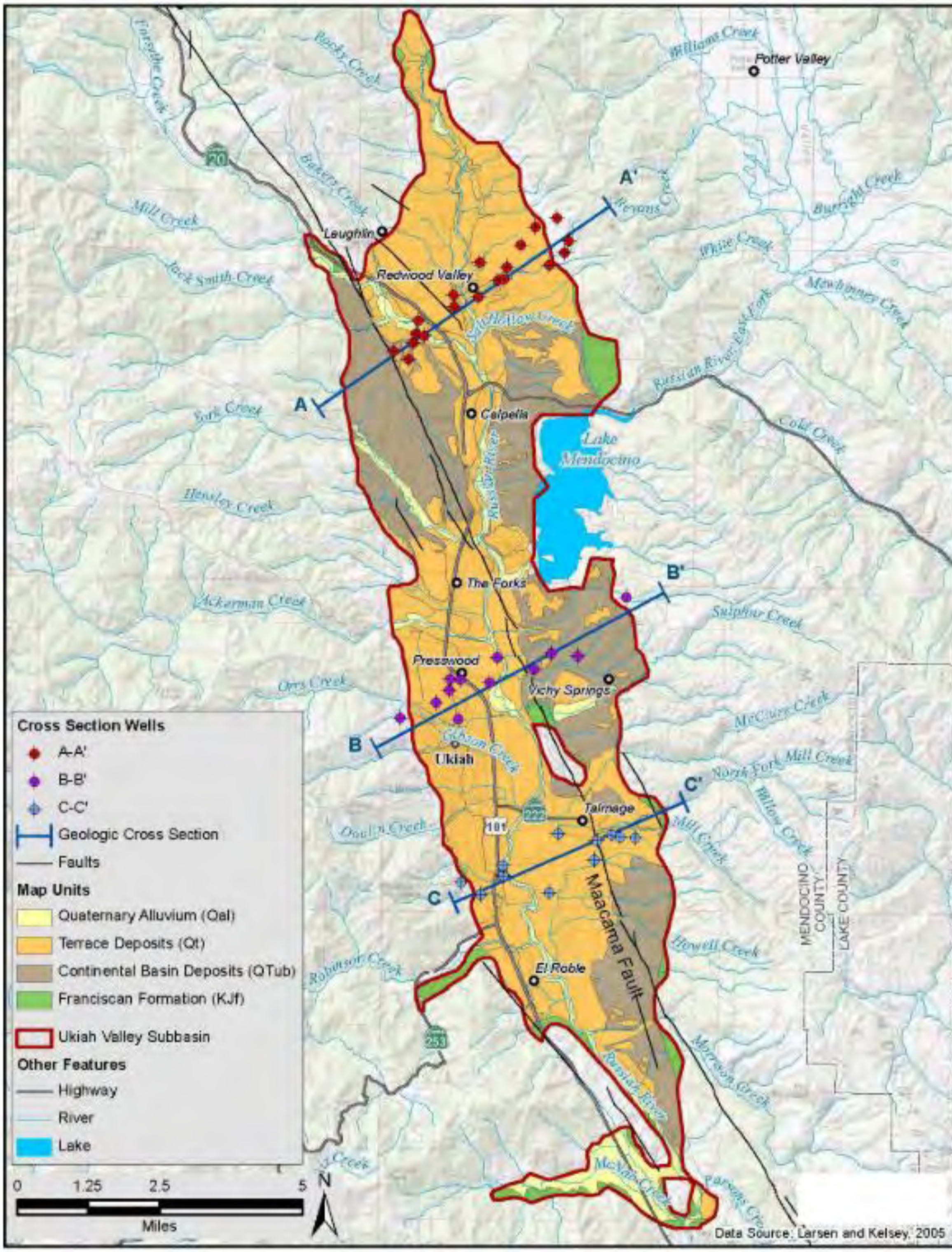


Figure 9. Major geologic units with cross sections locations (Ukiah Valley Basin Groundwater Sustainability Agency, 2021).

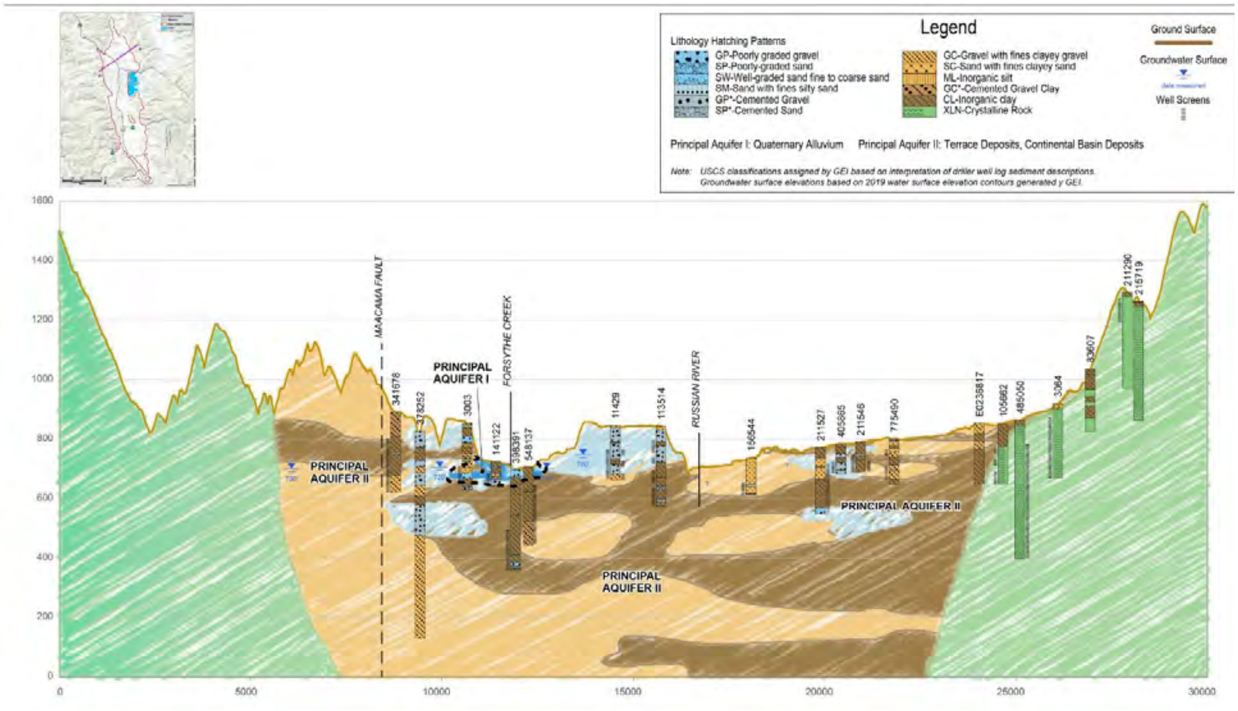


Figure 10. Cross section A (Ukiah Valley Basin Groundwater Sustainability Agency 2021).

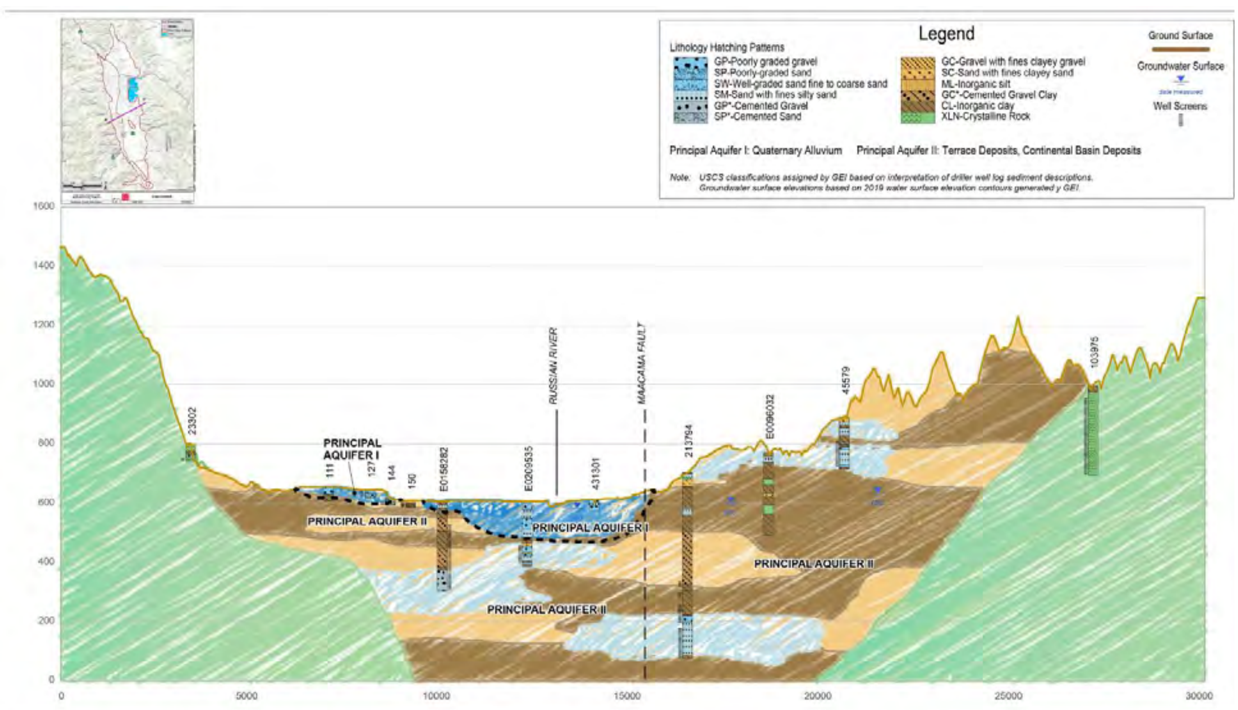


Figure 11. Cross section B (Ukiah Valley Basin Groundwater Sustainability Agency 2021).

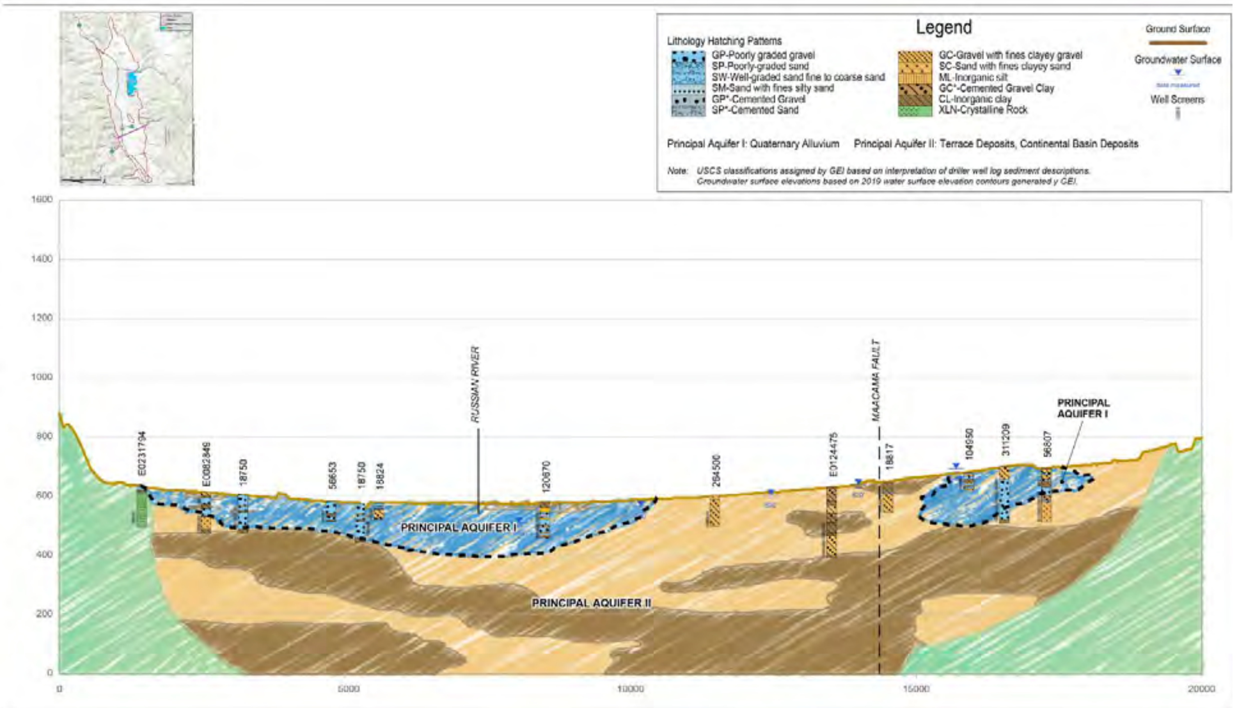


Figure 12. Cross section C (Ukiah Valley Basin Groundwater Sustainability Agency 2021).

Recharge, Discharge, and Flow

The GSP identifies potential areas of recharge and discharge by plotting soils with high infiltration potential and modeling groundwater contours to evaluate flow. Soils in Hydrologic Group A are considered regions of potential recharge/discharge. The location of potential recharge areas identified by soils in Hydrologic Group A corroborate findings in the literature that these soils tend to occur in coarse to slightly weathered alluvium with low clay content at current or historic river channels. Groundwater elevation contours (Figure 13) illustrate a general north-south flow, toward the Russian River, with lowest gradients in the alluvium and highest in the less permeable uplands.

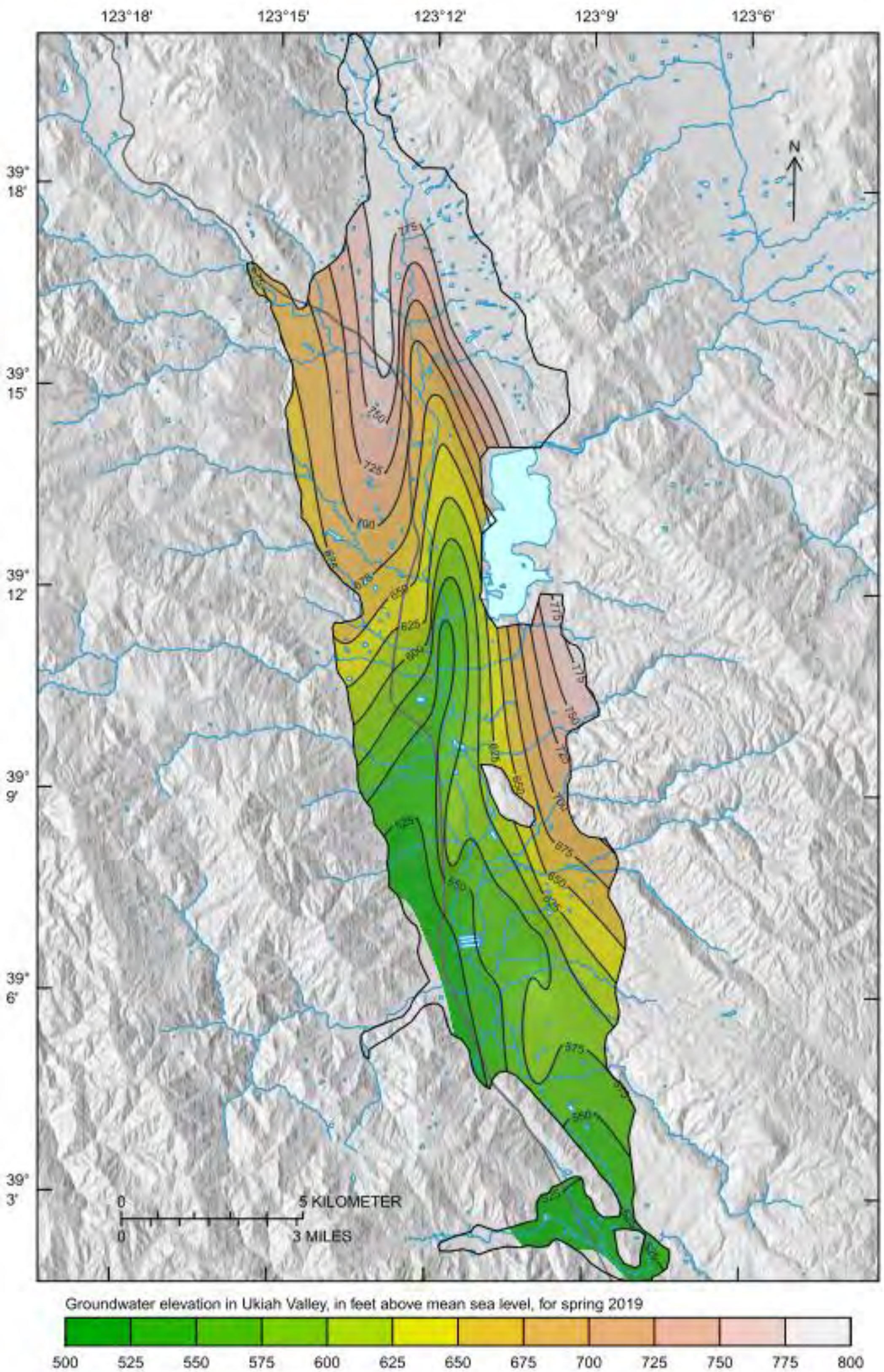


Figure 13. Groundwater elevation contours in the Ukiah Valley Groundwater basin, in feet amsl, from Spring 2019 (UVBGSA 2021).

Analyses of Current and Historical Conditions
The GSA analyzed current and historical trends to characterize changes over time in groundwater elevation, flow direction, gradients, seawater intrusion, land subsidence, water quality, land subsidence, and other factors.

Groundwater Elevation
Well information and monitoring data were compiled from public sources (DWR CASGEM Program database and State Water Resources Control Board GeoTracker database) and analyzed. There were only three CASGEM monitoring wells prior to 2014, so sporadic GeoTracker data was used to supplement. When data from recently installed DWR monitoring wells become available they will be used to update the model.

While there were noticeable seasonal fluctuations in groundwater elevations, they have remained relatively stable over the last thirty years. Lowest elevations tend to occur in October, and highest in March or April. The magnitude of seasonal fluctuations increased slightly during drought, but returned to normal after previous droughts ended. Groundwater flow direction was consistently from north to south and toward the Russian River, in both principal aquifers.

Groundwater Storage
As part of the Groundwater Sustainability Plan a simulation model was developed called the Ukiah Valley Integrated Hydrology Model (UVIHM). The UVIHM, which combines PRMS and MODFLOW models in the USGS GSFLOW modeling software (detailed discussions of these methods and models are provided in Appendix 2-D of the GSP) was used to simulate any changes in basin storage from 1992 to 2018, "the historic period". The model was calibrated using groundwater elevations from the CASGEM program, USGS streamflow data, and solar radiation data from a CIMIS station.
Storage in the basin followed precipitation patterns as one would expect, losing some water during dry periods and regaining it during wet periods. These fluctuations in water storage were not significant or concerning.

Seawater Intrusion
The Ukiah Valley groundwater basin is not in close enough proximity to the ocean for seawater intrusion to be a concern.

Groundwater Quality
Groundwater quality was assessed using data for a total of 176 wells from the California Groundwater Ambient Monitoring and Assessment (GAMA) Program database supplemented with data from the Department of Health Services (DHS) and GeoTracker. Groundwater quality constituents were quantified and compared to state and federal drinking water standards for boron, iron, manganese, nitrate, and specific conductivity.

The water quality analysis highlighted no exceedances in Principal Aquifer I, but there were several instances of boron, iron, and magnesium exceedances in Aquifer II. Due to its very slow infiltration rate, these are likely natural occurrences rather than anthropogenic contaminants. No exceedances of specific conductivity were found. None of the known contamination sites in the area appear to be having a quantifiable impact on water quality.

Land Subsidence
Land subsidence can occur due to over pumping of groundwater. It is not an issue in the Ukiah Valley groundwater basin.

Identification of Interconnected Surface Water Systems
The GSP identifies reaches of stream that are interconnected to groundwater by comparing 50-meter segments of streambed elevations (measured with digital elevation models and aerial imagery in a GIS) to modeled surrounding groundwater elevations in the fall and spring of each year from 2015 to 2020. The analysis found that 72% of streambed segments are not connected to groundwater in the fall, and 63% are not connected in the spring. Therefore 28% are connected to groundwater in the fall and 37% are connected to groundwater in the spring (Figure 14).

Identification of Groundwater-Dependent Ecosystems
CDFW GIS data were analyzed to determine whether any species that are threatened, endangered, rare, or species of concern reside within the basin and depend on groundwater dependent ecosystems. Vegetation was mapped using the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset, and riparian plant rooting depths were also analyzed in conjunction with modeled depth to groundwater.

The western pond turtle and the yellow-legged frog were identified as species whose needs should be taken into account when considering groundwater management, as both depend on the presence of a permanent groundwater-fed water source. Pumping that impairs this habitat requirement could have negative impacts on their survival.

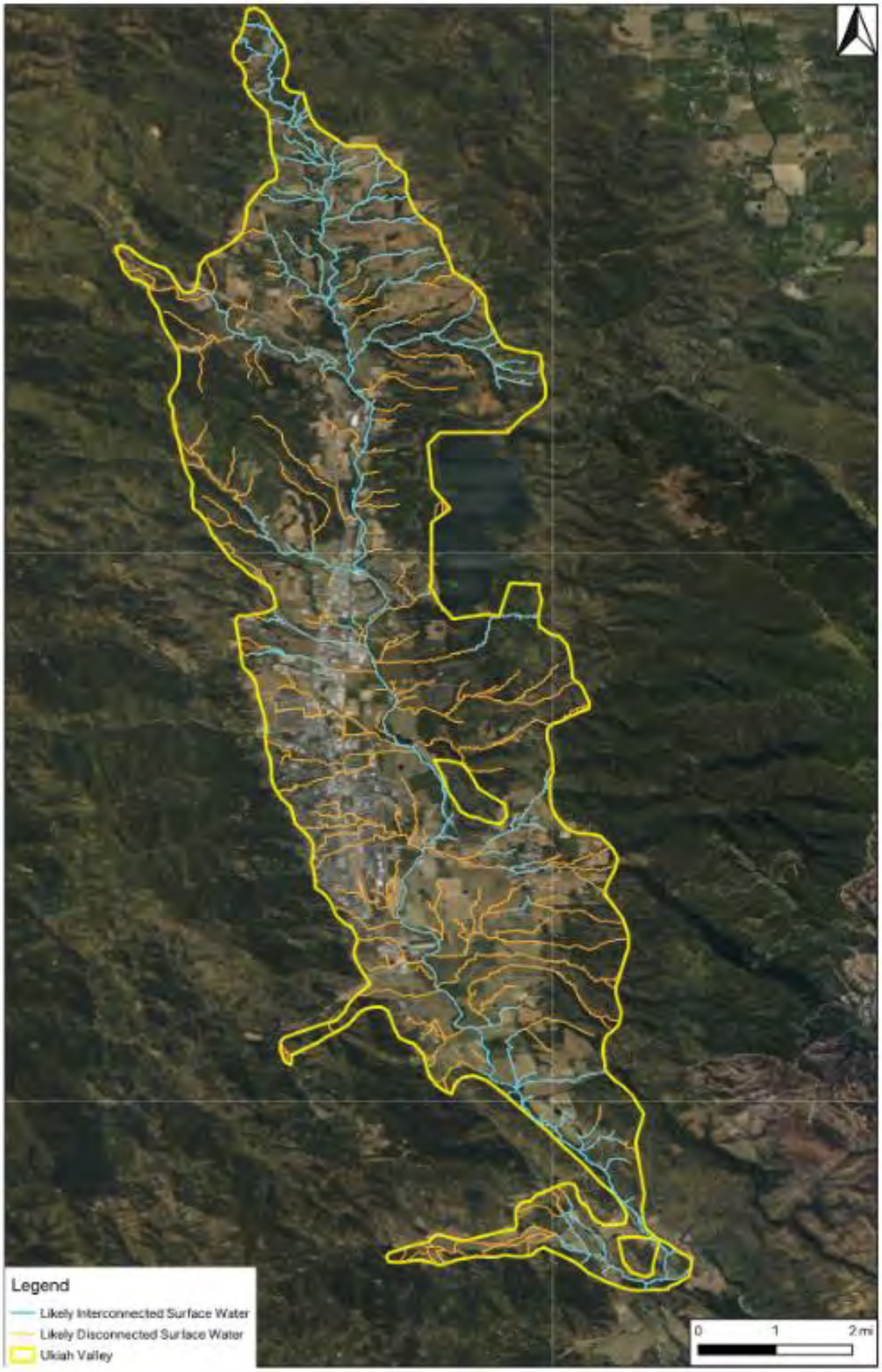


Figure 14. Likely interconnected surface water segments along the Russian River and its tributaries (UVBGSA 2021).

Water Budget
Inflows and outflows of the basin were characterized and quantified using the UVIHM model. The historical budget was estimated for a 27-year period from 1995 to 2018, the current budget is defined as the 2015-2018 water years, and future projections were made for 2017 – 2070. Various climate scenarios were also modeled in the future projections.

The components that make up the water budget include precipitation, soil moisture, flow from upstream, groundwater discharge into streams, unsaturated zone interflow, and Coyote Dam releases, evapotranspiration, stream recharge to groundwater aquifers, surface water diversions, outflow from the basin, percolation of precipitation, streambed recharge to groundwater, inflow from tributaries, groundwater pumping, and subsurface outflow.

Despite data gaps and uncertainties, these components and their carefully selected data inputs resulted in a reasonable, though simplified, representation of the Ukiah Valley groundwater budget (Figure 15), averages per water year type (Table 2), and surface water budget (Figure 16). As expected, available water coincided with wetter years.

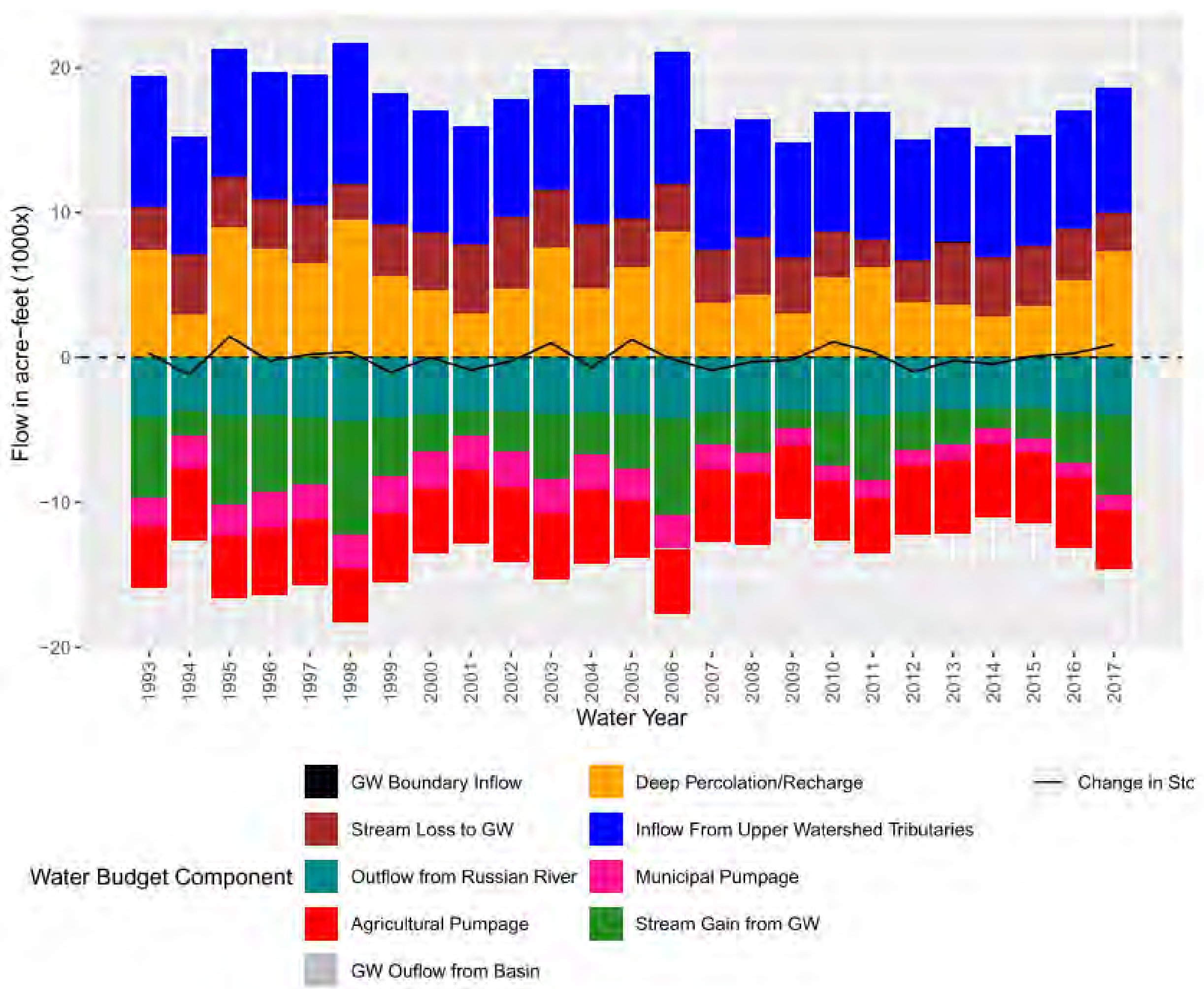


Figure 15. Ukiah Valley Basin Groundwater Budget by Water Year (UVBGSA 2021)

Table 2. Ukiah Valley Groundwater Basin estimated historical water budget for each water year type based on the average of 1995 – 2018 (acre-feet) (UVBGSA 2021).

Water Budget Component	Critical	Dry	Below Normal	Above Normal	Wet
Groundwater Boundary Inflow	5.4	5.3	5.3	5.3	5.3
Deep Percolation/Recharge	3352.3	3777.0	3898.7	5799.3	7879.3
Stream Loss to Groundwater	3992.6	4255.4	3967.4	3414.5	3156.7
Inflow From Upper Watershed Tributaries	7860.8	7982.3	8242.3	8488.0	9027.2
Outflow from Russian River	3583.0	3632.7	3744.6	3855.9	4072.3
Municipal Pumpage	1069.2	1069.0	1069.3	1069.0	1068.9
Agricultural Pumpage	4932.4	4932.1	4932.6	4932.0	4931.8
Stream Gain from Groundwater	1828.7	2205.7	2358.4	3851.7	5913.3
Groundwater Ouflow from Basin	1.0	1.0	1.0	1.0	1.0

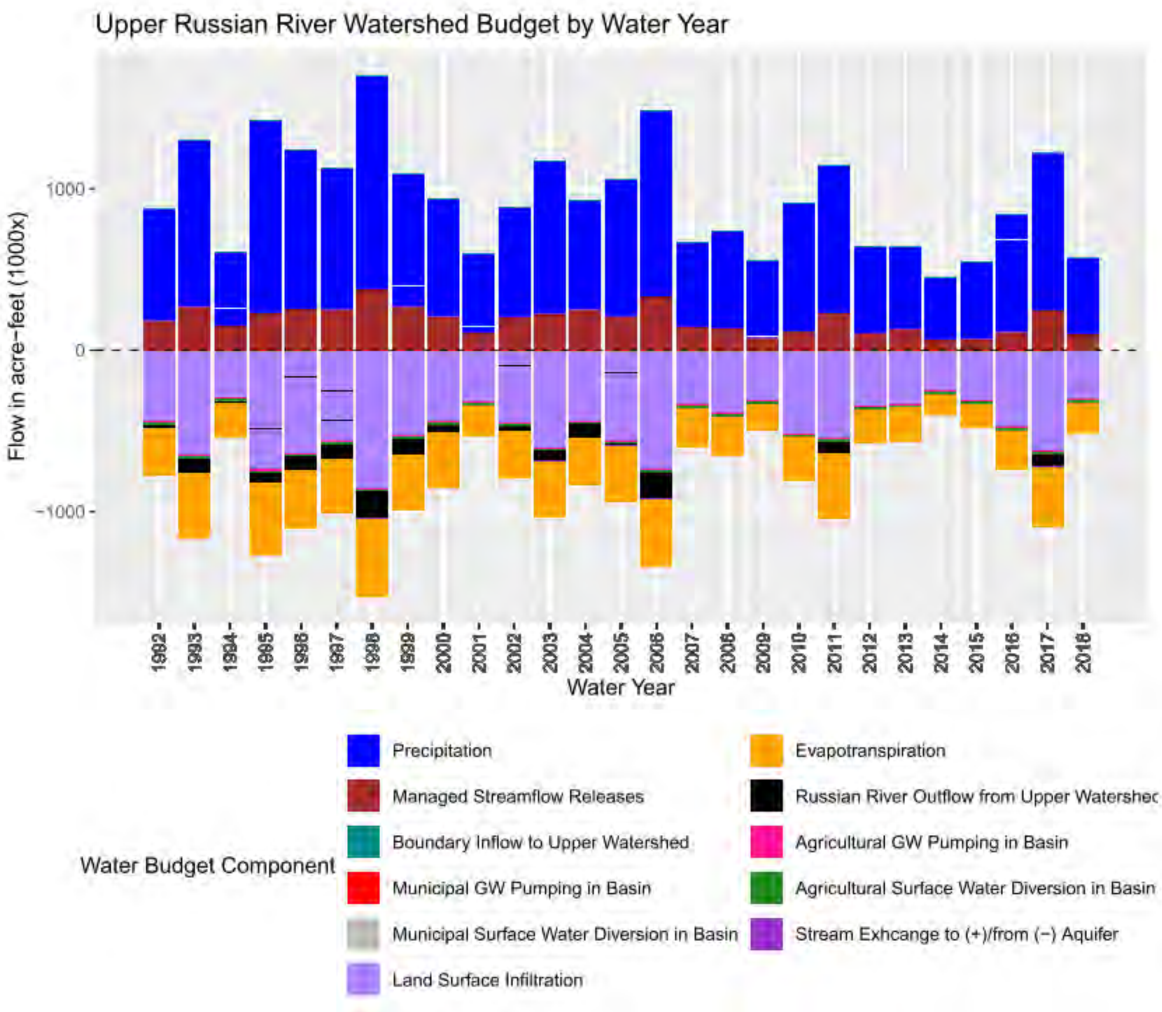


Figure 16. Estimated historical average monthly water budget for the upper Russian River watershed (UVBGSA 2021).

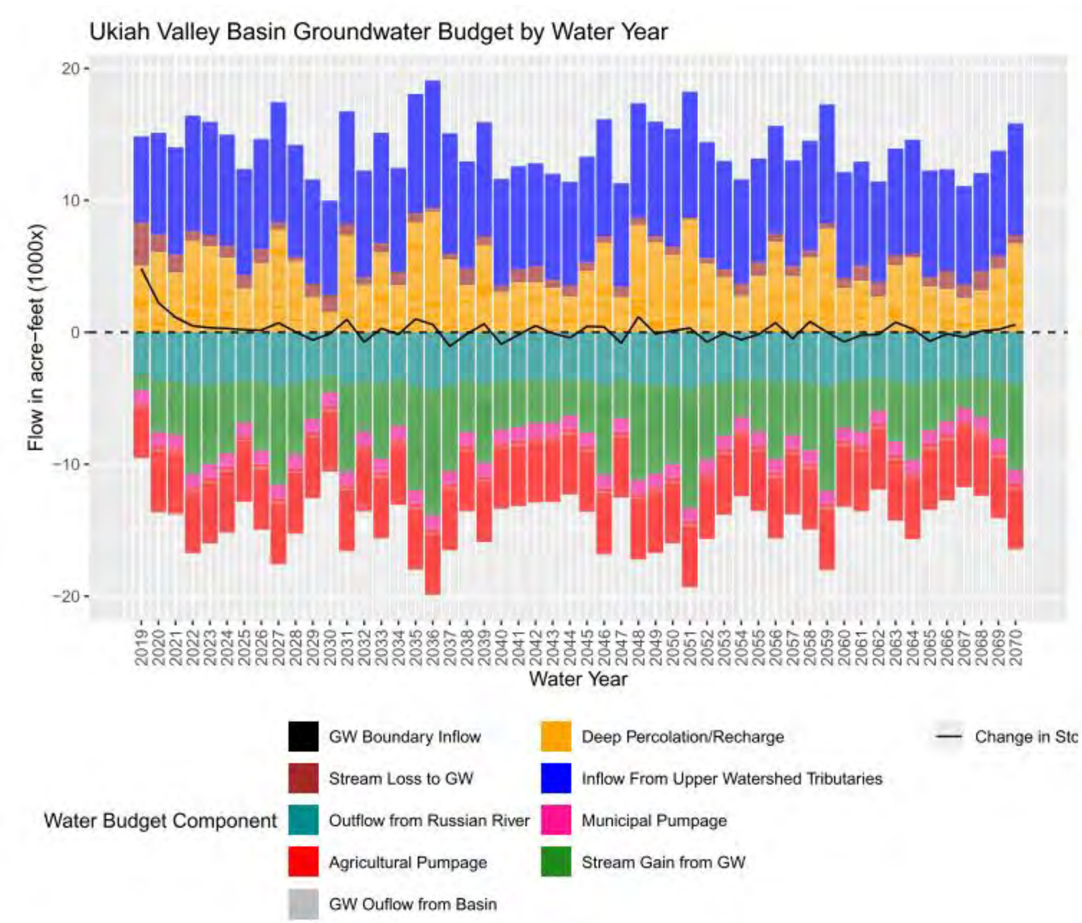


Figure 17. Estimated future annual groundwater budget for the basin averaged over 2017 – 2070 (UVBGSA 2021).

Table 3. Ukiah Valley Groundwater Basin estimated projected water budget for each water year type averaged over 2017 – 2070 (UVBGSA 2021).

Water Budget Component	Critical	Dry	Below Normal	Above Normal	Wet
Groundwater Boundary Inflow	5.3	5.3	5.3	5.3	5.3
Deep Percolation/Recharge	3003.2	3559.1	3773.0	5902.4	6954.7
Stream Loss to Groundwater	991.0	933.3	836.7	977.2	583.6
Inflow From Upper Watershed Tributaries	7774.3	7944.4	8020.1	8224.1	8808.8
Outflow from Russian River	3543.6	3612.9	3659.2	3758.3	3978.5
Municipal Pumpage	1069.5	1068.9	1069.2	1069.0	1068.8
Agricultural Pumpage	4932.9	4931.8	4932.4	4835.4	4935.5
Stream Gain from Groundwater	2920.1	3527.1	3738.4	5197.7	6780.3
Groundwater Ouflow from Basin	1.0	1.0	1.0	1.0	1.0

Table 4. Ukiah Valley Groundwater Basin estimated historical, current, and future water budgets (acre-feet). Future budgets include future baseline, 2030, and 2070 Climate Change Scenarios (UVBGSA 2021).

Water Budget Component	Historical: 1992-2018	Current: 2015-2018	Future Baseline: 2017-2070	Climate Change 2030 Scenario	Climate Change 2070 Scenario
Groundwater Boundary Inflow	5.3	5.3	5.3	5.3	5.3
Deep Percolation/Recharge	5422.8	6254.2	5123.1	1949.4	4100.1
Stream Loss to Groundwater	3660.7	3137.3	818.8	1363.7	1031.8
Inflow From Upper Watershed Tributaries	8440.6	8419.4	8271.4	7875.4	7498.3
Outflow from Russian River	3828.8	3831.4	3759.1	3471.1	3315.3
Municipal Pumpage	1854.7	1069.5	1069.0	1069.0	1069.0
Agricultural Pumpage	4630.0	4429.0	4914.0	4914.0	4914.0
Stream Gain from Groundwater	3632.2	4463.7	4889.5	2152.0	3758.9
Groundwater Ouflow from Basin	1.0	1.0	1.0	1.0	1.0

Key Insights

Natural runoff in the upper Russian River watershed is highly variable, and dependent on precipitation. The groundwater system receives recharge in the alluvial fans of tributaries, through infiltration into creek and riverbeds and through deep percolation of runoff from hillslopes into the valley floor. Precipitation occurs primarily between October and May, and irrigation occurs April through October. Groundwater demands have been relatively stable over the last ten years. Seasonal variability is accentuated by climate variability. Any long-term decrease in precipitation will lead to a dynamic response in baseflows and a likely decrease in groundwater levels.

Sustainable Yield

Sustainable yield refers to the maximum possible quantity of water that can be withdrawn from the basin without causing undesirable results, as a function of long-term conditions. The sustainable yield of the Ukiah Valley Groundwater Basin, for example, is much higher than historical groundwater pumping, as undesirable results have not occurred. However, it is an explicit requirement of the Sustainable Groundwater Management Act that Ukiah Valley's sustainable yield be calculated. The UVIHM was used to simulate various pumping scenarios and project the sustainable yield of the basin. However, the model will need to be re-run to update data gaps and uncertainties in climate change, land use and crop changes, and population growth. Sustainable yield of the basin is estimated as 6,500 acre-feet. However, due to this value's relative uncertainty, it is recommended that the basin's sustainability is based on the tracking of sustainable management criteria rather than sustainable yield.

Data Gaps

Data gaps in the basin's characterization include:

1. Some gaps in solar radiation, precipitation, and temperature historical data.
2. Evapotranspiration data (closest CIMIS station is too far south).
3. Uncertainty in the precise extents of geologic formations and some soil characteristics.
4. Precise aquifer characteristics (transmissivity and conductivity).
5. Interaction of principal aquifers with streams and their vertical flow.
6. Stream cross-sections and characteristics.
7. Streamflow data and measurements.
8. A more complete well inventory.
9. Additional monitoring wells are needed for a more accurate groundwater elevation model.
10. More in-depth studies on groundwater dependent ecosystems and interconnected surface water systems.

11. Uncertainty in modeled aquifer storage.
12. Limited water quality data.
13. Potential impacts of climate change.

Projects and Management Actions (PMAs)

The PMAs summarized below will help to achieve sustainability goals by avoidance of aforementioned undesirable results. Priorities during their development include minimizing impacts on the basin's economy, maximizing external funding, and prioritizing voluntary and incentive-based programs. Projects in Tables 5-7 are not prioritized.

Table 5. Existing or Ongoing Projects and Management Actions (Ukiah Valley Basin Groundwater Sustainability Agency 2021).

Project Name	Description/organization
Purple Pipe Project	Expanding access to recycled water. City of Ukiah Water Resources Department.
Water Meter Replacement	Replacing outdated residential water meters. Redwood Valley Tribe.
Rainwater catchment and usage	60,000-gallon rainwater catchment tank being installed at the Pinoleville Pomo Nation administrative offices.
Redwood Empire Fairgrounds Water System Upgrade	Fairgrounds plumbing system replacement.
Irrigation upgrades and turf to xeric landscape	Mendocino College Ukiah.
Sports field conversion to non-irrigates surface	Ukiah Unified School District.
Forsythe floodplain restoration project	Removal of levee to allow expansion of floodwaters, reduction of erosion, increased infiltration, and restoration of the riparian corridor. Mendocino County RCD.

Table 6. Planned and potential future projects (Ukiah Valley Basin Groundwater Sustainability Agency 2021).

Project Name	Description/organization
Rehabilitation of existing reservoirs	Reservoirs provide flexibility in water supply and increase irrigation efficiency. Rehabilitation will focus on installation of pond liners and removal of debris.
Construction of additional off-stream reservoirs	Off-stream reservoirs reduce instantaneous water demand and river diversions, and increase drought resilience.
Construction of additional off-stream storage tanks	Store water during high flows to be used during high demand.
Well analysis, rehabilitation, and impact mitigation	Improve supply and reliability for domestic well users, adaptively managing undesirable results through different pumping patterns and diversions. Evaluate appropriate recharge locations. Demonstrate that new wells can be developed without noticeable impact on sustainability indicators. Develop a better accounting of agricultural production wells.
Purple Pipe Project—Phase IV	Continued expansion of pipeline, construction of a million-gallon storage tank, ponds, booster station for expanded distribution of recycled water.

Table 7. Potential managed aquifer recharge and injection well projects (Ukiah Valley Basin Groundwater Sustainability Agency 2021).

Project Name	Description/organization
City of Ukiah Groundwater Recharge	Construction of a large recharge basin at Riverside Park that would facilitate infiltration through the creation of seasonal wetlands.
Rogina Mutual Water Company and Millview County Water District MAR and/or Injection Wells	Feasibility study and possible implementation of ASR wells in well fields.
Mendocino County Water Agency Groundwater Recharge Projects	Evaluation and geophysical study of reclaimed mines and gravel pits as low-cost options for recharge.
City of Ukiah Western Hills Source Water Protection	Acquire undeveloped headwater properties in the hills west of Ukiah in order to preserve them and maintain natural runoff and groundwater recharge patterns in the area.
Stream enhancements	Feasibility studies on storing flows in the tributaries and creating recharge basins in river channels. Restoration projects that reduce the impacts of channel incision and gravel mining.
Storm water collection and managed aquifer recharge	Targets small drainage areas and collects stormwater runoff for infiltration. Feasibility studies and pilot projects are needed.
Aquifer storage and recovery feasibility and implementation	Identifying suitable locations for managed aquifer recharge to increase groundwater storage in shallow aquifer layers. Should target agricultural lands close to the Russian River and its tributaries.
Reduce evaporative losses	Storage ponds are subject to significant losses to evaporation. Possible solutions include shade balls (90% reduction), and WaterSavr (powder product that sits on the water surface—30% reduction).

Identifying Groundwater Recharge Project Sites

CLSI was funded through the 2020 Sustainable Groundwater Management Act (SGMA) Groundwater Coordinator Program to aid in the mission of the GSA by defining groundwater recharge projects. The following section summarizes the results of defining potential locations of groundwater recharge projects in the watershed.

Approach

Potential recharge approaches include:

Spreading basins: These basins can facilitate infiltration by concentrating a large volume of water across the land surface for an extended period of time.

Off stream reservoirs: These ponds are similar to spreading basin but are filled in the winter when runoff is abundant and then water is released into a creek, well or field to infiltrate during the dry season when there is storage space available in the aquifer

Flooding agricultural fields (Flood-MAR): This approach uses flood or storm water for managed aquifer recharge on agricultural lands. Runoff is diverted and directed onto agricultural fields and allowed to percolate into the groundwater. There may be limitations to this approach in Ukiah Valley as when floodwater is available there may not be additional storage space in the aquifer.

Injection wells and/or dry wells: This method requires installation and operation of equipment to directly inject water into aquifers. Most effective with a consistent, dedicated water supply, such as recycled water. Use of this method does not depend on soil characteristics.

Streams and canals: These features can be used to infiltrate water and increase groundwater recharge.

Direct recharge through spreading basins, off stream reservoirs and Flood-MAR are the focus of this plan. Alluvial aquifers can be recharged by direct application of water to the land surface above unsaturated alluvium. Soils in hydrologic group A (Figure 18 and Table 8) are hydrologically conductive and indicate the highest potential for facilitating groundwater recharge. This approach also serves to highlight the broadest possible number of sites that are suitable for direct recharge by many different means, which can then be filtered and categorized by their relative suitability for more specific recharge approaches. Potential recharge sites were identified using the following data sources and processes:

U.S. Department of Agriculture Gridded Soil Survey Geographic Database

U.S. Department of Agriculture Gridded Soil Survey Geographic Database (SSURGO) was used in a Geographic Information System (GIS) to characterize soils and determine locations of soil types in Hydrologic Group A. Soil mapping units for the Ukiah Valley indicate whether or not the water table is within 200 cm of the land surface. The soils map indicates that the water table is greater than 200 cm in almost all mapping units. Soils mapping units with depths to water less than 200 cm, and therefore less suitable for recharge, were removed from consideration.

Digital Elevation Model

Slope was calculated from a publicly available Digital Elevation Model (DEM). Areas with topographic slopes greater than 5% are too steep for most recharge projects. Areas with slopes greater than 5% were therefore excluded by creating a binary vector mask from calculated slope values.

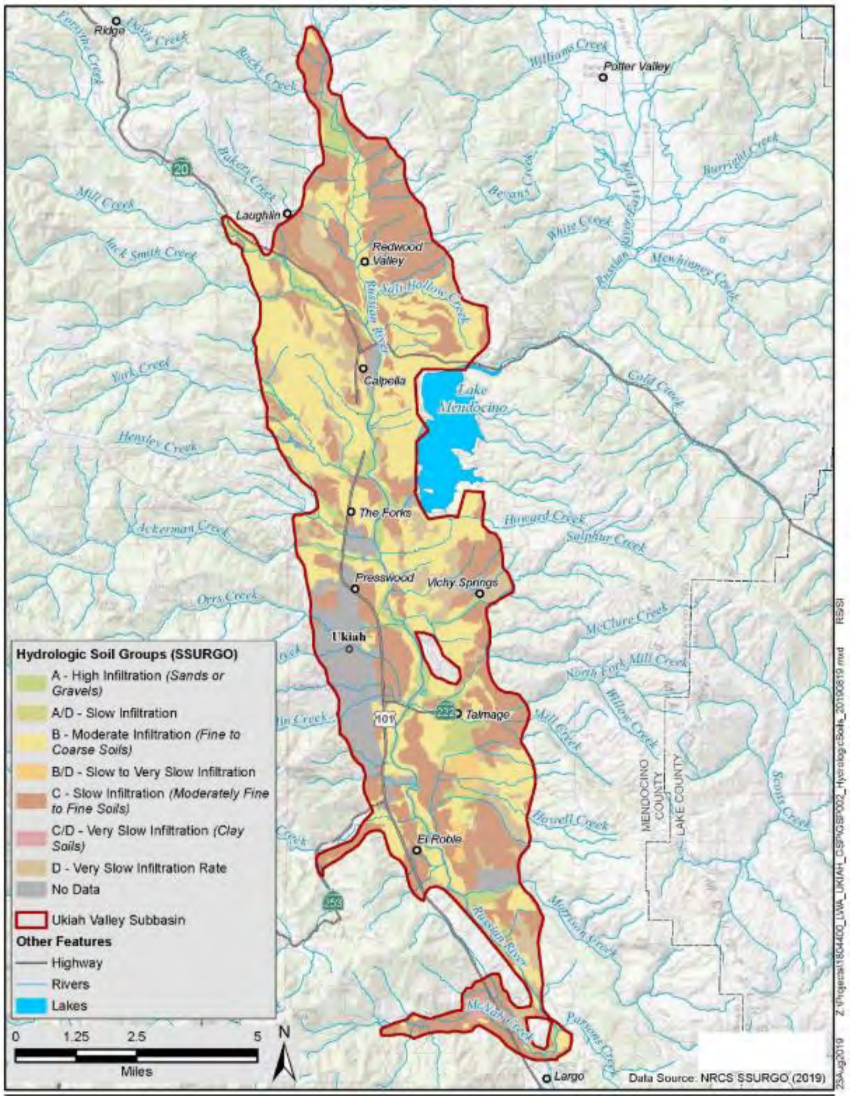


Figure 18. Hydrologic soil groups (Ukiah Valley Groundwater Sustainability Agency, 2021).

Table 8. Hydrologic Soil Groups (GSA 2021)

Hydrologic Group	Description
A	Low runoff potential, high transmission and infiltration rates, well drained sands or gravelly sands, highest permeability, highest recharge potential.
B	Low runoff potential, unimpeded transmission and infiltration, moderately well drained, moderately fine to coarse textures, second highest permeability and recharge potential.
C	Moderately high runoff potential, water transmission somewhat restricted, limited potential to contribute to groundwater recharge, low infiltration rate, fine texture (or presence of an aquitard).
D	High runoff potential, very restricted water transmission, very limited capacity for recharge.

Classification and Assessment with Landsat of Visible Ecological Groupings
Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG) was used to exclude urban and residential areas are not available for recharge projects.

Subwatersheds
Larger catchment areas have greater potential for high tributary streamflows, and were therefore prioritized in final site selection by using the defined HUC 12 watersheds.

Analysis
The first two rounds of this analysis used hydraulic conductivity parameters that proved to be too narrow resulting in a very limited number of suitable sites. For the current analyses, soil characteristics were generalized by "Hydrologic Group A," which simplifies and allows mapping of soil infiltration potential. Alluvial fan locations were also included and reviewed.

Using GIS, the Hydrologic Soil Group A was selected from the SSURGO dataset and isolated as its own geographic layer. This was then intersected with the slope information to retain areas under 5% slope. The urban landcover type from the CALVEG dataset was then isolated and used to eliminate urban areas. The resulting locations were selected and then spatially joined with the subwatershed dataset to incorporate catchment areas into the analysis. Results were then manually refined alongside the groundwater elevation maps generated by the GSA to prioritize those in the northern portions of the watershed, such that recharged water would add to the southward groundwater flow and affect a greater portion of the basin. Final results show only parcels that are five or more acres in area.

Results
The green areas of Figures 19-__ depict the results of the GIS analysis. All the green locations are not in urban areas, are on parcels larger than 5 acres, have soils in hydrologic soils group A that have high infiltration rates and are on slopes of less than 5%. Each of these figures has numbered parcels that correspond with the land ownership information in the corresponding table in Appendix 1.

The type of project considered as part of this plan would store diverted water from winter flows and release it from the pond into the aquifer in summer. For example, an off-stream pond is built with a fairly large storage capacity such as 49 acre feet. The pond would be lined to avoid leakage. Water would be diverted from a nearby stream channel during winter storms. The timing of diversions requires completion of a study of stream flows and other water rights and completion of a water availability study. Once the reservoir is filled it would be covered with a structure or other practices to reduce evaporation. Water from the reservoir would need to be infiltrated into the aquifer through a pipe system, cistern or other facility. This facility would be sized according to the site-specific features of geology and stratigraphy as well as the overall purpose of the recharge and whether a slow trickle or large input to the aquifer or nearby stream are needed.

Downstream of the pond a series of wells will be instrumented with pressure transducers to continuously monitor changes in groundwater levels and determine the effects of the recharge. This system can be used to determine the best timing for the recharge for the conditions of a particular year such as rainfall, groundwater levels in spring, temperatures and other parameters.

For areas of the groundwater basin with numerous relatively shallow domestic wells, upstream water releases from the pond during the dry season could benefit rural residences. Summer water releases from the pond could also be used to augment stream flow in spring to benefit outmigrating steelhead smolts. To augment the stream the release would have to be designed to affect shallow groundwater.

__Tributary Areas__

Forsythe Creek

Two areas of Forsythe Creek have areas capable of supporting a recharge project. Figure 19 shows the downstream reach of Forsythe Creek to its confluence with the West Fork Russian River. Most of the green areas are very close to the Forsythe Creek channel and within the floodway. Several green areas would require several parcels to build a project. Parcels 21, 24, 18, 11, 23 and 27 appear to be the most feasible sites for a recharge project. These parcels are large and include Forsythe Creek but could also support a pond at a distance from the channel and out of the floodway. Additionally, these sites are primarily grassland with few buildings.

Figure 20 shows the upstream reach of Forsythe Creek and green areas with higher infiltration capacity. Parcels 113, 111 and 116 include two green areas that could support a recharge project. Due to the locations of these sites in the headwaters of Forsythe Creek it may be difficult to fill the pond and not effect downstream diverters.

West Fork Russian River

Figure 21 shows potential recharge sites in the upper West Fork Russian River. Parcels 125 and 129 have the greatest potential for a project. Both sites are fairly large, have few nearby buildings and are mostly grassland.

York Creek

Figure 22 depicts the potential recharge areas in Upper York Creek. The green areas are narrow and it would be difficult to design a pond outside the floodway of York Creek. The green areas are all vineyards as well.

Figure 23 shows the potential recharge area in the lower reach of York Creek. All of the green areas are currently vineyards and it could be difficult to develop a project on these sites.

Hensley Creek

Figure 24 shows the green areas in lower Hensley Creek. All of the green areas are currently vineyards and it could be difficult to develop a project on these sites.

Mill/McClure Creeks

Figure 25 shows the potential recharge areas for Mill and McClure Creeks. Two parcels – 135 and 131 could accommodate a recharge project but both are vineyards and could be difficult to develop for a recharge project.

Sulphur Creek

Figure 26 depicts potential recharge projects along Sulphur Creek. There is only one parcel -84, that is large enough for a recharge project and includes only a small tributary. Here may not be adequate water flow to fill a pond for recharge.

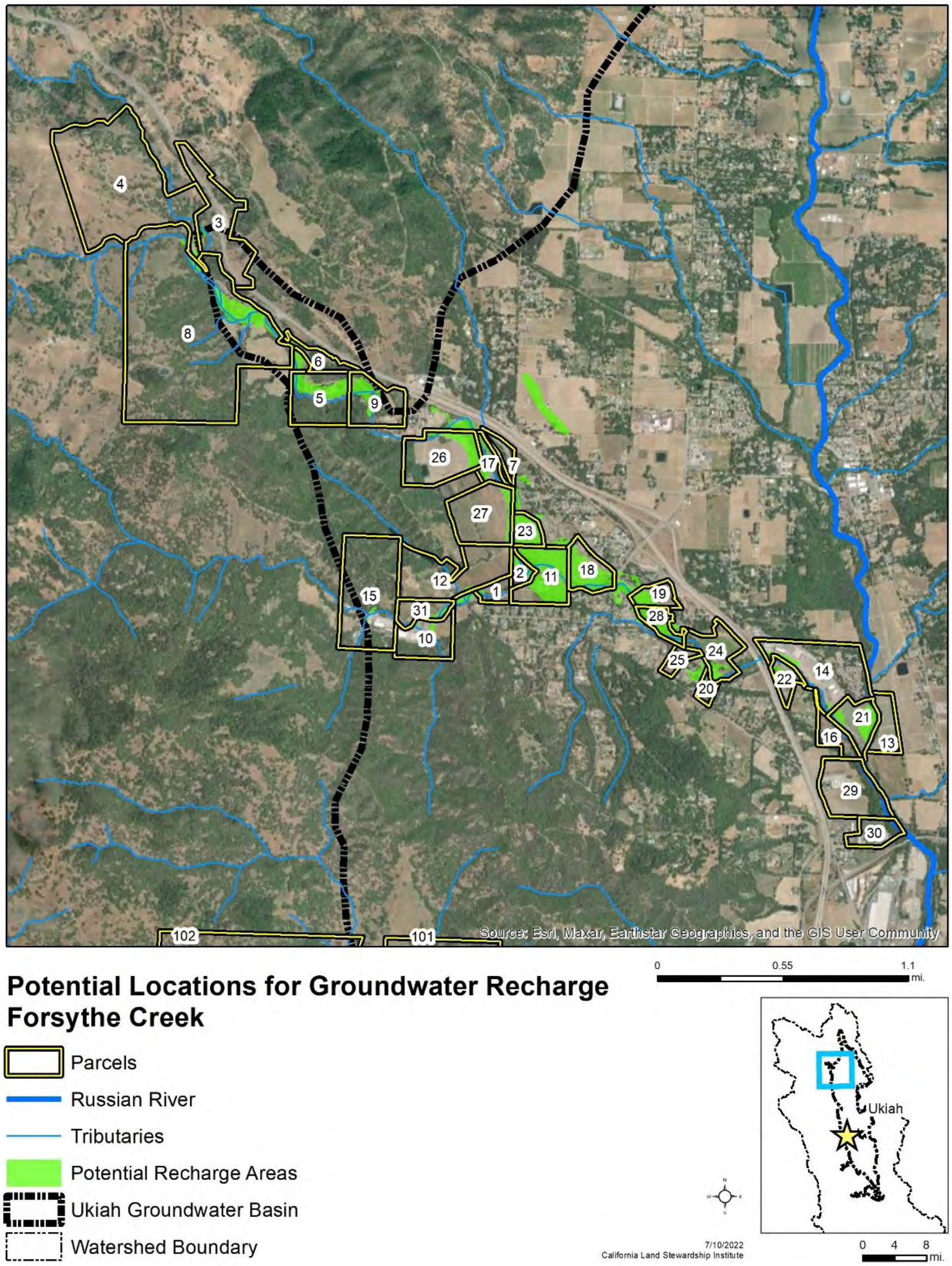


Figure 19. Potential lower Forsythe Creek recharge sites

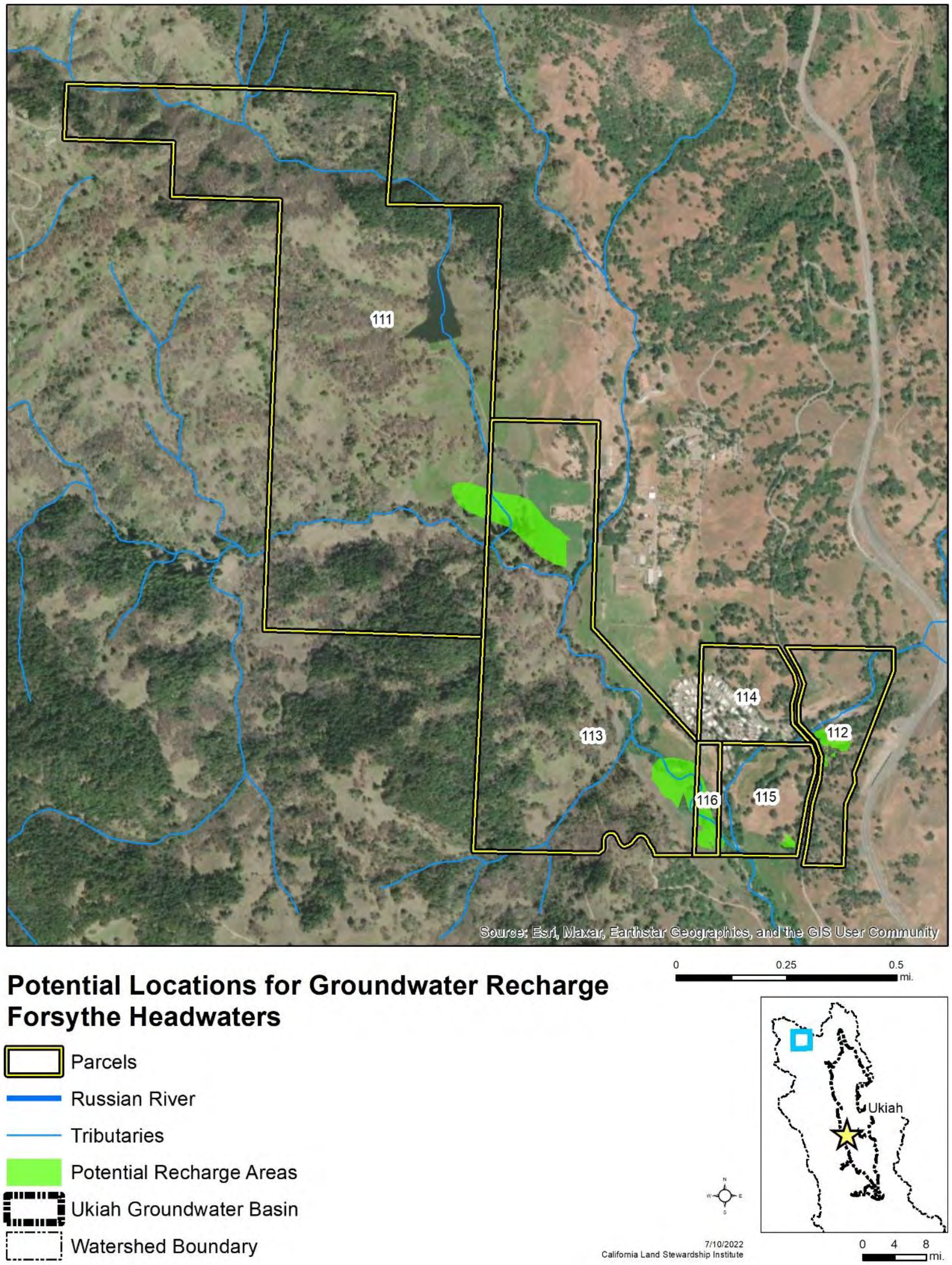


Figure 20. Potential Forsythe Creek headwaters recharge locations

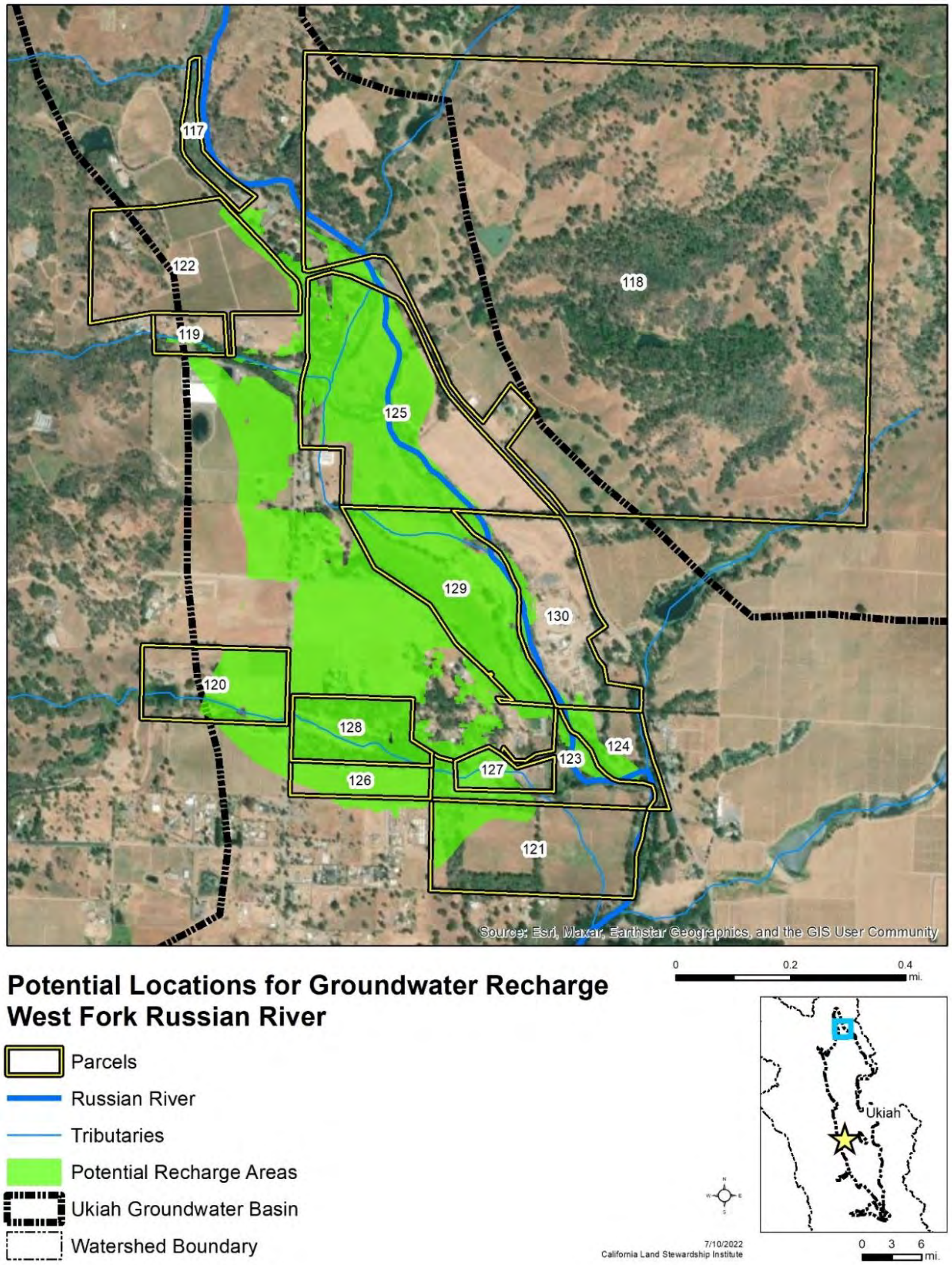


Figure 21. Potential West Fork Russian River recharge locations

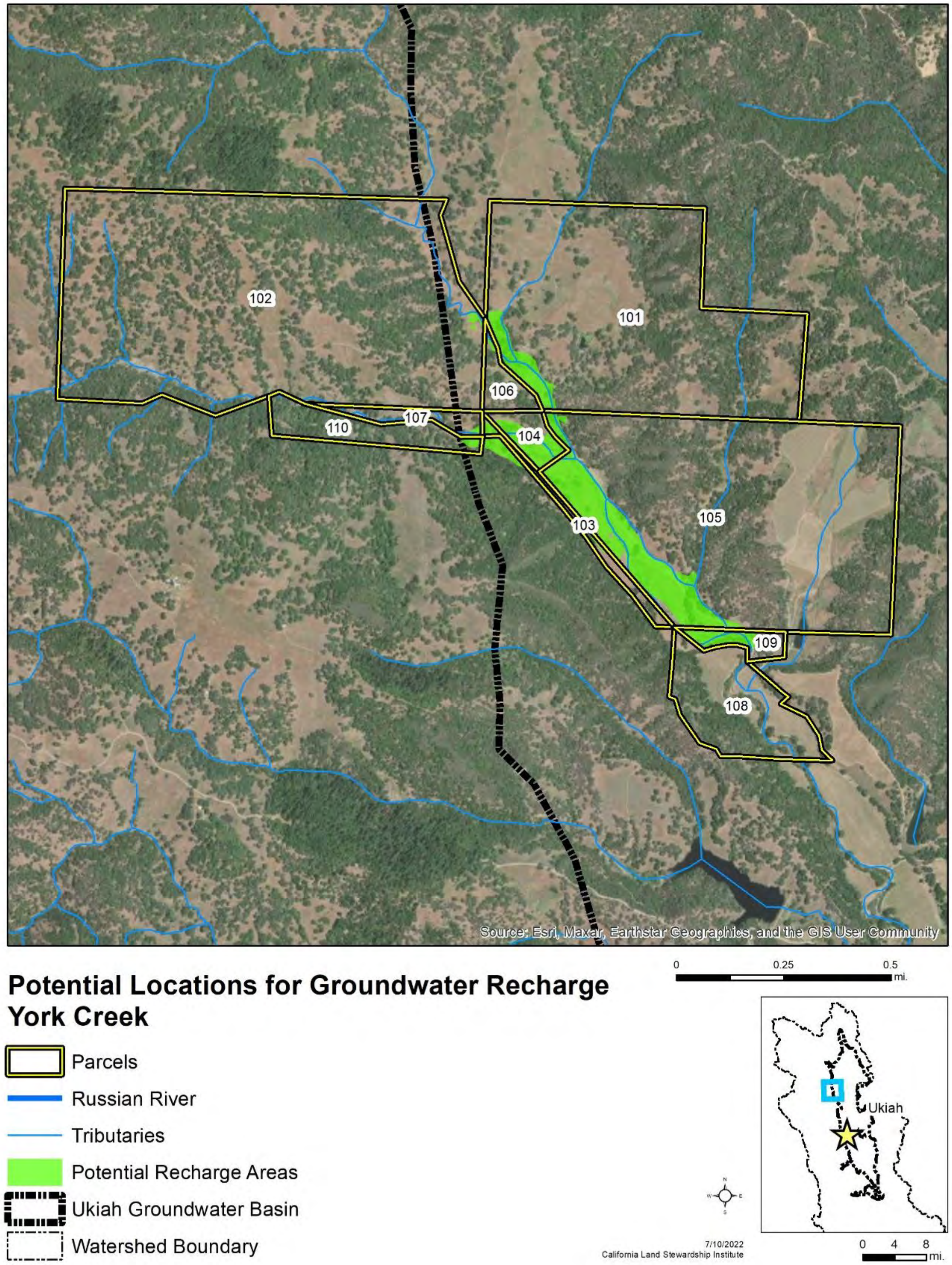


Figure 22. Potential upper York Creek recharge locations

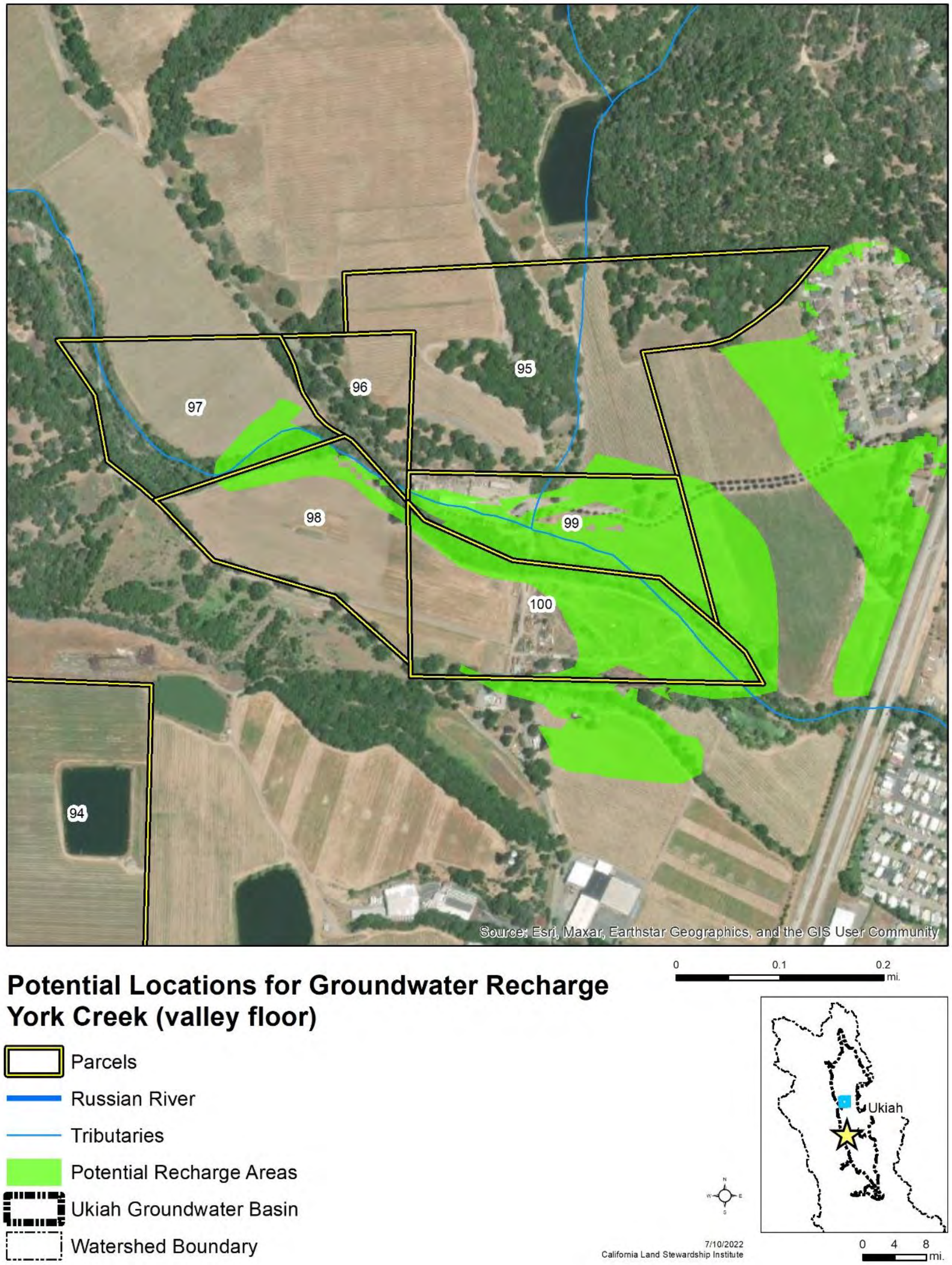


Figure 23. Potential lower York Creek recharge locations.

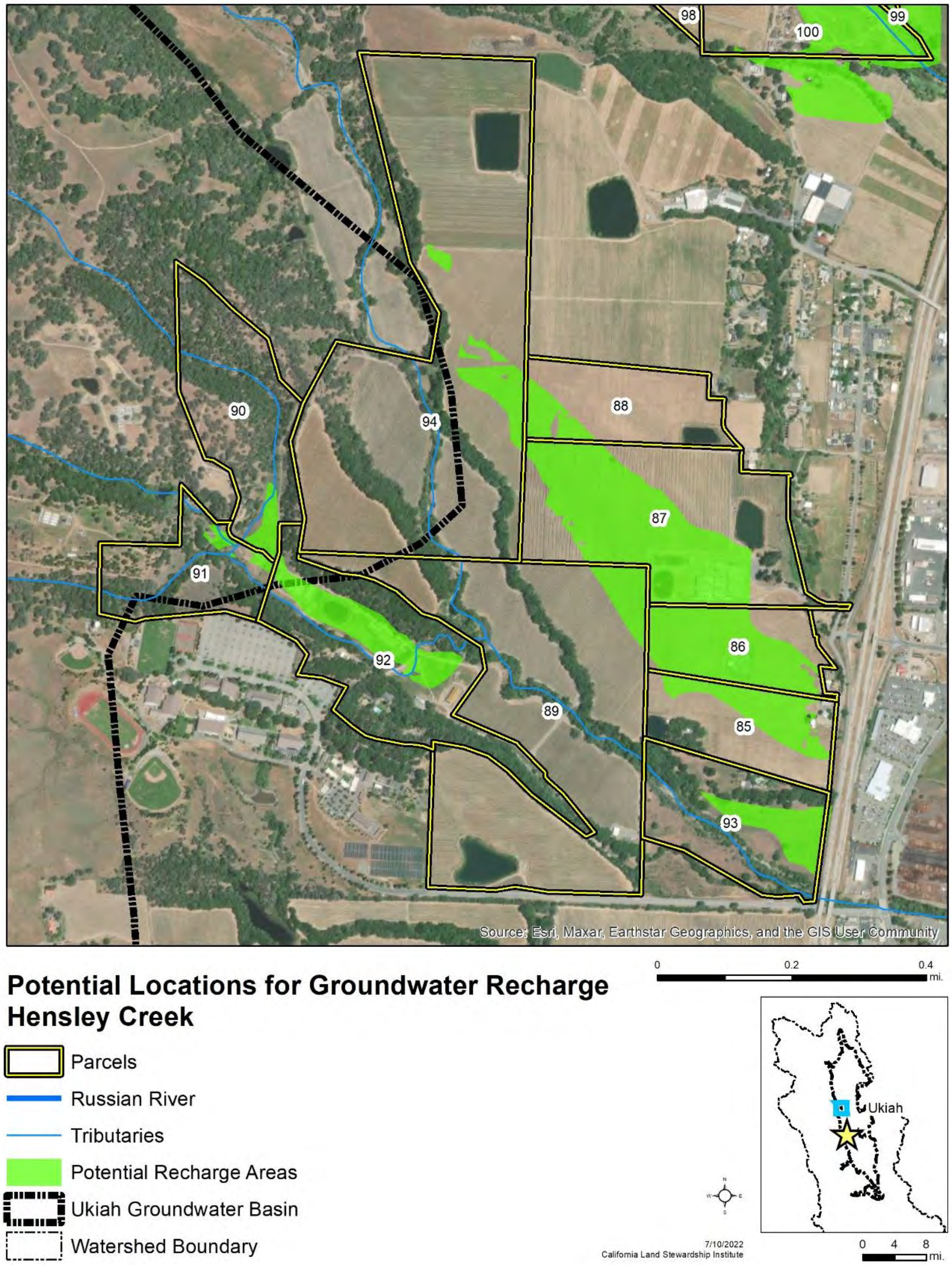


Figure 24. Potential Hensley Creek recharge locations.

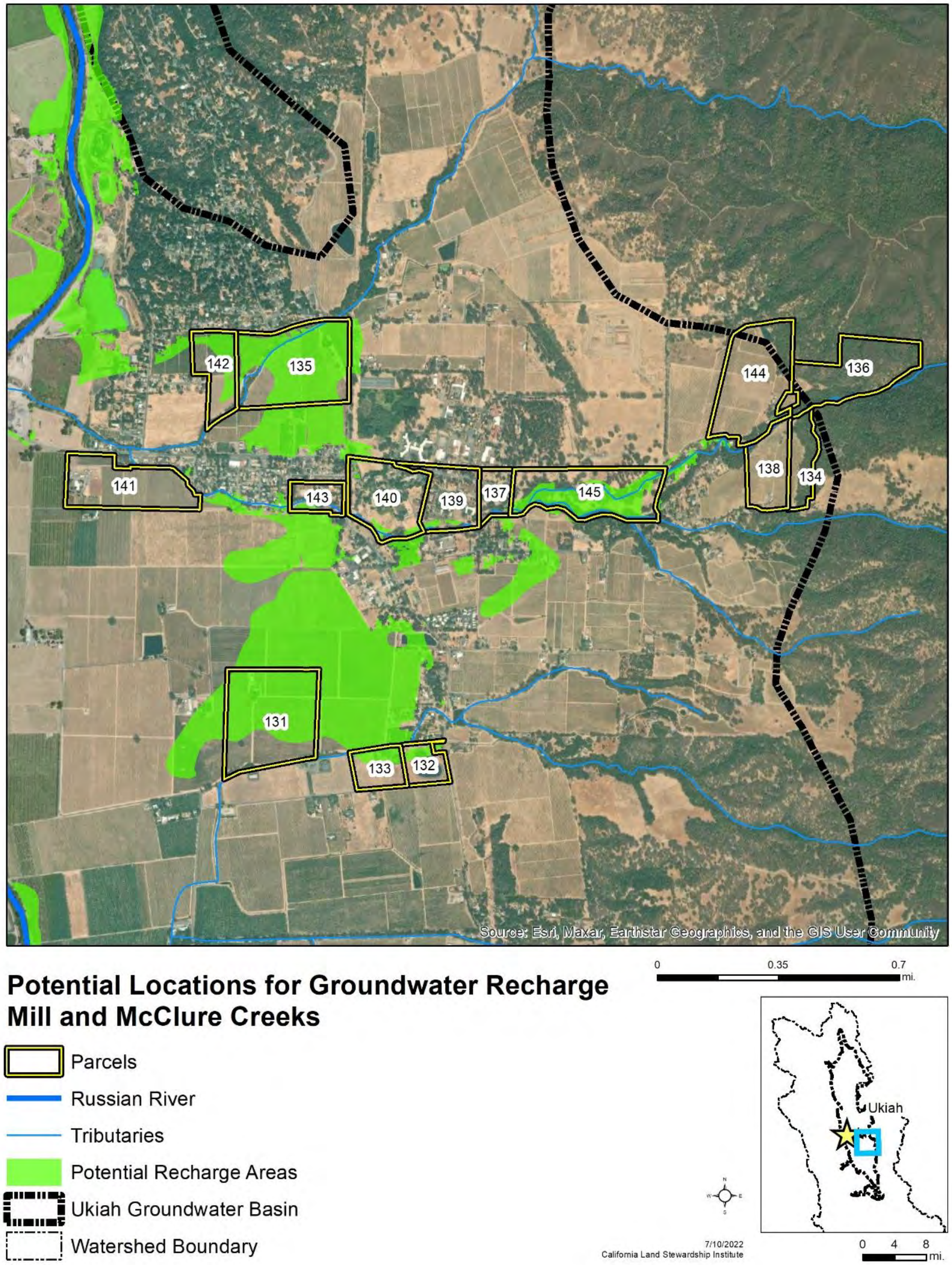


Figure 25. Potential Mill and McClure Creeks recharge locations.

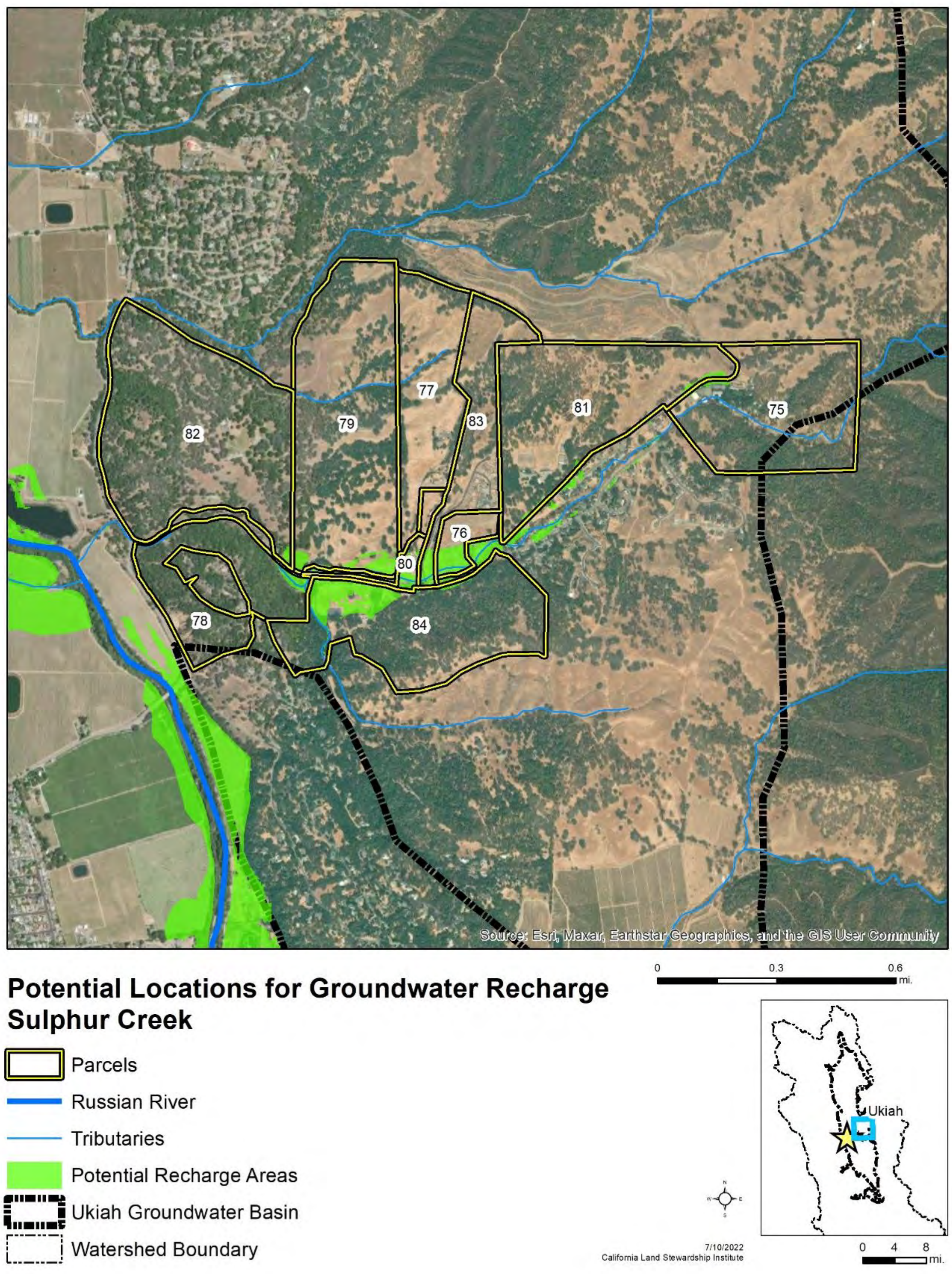


Figure 26. Potential Sulphur Creek recharge locations.

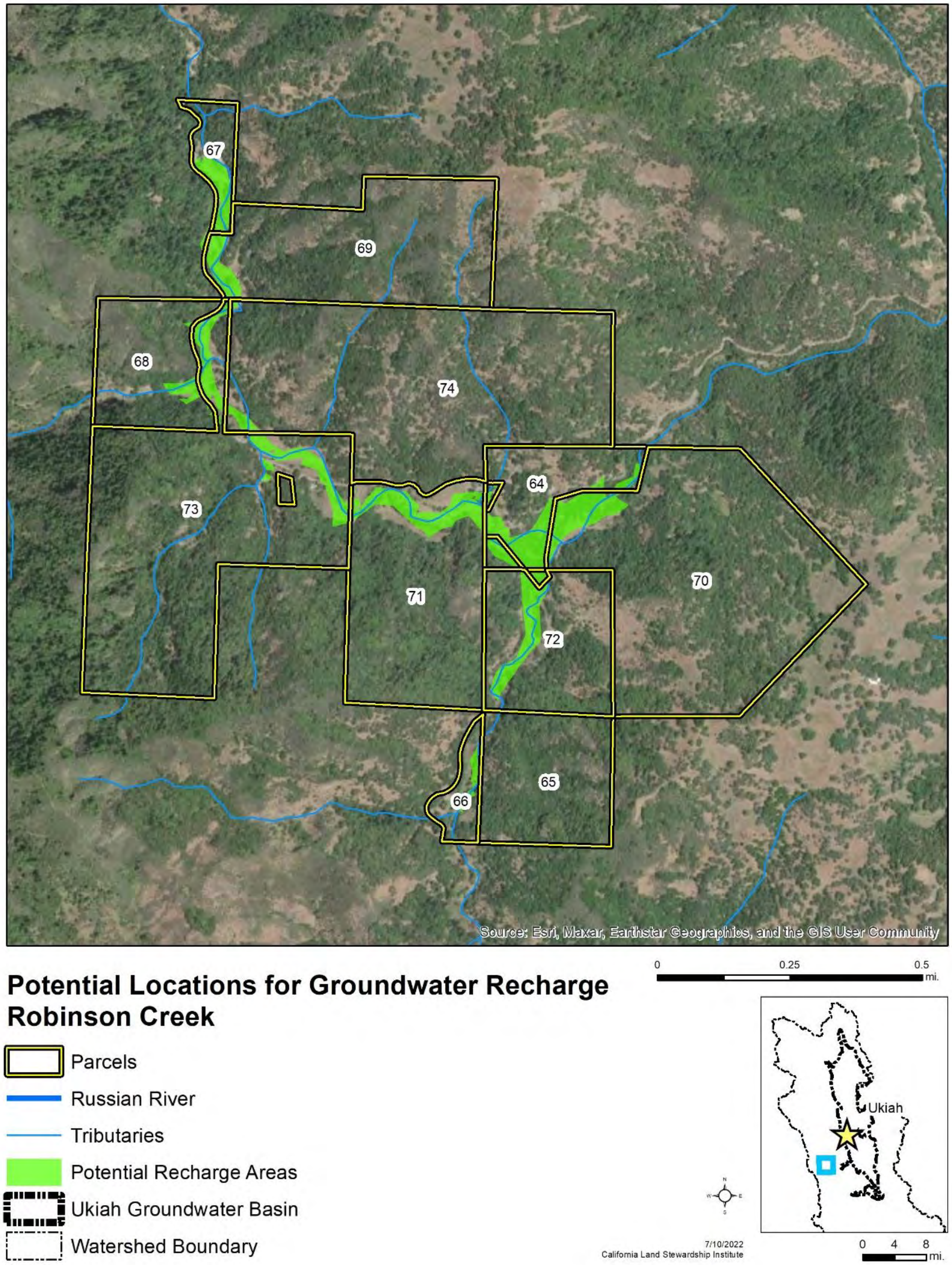


Figure 27. Potential Robinson Creek recharge locations.

Robinson Creek
Figure 27 depicts the potential recharge project sites along Robinson Creek. The green areas are located in a fairly narrow creek canyon where it will be difficult to construct a recharge project outside the creek floodway.

Morrison Creek
Figure 28 depicts the potential recharge project sites along Morrison Creek. Parcels 56 and 45have large green areas, are former surface gravel mines associated with the development of Highway 101 and are adjacent to Morrison Creek. These parcels are used for grazing. Additionally, Morrison Creek is an alluvial fan with high infiltration rates (Figure 31).

McNab and Parsons Creeks
The potential McNab and Parsons Creeks recharge locations are shown in Figure 29. The green areas are too small and adjacent to a waterway for a recharge project to be designed outside the floodway.

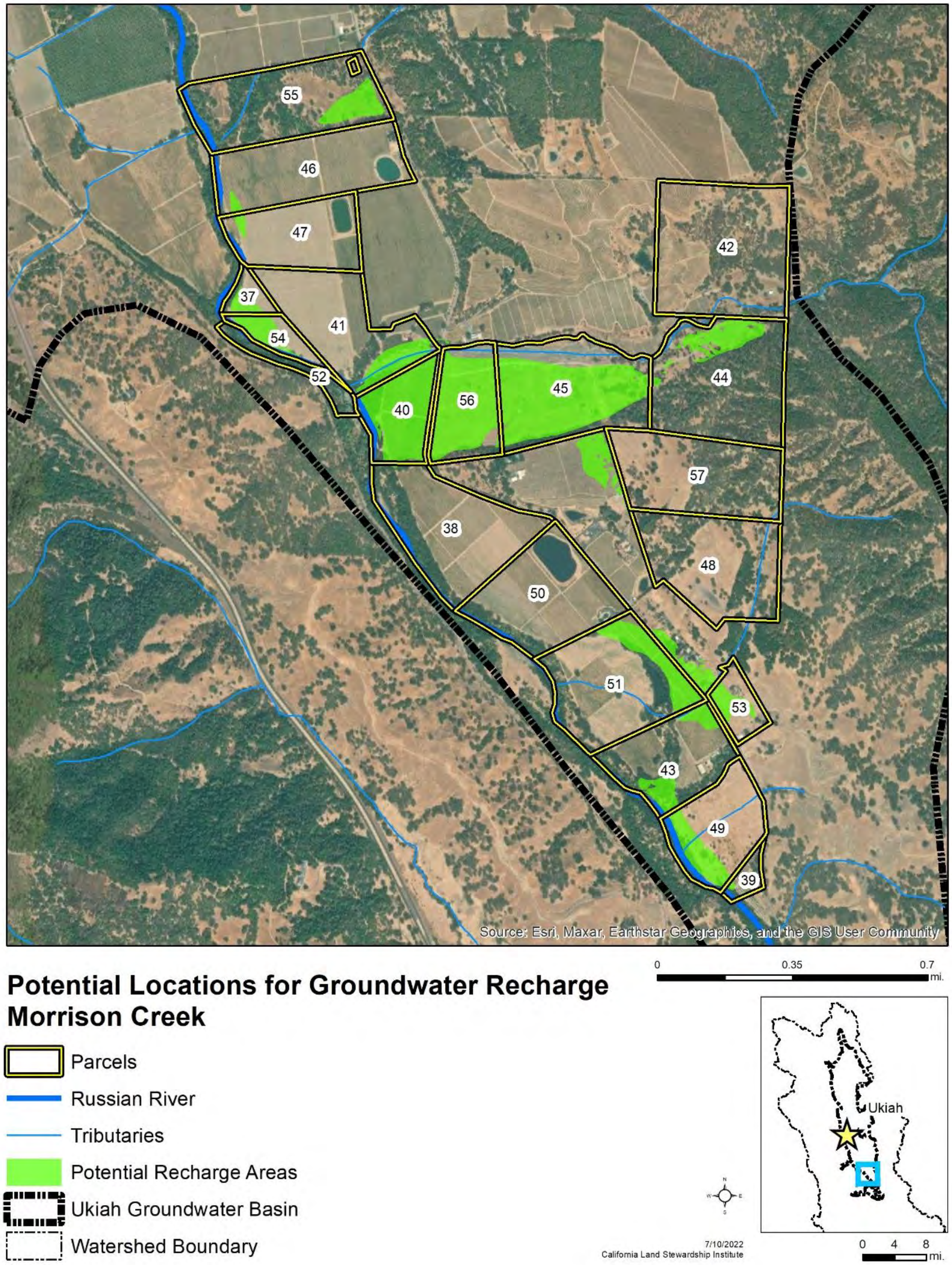


Figure 28. Potential Morrison Creek recharge locations.

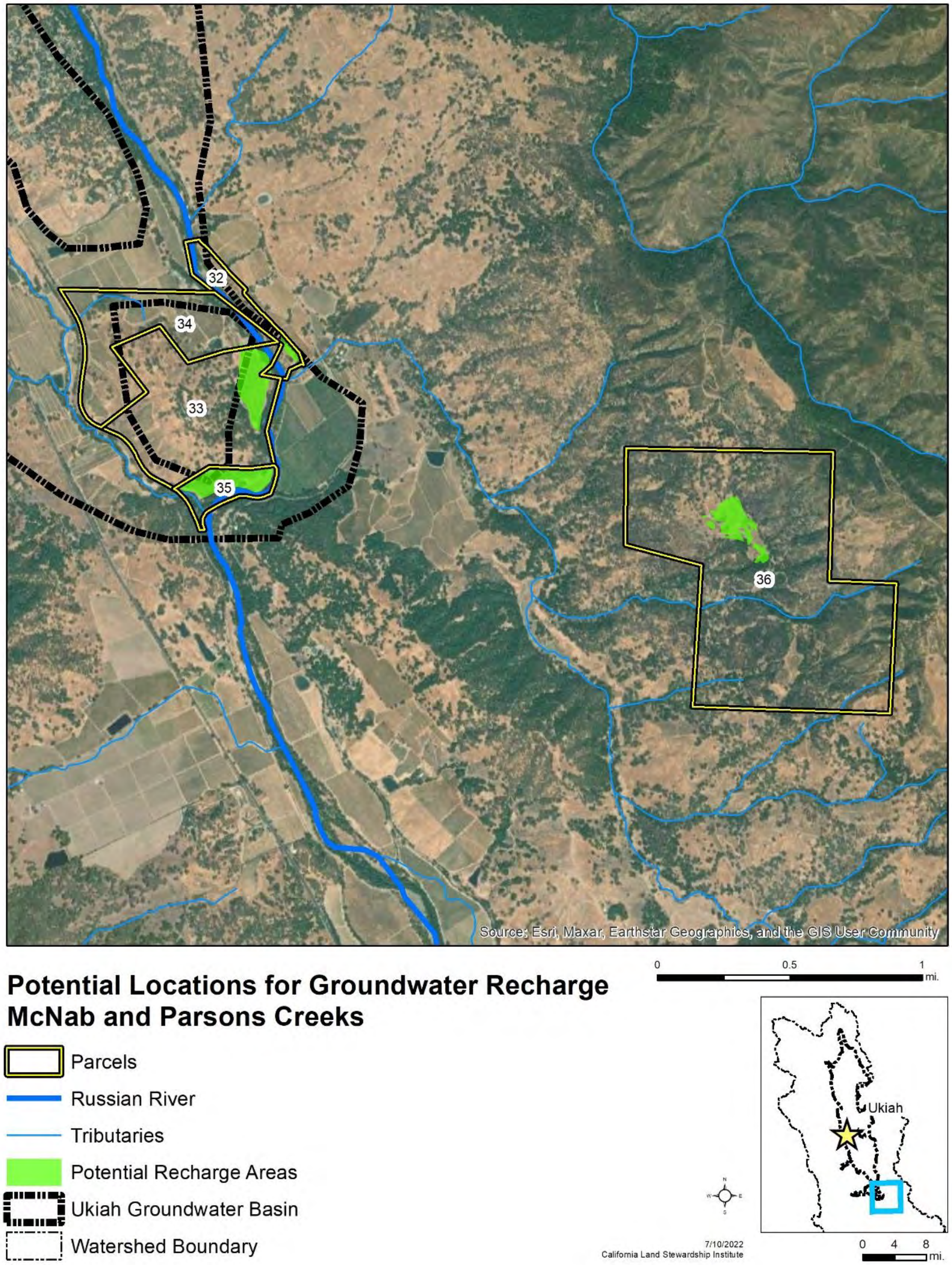


Figure 29. Potential McNab and Parsons Creeks recharge locations.

Alluvial fans

Alluvial fans are conical deposits of cobble, gravel and sand that typically occur where a stream exits a high slope bedrock channel and flows onto a valley floor that is low slope. Stream flow suddenly slows down and deposits its bedload. Overtime this creates a cone of material as the stream migrates over the surface of the fan. This deposit of highly permeable sediment often infiltrates stream flow providing water to the groundwater basin. These fans often have a freshwater pond or wetland at the distal end of the fan where the water exits the fan. These fan areas may provide for a high rate of infiltration of applied water and assist with groundwater recharge.

Figures 30-31 show potential project locations on alluvial fans. For Mill, McClure, Morrison, McNab, Parsons Creeks the potential recharge locations are the same as shown in Figures 25, 28 and 29. Howell Creek is included on Figure 30 but has only several small potential recharge areas.

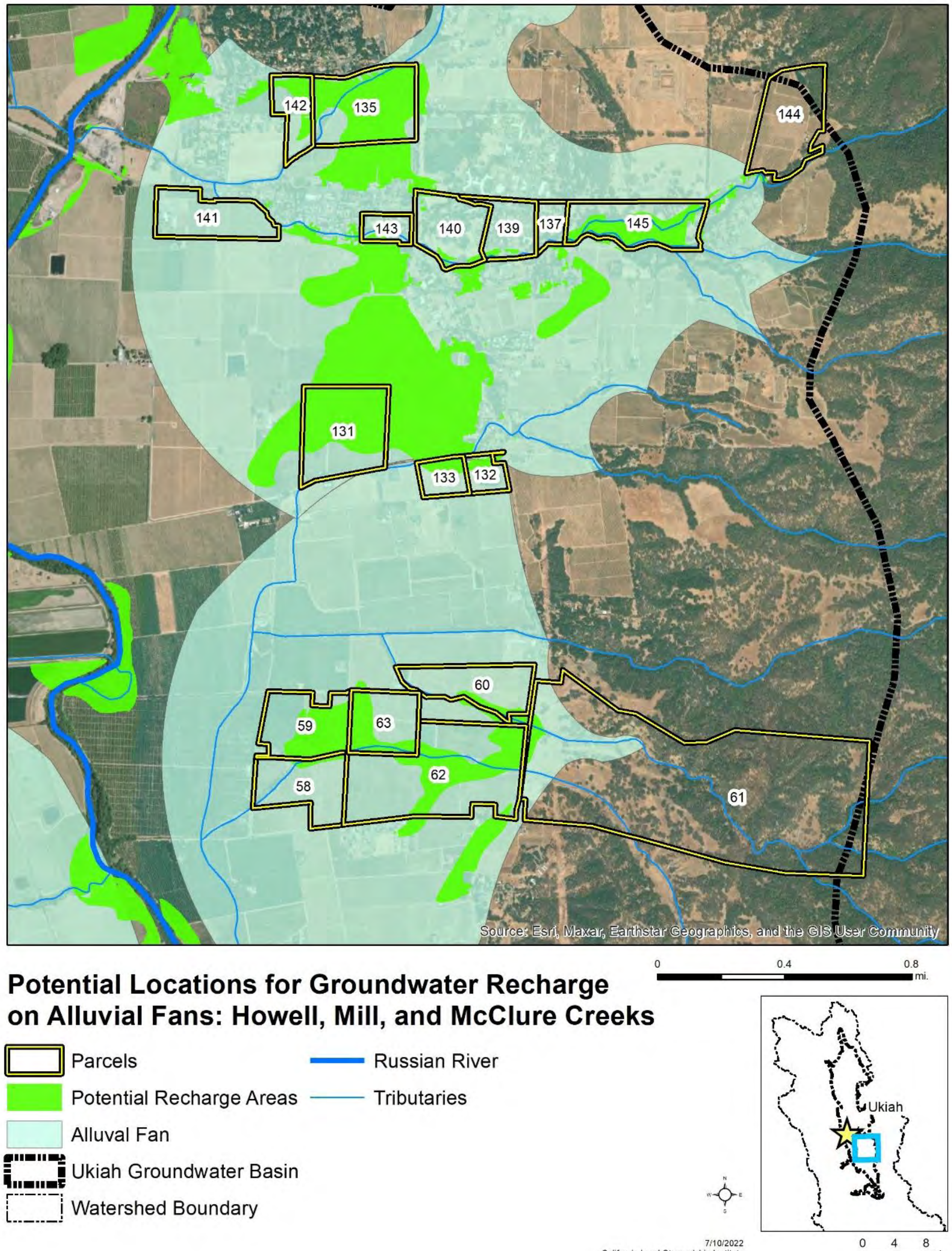


Figure 30. Potential recharge locations on Howell, Mill, and McClure Creek alluvial fans.

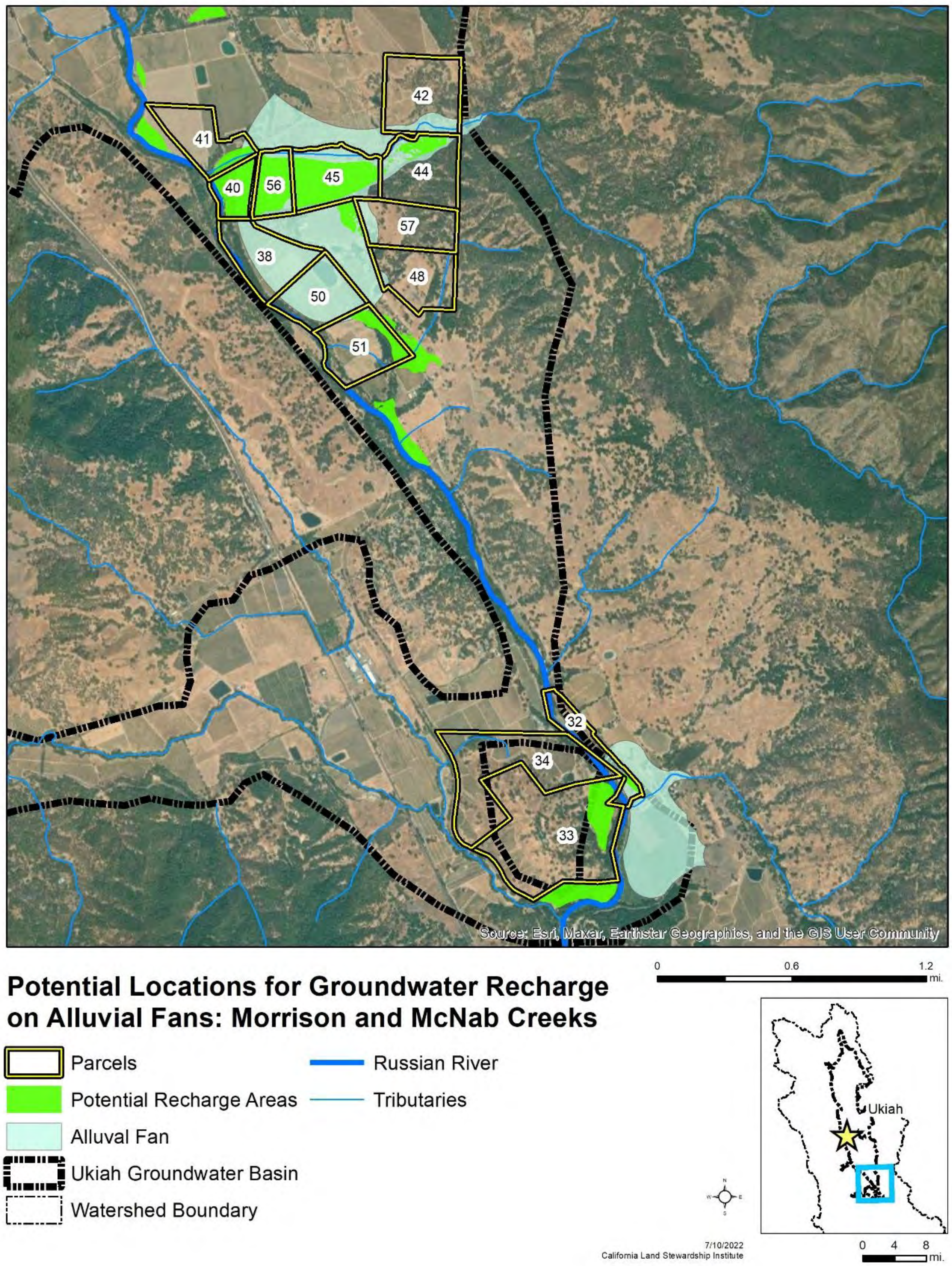


Figure 31. Potential recharge locations on the Morrison and McNab Creek alluvial fans.

Other potential approaches

On-stream reservoirs
Most tributaries of the Russian River in Ukiah Valley lose water to underlying aquifers, and many run dry in the spring in the valley. Extending the flow duration of these tributaries, especially in their mountainous reaches could augment streamflow and recharge groundwater. Mill Creek is ideally suited for this approach, as it already has three on-channel reservoirs that could be utilized.

Vineyard drainage
Hillslope vineyards often have intricate drainage systems that intercept storm water. These operations provide ample opportunity to increase infiltration through basin spreading. Many have already employed catchment basins to catch sediment before discharge into waterways, which may be expanded upon.

<u>Prioritizing Potential Recharge Sites</u>
CLSI organized a meeting with members of the GSA, TAC and the GSP consultants on Sept. 28, 2022. The group had been provided the first report identifying potential recharge areas. The following were in attendance, Laurel Marcus and Brandyn Balch, CLSI; Laura Foglia and Amir Mani, Larry Walker Associates; Supervisor Glenn McGourty, GSA member, Devon Boer, Mendocino County Farm Bureau, Beth Salomone, Russian River Flood Control District TAC member, Sean White, City of Ukiah TAC member, Erik Cadaret, GSA coordinator. Zac Robinson GSA member was invited but did not attend. We discussed the goals of the GSP for recharge projects: manage recharge to increase groundwater flows in the Russian River in the late summer and if possible, extend water availability through the dry season in shallow domestic wells in Redwood Valley or other areas.

The group selected two locations for more detailed review. These are:

- West Fork Russian River
- Morrison Creek

The group discussed the need for analyses of the watershed area draining to the site and hydrologic analysis to determine the amount of available water that could be used for recharge. The group also discussed the need to create an incentive for the landowners involved such as use of a portion of the stored water for allowing use of their land to build a pond.

Table 9 lists the watershed drainage area and flow volumes for various interval floods for Morrison Creek and West Fork Russian River. Appendices 2 and 3 include data for both of these waterways used to create Table 9. Both sites appear to have adequate flow for a diversion to fill a pond for later recharge. However, a water availability analysis, which is a review of how this wet weather diversion would affect downstream water rights holders, would have to be completed.

Table 9. Features of Potential Recharge Sites

Project Location	Coordinates of site center point		Watershed area draining to site	Annual Precipitation	2-year frequency flow	5-year frequency flow	10-year frequency flow	Notes
	Lat.	Long.	Sq. Miles	Inches	CFS	CFS	CFS	
West Fork Russian River	39.31337	-123.218	17.1	48.7	1080	2020	2690	Potential for off stream pond upstream of recharge area, need to look at other water rights and complete water availability analysis. May be able to flood adjacent vineyards also
Morrison Creek	39.08166	-123.145	9.1	45.6	573	1100	1480	Potential for off stream pond upstream of recharge area, need to look at other water rights and complete water availability analysis. May be able to flood adjacent vineyards also.

Data used from: U.S. Geological Survey, 2016, The StreamStats program for California, online at http://water.usgs.gov/osw/streamstats/california.html, accessed on (10/1/2022).

Appendices 2 and 3 include all the data used for this analysis.

Project Concepts

Figures 32a, b, c and-33a, b, c depict concept level drawings for each of the two potential recharge sites.

West Fork Recharge Site
We developed three different locations and sizes of recharge ponds at the West Fork location. A great deal of site-specific data will need to be collected in order to complete an engineered design for a recharge pond. The pond will need a diversion point along the West Fork Russian River with a pump and a pipeline to the pond to fill it. The pond will also need a discharge facility that facilitates groundwater recharge. Water from the pond could be discharged into a cistern, an injection well or other facility depending on site specific conditions. The project may benefit from a covering over the pond to reduce evaporation. This site is located in the northern area of Redwood Valley. Redwood Valley has a large number of shallow domestic wells. Recharging shallow groundwater during the dry season could benefit these wells.

We calculated the number of days needed to fill the pond at a 5 cfs diversion rate for 24 hour/day. Table 9 lists the flow levels on the West Fork Russian River for various frequency flow events. The 2-year frequency flow is 1080 cfs. This is the 50% frequency flow and most likely to occur each year. A 5 cfs diversion was chosen to evaluate the availability of water to fill the pond. A number of hydrological evaluations will be needed to finalize the diversion rate and to determine if the diversion would cause any problems for downstream diverters or instream flows needed for fish and aquatic life.

Figure 32a. Scenario 1 for West Fork Recharge site

Scenario 1 has a perimeter of 1910 feet. Table 10 lists the storage volumes for three different average depths for the pond and the diversion period needed to fill the pond at a 5 cfs rate for 24 hours/day.

Figure 32b. Scenario 2 for West Fork Recharge site

Scenario 2 has a perimeter of 1475 feet. Table 10 lists the storage volumes for three different average depths for the pond and the diversion period needed to fill the pond at a 5 cfs rate for 24 hours/day.

Figure 32c. Scenario 3 for West Fork Recharge site

Scenario 3 has a perimeter of 1391 feet. Table 10 lists the storage volumes for three different average depths for the pond and the diversion period needed to fill the pond at a 5 cfs rate for 24 hours/day.

Table 10. Storage volumes for Scenarios 1-3 West Fork Site.

Scenario	Average pond depth in ft.	Storage Volume in acre feet (AF)	Days to fill at diversion rate of 5 cfs
1	10	26.5	2.7
1	15	39.8	4
1	17	48.3	4.9
2	10	30.9	3.1
2	15	46.4	4.7
2	17	52.6	5.3
3	15	37.9	3.8
3	17	42.9	4.3
3	20	50.6	5.1

Morrison Creek Recharge Site

We developed three different locations and sizes of recharge ponds at the Morrison Creek location. A great deal of site-specific data will need to be collected in order to complete an engineered design for a recharge pond. The pond will need a diversion point either along the Morrison Creek or the mainstem Russian River with a pump and a pipeline to the pond to fill it. The pond will also need a discharge facility that facilitates groundwater recharge. Water from the pond could be discharged into a cistern, an injection well or other facility depending on site specific conditions. The project may benefit from a covering over the pond to reduce evaporation.

We calculated the number of days needed to fill the pond at a 5 cfs diversion rate for 24 hour/day. Table 9 lists the flow levels on Morrison Creek for various frequency flow events. The 2-year frequency flow is 573 cfs. This is the 50% frequency flow and most likely to occur each year. A 5 cfs diversion was chosen to evaluate the availability of water to fill the pond. A number of hydrological evaluations will be needed to finalize the diversion rate and to determine if the diversion would cause any problems for downstream diverters or instream flows needed for fish and aquatic life. Scenarios 2 and 3 also offer the option of filling the pond from the mainstem Russian River.

Figure 33a. Scenario 1 for Morrison Creek Recharge site

Scenario 1 has a perimeter of 1409 feet. Table 11 lists the storage volumes for three different average depths for the pond and the diversion period needed to fill the pond at a 5 cfs rate for 24 hours/day. Scenario 1 would likely use a diversion in Morrison Creek.

Figure 33b. Scenario 2 for Morrison Creek Recharge site

Scenario 2 has a perimeter of 1524 feet. Table 11 lists the storage volumes for three different average depths for the pond and the diversion period needed to fill the pond at a 19.83 cfs rate for 24 hours/day from the Russian River. Scenario 2 could use a diversion from the mainstem Russian River or Morrison Creek.

Figure 33c. Scenario 3 for Morrison Creek Recharge site

Scenario 3 has a perimeter of 1687 feet. Table 11 lists the storage volumes for three different average depths for the pond and the diversion period needed to fill the pond at a 19.83 cfs rate for 24 hours/day from the Russian River. Scenario 3 could use a diversion from the mainstem Russian River or Morrison Creek.

Table 11. Storage volumes for Scenarios 1-3 Morrison Creek Site.

Scenario	Average pond depth in ft.	Storage Volume in acre feet (AF)	Days to fill at diversion rate of 5 cfs
1	10	21.2	2.1
1	15	31.8	3.2
1	20	42.4	4.3
1	25	53	5.3
			Days to fill at diversion rate of 19.83 cfs from mainstem Russian River
2	10	30.4	1.5
2	15	45.5	2.3
2	17	52	2.6
2	20	60.7	3.1
3	10	38	1.9
3	15	57	2.9
3	20	76	3.8

Costs

Construction of a recharge pond will require significant engineering design and permitting before a realistic cost estimate can be prepared. We collected costs for some recent pond construction projects and increased them for inflation. A 15.3 AF pond built on flat ground using all onsite material with no off-site disposal and a liner cost $200,000 in 2014. Using an annual inflation rate of 3% each year for 2015 to 2020 and a rate of 20% for the 2020-2024 period the cost in 2024 (Public Policy Institute of California Economic Policy Center 2024) would be approximately $286,500. This cost does not include the pumps, pipelines, diversion structures and other features needed for the recharge pond.

Another pond was also evaluated. This pond was 50 AF and cost $400,000 in 2009. The pond was built on flat ground with all on site materials and a liner. Using the same methodology as above the cost would be $645,080 in 2024.

II. STREAM REVEGETATION

This section of the watershed plan identifies potential project locations for revegetating tributary creeks in the watershed with native riparian species.

RIPARIAN ECOSYSTEM

The riparian ecosystem occurs along river and creek floodplains and channel margins and near springs and seeps. The trees and small plants that make up this ecosystem require year-round water either from surface flows or relatively shallow groundwater. Riparian plants are not drought tolerant.

The riparian ecosystem is diverse in both animal and plant species. Tall mature trees, dense understory shrubs, vines, herbaceous plants and seedling to small trees of many species provide a variable architecture of growth forms. This variability supports numerous different migratory and resident birds, amphibians, reptiles and mammals. Insects are abundant and diverse.

The extent and quality of this habitat depends on both the condition of the watershed and the geomorphology of the creek or river channel. Channel geomorphology is the result of many features in a watershed including hydrology and geology.

Streamflow in creeks and the Russian River in Ukiah and Redwood Valleys is generated from rainfall and also affected by the interaction of surface and groundwater. In fall/early winter stormwater runoff from the hillslopes and creeks will infiltrate into the alluvium of the valleys. When enough rainfall has infiltrated the groundwater level rises to intersect the stream channel and stream flow occurs. Streamflow will continue after a storm event has ended as groundwater continues to drain from alluvium into stream channels.

Summertime flows in creeks are highly affected by the thickness and permeability of the alluvial deposit, the permeability of the underlying bedrock layer, the annual rainfall and the proximity and size of surface water/groundwater diversions. The Franciscan Complex is the bedrock formation under these valleys, but is not considered a water bearing formation. Low production wells are typical in the Franciscan Complex. Cracks and faults in the rock can produce springs and flow into creeks.

Geomorphology

The heterogeneous nature of the Franciscan Complex has created highly variable stream systems in this watershed. The Russian River Independent Science Panel (2015) completed a classification system for Russian River watershed streams based on geomorphic features. This classification uses the features of the creek that most affect flow processes and sediment transport. One of these features is confinement of the channel by large rock or canyon walls (Table 12 and Figure 34).

Table 12. Definition of Confinement as measured on a 7.5-minute topographic map with a 40 ft. contour interval

Distance between contour lines Map Scale 1"=2,000'	Confinement Class
1/8" or less	Confined
1/8" to 1/4"	Moderately Confined
Greater than 1/4"	Unconfined

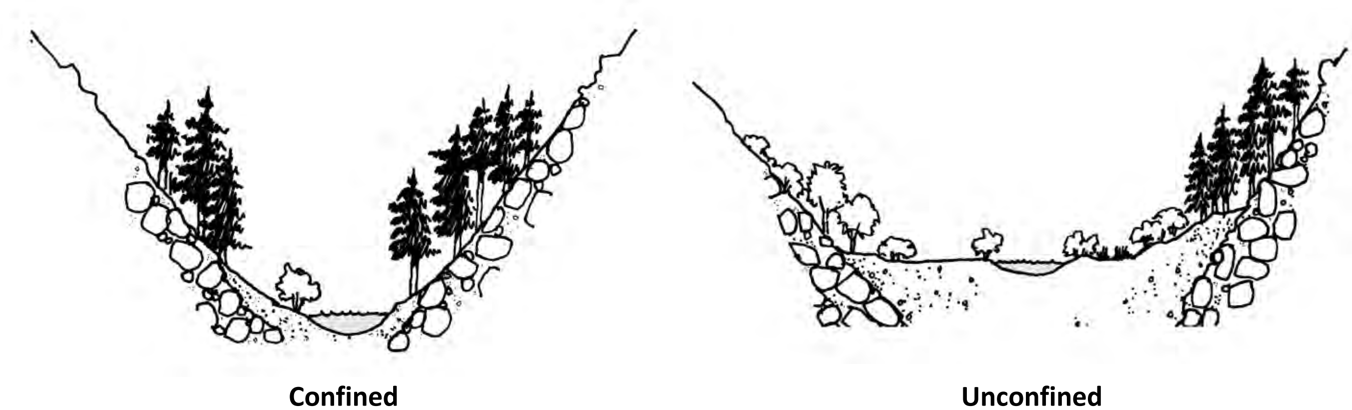


Figure 34. Stream Channel Confinement

Confined Bedrock Channels
Creek channels in the steep mountains along the edges of the watershed are confined by the bedrock that dominates the creek bed (Figure 35). The creek cannot change course and has no floodplain. Stormflows are high velocity, deep and able to move large boulders. Landslides due to undercut streambanks from flood events may occur in confined channels.

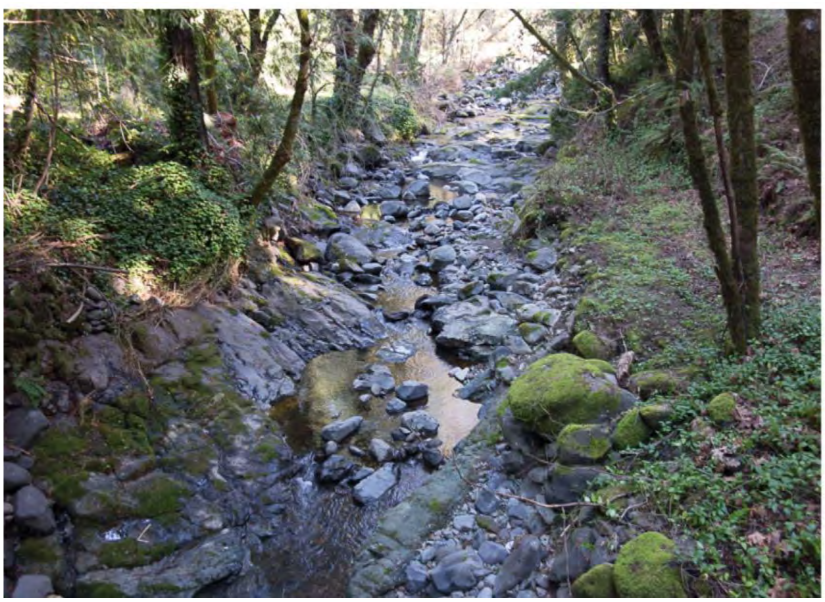


Figure 35. Confined bedrock channel

Semi-Confined Channels
Along the creeks in mountains there are areas where the channel is wider and lower slope and will have gravel bars and a small floodplain (Figure 36). These are semi-confined channels where the stream is still restricted by large rock or canyon walls but not to the same degree as a confined channel.

Figure 36. Semi-confined channel

Unconfined Alluvial Channels
On the floor of Ukiah and Redwood Valleys, creek channels are unconfined with little to no large rock to affect the course of the creek (Figure 37). These creeks have floodplains where storm water overtops banks and spreads out. These channels meander and form gravel bars and pools.

Figure 37. Unconfined alluvial channel

Dynamic equilibrium occurs between the work done (sediment transported by the flow) and the load provided (sediment delivered to the stream from tributaries and hillslopes) (Figure 38). In an equilibrium condition, a stream will have the precise slope needed to produce the velocity to transport the sediment load (Leopold, 1994). Since the river cannot increase, or decrease, the amount of water received in a storm, it adjusts its slope and cross-sectional shape to achieve a balance, or equilibrium condition. These adjustments affect the velocity of the flow which in turn increases, or decreases, the amount of sediment deposited or transported. As channel slope and velocity change, bed and bank erosion may increase causing the channel to deepen and/or widen.

The dependent variables that mutually adjust in the river channel are depth, slope, velocity, and roughness. When the independent variables of flow volume or sediment supply change, the dependent variables adjust. For example, a decrease in sediment supply caused by on-stream dam causes an increase in channel width, or depth, leading to bank erosion as the stream channel makes up for the lower sediment supply by eroding its channel.

The size and frequency of floods affect the size and shape of the river channel. A channel in equilibrium will adjust its width, depth and slope over time to accommodate the dominant discharge, also termed the channel forming flow, or bankfull discharge (Figure 39). This is the most commonly occurring size flow that has adequate power to erode and rearrange the sediment of the channel. For many rivers, this is the 1.5-2.0-year frequency flood. Larger floods spill out of the channel onto the floodplain or valley floor. These processes of dynamic equilibrium in alluvial unconfined channels create streams that meander through their floodplain with channel bedforms such as riffles (channel wide deposit of rock) and pools and gravel bars. These bedforms may support salmonid habitats.

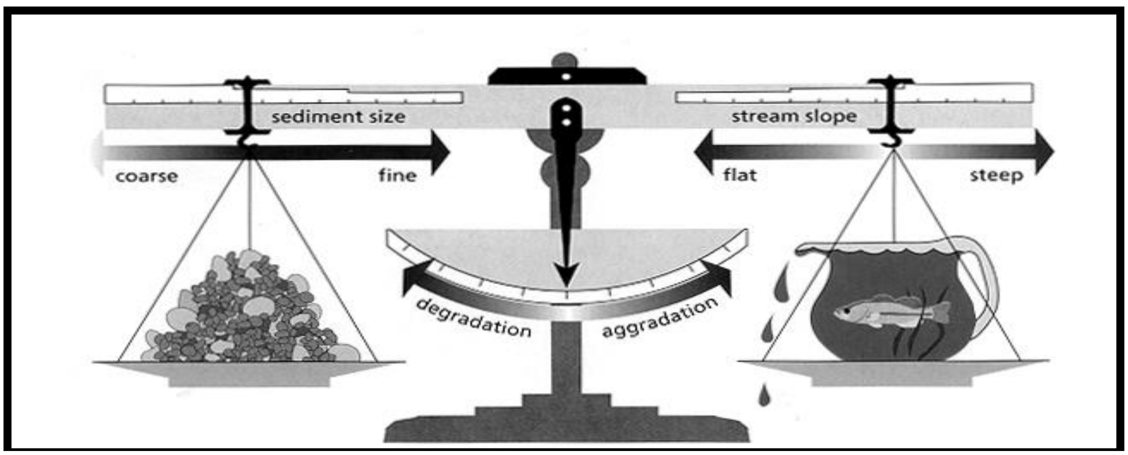


Figure 38. Factors affecting channel degradation and aggradation. The size of the channel is determined by the stream's energy, the slope and the flow of water in balance with the size and quantity of the sediment particles the stream moves.

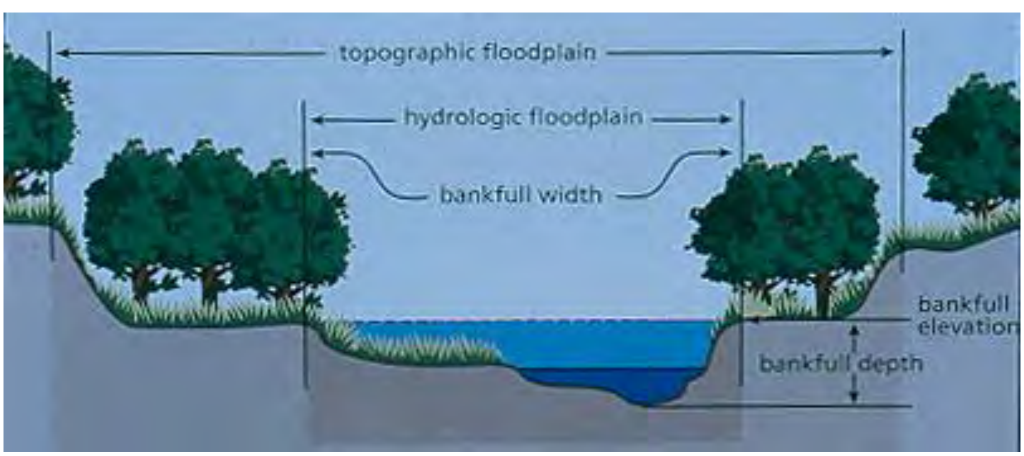


Figure 39. Illustration of bankfull channel.

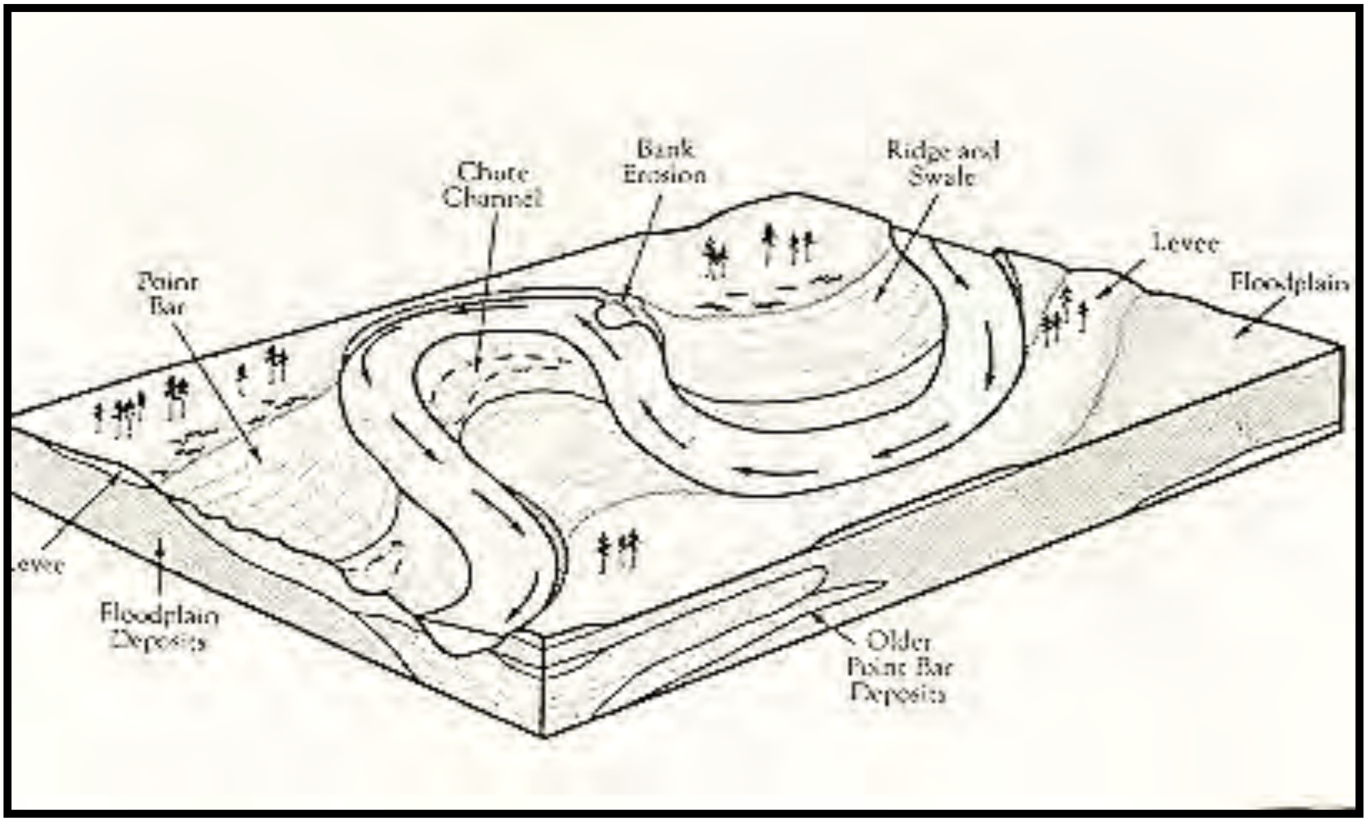


Figure 40. As unconfined alluvial channels meander banks erode and new gravel bars and riffles are deposited

Dissected Alluvium Channels

When the pull apart basins formed and began to be filled with sediment (page 7) two geologic formations were created - Continental Basin Deposits and Terrace Deposits. These sedimentary formations are high in clays and silts with layers of sand and gravel. In some locations in the watershed these layers were uplifted by more recent faulting and creeks cut though the material (Figure 41). These channels are termed Dissected Alluvium Channels.

Figure 41. Dissected alluvium channel on West Fork Russian River.

Alluvial Fan Channels

Located between the bedrock confined channels in the mountains and the unconfined alluvial channels of the valleys are Alluvial Fan Channels. Alluvial fans are cone or fan-shaped alluvial deposits that form at the sharp transition from a steep bedrock canyon and a relatively flat valley floor. Braided or multichannel streams are common on alluvial fans. The Russian River basin is characterized by poorly consolidated rock types, abundant tectonic activity, and infrequent, but intense precipitation, all of which are ideal for alluvial fan formation. Alluvial fans are composed of coarse, unconsolidated, and highly permeable alluvium that becomes slightly finer-grained towards the downstream end of the fan. Consequently, water infiltrates at the head of the fan and water flow becomes subsurface between storm events and during the dry season (Woods et al. 2006, Winter 2007). Water frequently emerges at the base of the fan and forms wetlands.

Figure 42. Alluvial fan channel on Morrison Creek

Riparian Habitat

Following a flood, a layer of new fine-grained alluvium is deposited on floodplains and gravel bars along unconfined alluvial channels. As spring progresses this fresh sediment is covered by wind-blown seeds of willow, Fremont cottonwood and, in some creeks, alder. These three are pioneer species that produce numerous seeds that can grow quickly on mineral soil. The seeds rapidly germinate and begin growing roots. The roots need to chase the groundwater as it recedes with the onset of the dry season. While thousands of seedlings may populate a gravel bar in March only a few will survive the dry summer (Figure 43).

Figure 43. Willow seed on a gravel bar and produces numerous seeding willow

As the pioneer species grow, they increase the roughness in the channel, which is turn slows water velocities and reduces scour. Overtime these trees can establish a thicket of vegetation where organic materials can accumulate. The scour channel migrates away from the thick vegetation over time.

The original plant thicket begins to diversify. Riparian trees such as Ca. buckeye, box elder, big-leaf maple, Ca. black walnut, Oregon ash and valley oak produce fewer, much larger seeds than the pioneer species. These seeds need organic matter to germinate and grow (Figure 44). The seedlings of these trees also have to extend their roots to reach the summer groundwater level to survive the dry season. This second group of trees are less tolerant of the mechanical damage floodwater can cause as well as of long-term inundation. They are more successful growing distant from the scour channel. Figures 48-51 depicts the primary riparian species found in the Russian River.

Alluvial channels and their undeveloped floodplains have variable riparian habitat. There are sloughs and ponds where floods have scoured out trees or the river channel has relocated and left an abandoned channel. Large mature trees border patches of pioneer trees as well as dense tangles of vines and herbaceous plants. Wetlands are common and numerous down and standing dead trees punctuate the floodplain.

Figure 44. Willow can withstand flow velocities up to 6 ft/second. Oregon ash germinates in willow thicket

In contrast to the extensive and biodiverse riparian forest of unconfined alluvial channels and their floodplains, confined and semi-confined channels have narrow strips of riparian forest. In confined bedrock channels trees must germinate and grow amongst rocks located between the channel and the rock walls of the gorge or hillslope of the canyon. This area is subject to scour in flood events. The riparian trees do not extend upslope from the channel as it is too dry and forest trees or chaparral typically occupy this area. Semi-confined channels usually offer a wider area for riparian trees to grow and have lower velocity flows and thus less scour. There is not much room in either channel type for an extensive riparian forest.

Alluvial fans are a unique landscape feature that is fairly common in the Russian River watershed. Alluvial fans typically have several channels and historically supported oak savannah – widely spaced valley or live oak in a grassland setting (Figure 45). Larger channels on the fan may support alders or willow, but due to the high slope in alluvial fan channels these trees are easily scoured out.

Shade Canopy

Riparian forest provides several essential functions to the aquatic ecosystem of the adjacent waterway. Dense summer time canopy of streamside trees shades the steam flow in the creek (Figure 46). This shade will reduce direct sunlight reaching the water and helps to maintain cool water temperatures needed by salmonids. As banks erode, trees fall into the channel changing currents and creating variability essential to high quality salmonid habitat. Riparian forest also produces copious insects which fall into creeks providing an additional food source for fish. Aquatic habitats with riparian forest support the food, water and habitat needs of a wide variety of terrestrial species also (Figure 47).

Figure 45. Alluvial fan channel at Morrison Creek showing oak savannah vegetative cover

Figure 46. Riparian trees shade streams and reduce solar inputs helping to maintain cool temperatures.

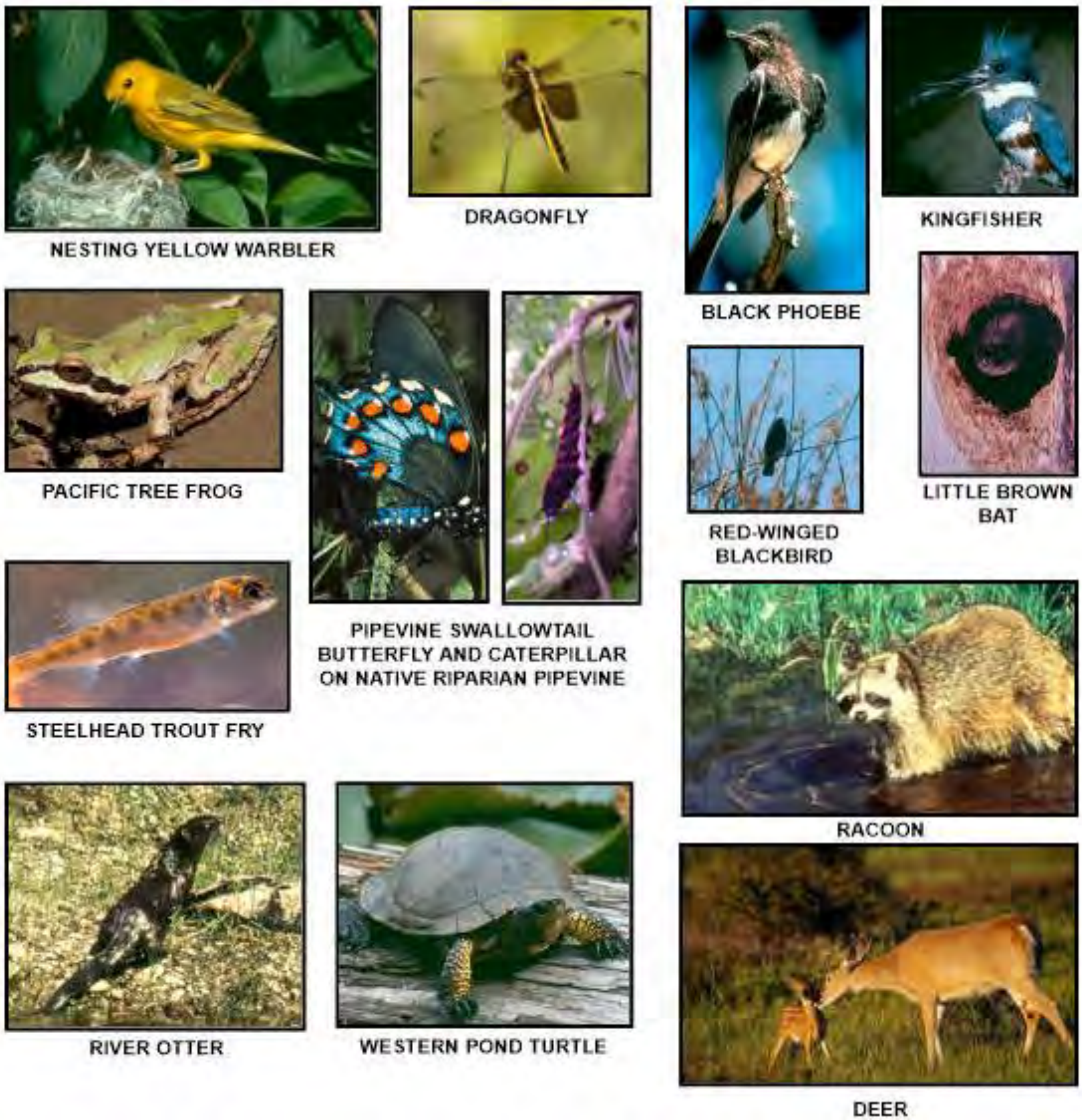


Figure 47. Riparian wildlife

Willow (*Salix spp.*)
Range: Interior and coastal northern California as well as the central valley and southern California.
Description: Willows have the unique ability to actively propagate in and around the bankfull channel. They are remarkably tenacious and can withstand the inundation and the high velocity of floodwaters. Their wood is soft, light and able to bend in high flows. Their deciduous leaves vary in form, but are frequently long and narrowly pointed.

White Alder (*Alnus rhombifolia*)
Range: From northern Idaho southward through the California Coast Ranges and western slopes of the Sierra Nevada.
Description: White alder have mottled gray bark with flecked branches and shiny, dark green leaves. Leaves also tend to have a toothed border. They grow 30 to 40 feet high and 8 to 12 inches in diameter. Mature cones are shed in midwinter. White alder commonly grow adjacent to the low flow channel.

Fremont Cottonwood (*Populus fremontii*)
Range: Sacramento Valley and Coast Ranges in northern and southern California. Found on open gravel bars and mature riparian forests.
Description: Bark is thick, dark, deeply furrowed and boldly ridged. Winter buds are light green, hairless, and about ½ inch long. Leaves are 2 inches long. Cottonwoods grow up to 120 feet high and are in the same family as willows. Cottonwood is one of the colonizer species able to germinate next to the bankfull channel.

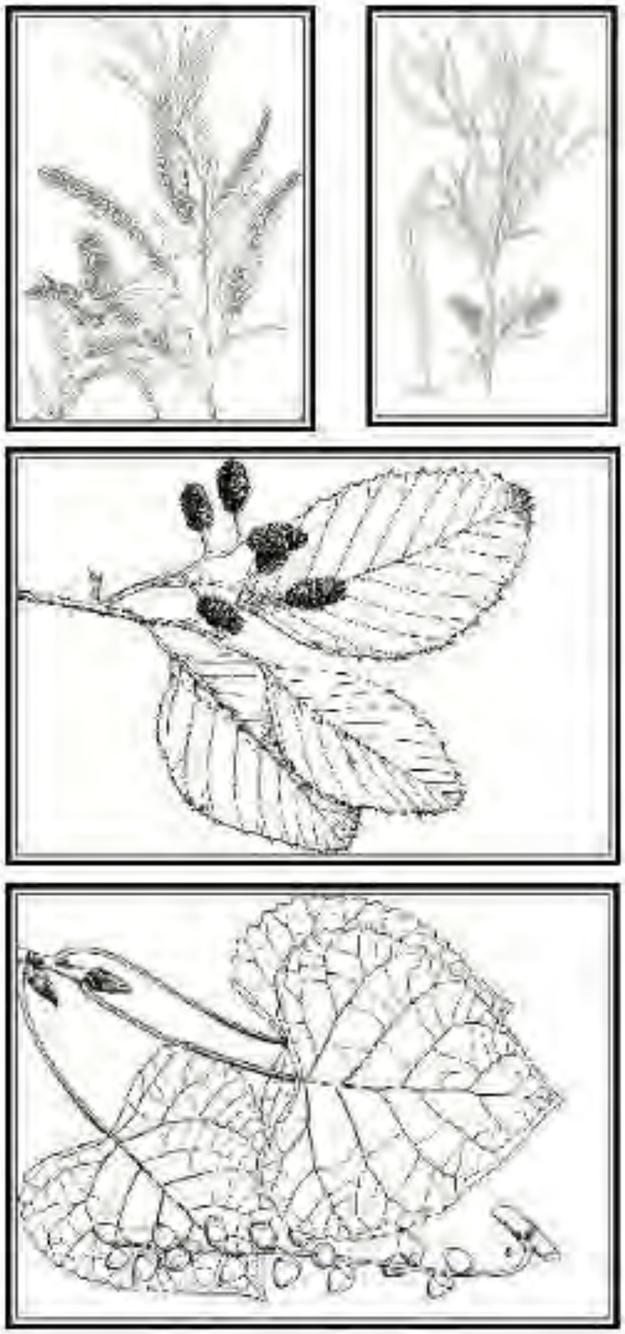


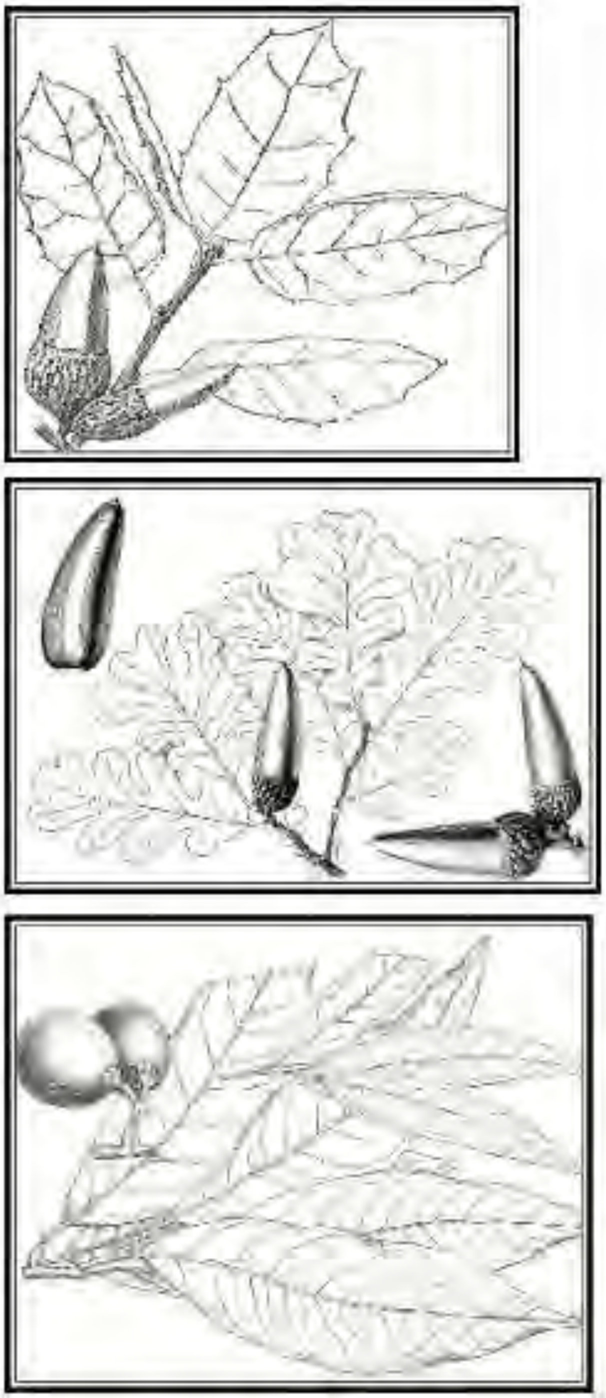
Figure 48. Riparian pioneer species

California Black Walnut (*Juglans californica* var. *hindsii*)
Range: The original distribution of California black walnut was limited to Walnut Creek, Atlas Peak and Gordon Valley in Napa County, and the lower Sacramento River. The native walnut was used extensively as a rootstock for English walnut orchards and has naturalized in many areas.
Description: Walnuts have compound leaves made up of 9-17 pointed leaflets. Walnuts grow very quickly as saplings and then much slower as mature trees. Black walnuts drop into creeks and rivers and are distributed to new growing areas.

Box Elder (*Acer negundo*)
Range: Coast ranges from Sonoma to Santa Barbara Counties.
Description: Box elder is in the same family as the maple. These trees grow from 20 to 50 ft tall with separate male and female flowers and numerous seed pods produced on female trees. Box elder grows away from the active channel in areas of the riparian corridor less prone to scour and high water.

California Buckeye (*Aesculus californica*)
Range: Coast ranges from Mendocino County to San Luis Obispo County, Sierra foothills and parts of southern California.
Description: California buckeye has distinctive leaves with five leaflets. Buckeyes are one of the first of the deciduous trees to leaf out. Buckeye has numerous spikes of white flowers which produce leathery hulled fruits. Inside each fruit is a single shiny brown seed which gives the tree its name. This tree avoids the drought of summer by going dormant as early as July in very dry areas.

Figure 49. Riparian mid and upper bank and floodplain species



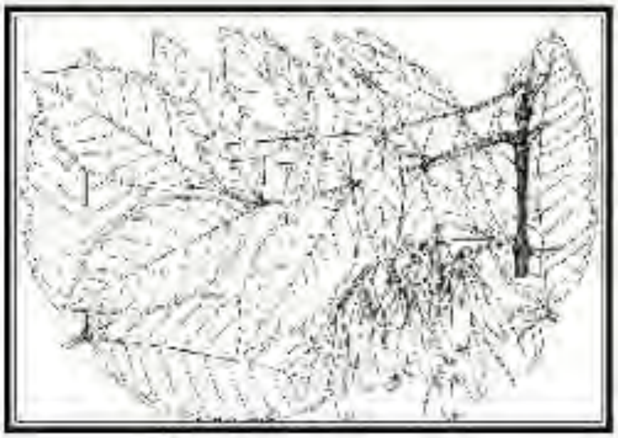
Coast Live Oak (*Quercus agrifolia*)
Range: From California Coast Ranges south down to Baja California, Mexico.
Description: The coast live oak (also known as the California live oak) is found in a variety of habitats, including well-established floodplains and mountains up to 4500 feet. The characteristically long and crooked limbs branch out from the short trunk. Its leaves are hard, waxy, convex in shape and generally a dark shiny green. Coast live oaks grow to 25-50 feet in height and 1-2 feet in diameter.

Valley Oak (*Quercus lobata*)
Range: Floodplains and valleys of the California Coast Ranges and western foothills of the Sierras extending south to Santa Monica, California.
Description: The valley oak is the largest of the western oaks ranging from 60-75+ feet in height with a diameter of 30 to 40+ inches. It loses its mature leaves in the fall and produces acorns in large quantities. Valley oak occupies the outermost portion of the riparian corridor and when eroded into the stream channel provides large wood for steelhead habitat.

California Bay Laurel (*Umbellularia californica*)
Range: From southwestern Oregon down to the southern border of California.
Description: The bay laurel is an evergreen tree growing to heights of 120 feet and up to 4 feet in diameter. It occurs in floodplain riparian forests as well as mixed evergreen forests and other upland areas. It is a slow growing tree that lives for hundreds of years. Leaves have a pungent camphoric odor and seeds ripen in the fall.

Figure 50. Riparian mid and upper bank and floodplain species

Big Leaf Maple (*Acer macrophyllum*)
Range: From the coast ranges of British Columbia through Washington, Oregon down as far south as San Diego County, California.
Description: Bark of this deciduous tree is brown or bright reddish brown and deeply furrowed. Palmate leaves are 8-12 inches long, flowers bloom in drooping spikes 4-6 inches long. Fruit has distinctive two-wing structure, about 1½ inches long. These trees grow 30-50 feet in height and have been known to live 150 to 200 years or more. Maple can tolerate greater amounts of shade than many riparian species and lives in the midlevel and outer riparian corridor and floodplain.



Oregon Ash (*Fraxinus latifolia*)
Range: Coastal ranges of Washington, Oregon and northern California.
Description: This widespread tree is used as a hardwood for furniture. Oregon ash can grow to 75 ft. tall and live over 200 years. Oregon ash grows in moist streamside areas away from the active channel and prefers full sun. This ash produces large volumes of seed on female trees.

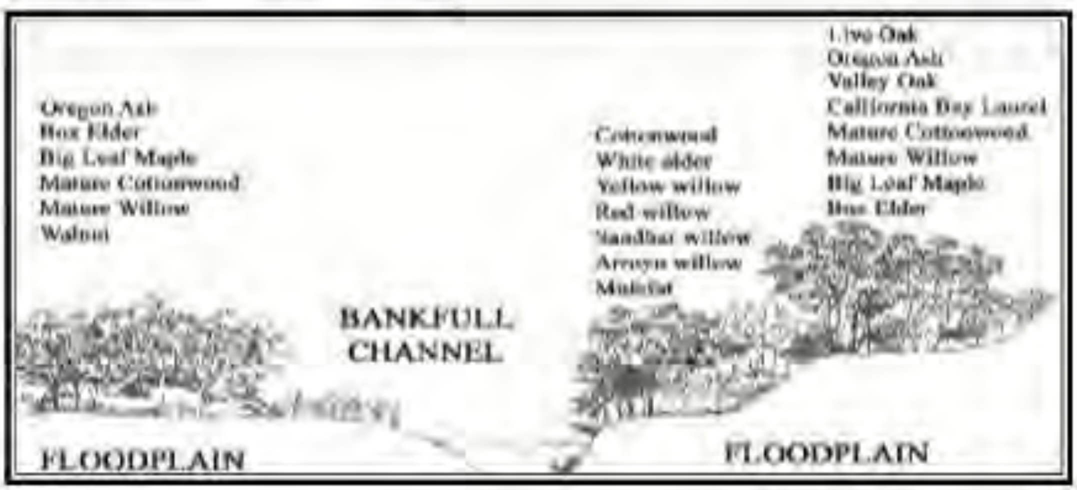


Figure 51. Riparian mid and upper bank and floodplain species

HISTORICAL CONDITIONS

The Ukiah Valley Groundwater Basin watershed has undergone significant changes in the past 170 years. These changes have resulted in alluvial unconfined creek and river channels that are highly incised, disconnected from their floodplains, no longer in a state of equilibrium and unable to sustain riparian habitats. Summer time flows on the Russian River have increased, a change that supports some riparian growth.

Tributary Creeks

Based on geology, stream gradients, and channel types, we can speculate on pre-development conditions of creeks in this area. It is likely that the numerous bedrock canyon channels along the western side of the Ukiah and Redwood Valleys had flow during the summer due to cooler, fog-induced conditions as indicated by the occurrence of redwood forest. The eastern mountain streams may have had summer flows in the bedrock channels. However, the eastern mountains are also covered in drought tolerant vegetation and some creeks may not have supported perennial flows. Semiconfined alluvial channels occur on four creeks on the western side of the valley. These channels may have supported year-round pools if the alluvial deposit was deep enough to provide groundwater. The dissected alluvium channels on the West Fork Russian River, Mariposa, Salt Hollow, McClure, McNab and Mill Creeks are relatively low slope and, cut through the Consolidated Basin and Terrace Deposits and could have had summer pools. Alluvial fan channels would not have supported summer pools. The unconfined alluvial reaches of tributary creeks may have had summer pools during high rainfall years, but likely were dry many years.

Russian River

The Russian River once had a wide, shallow channel with a floodplain covered in riparian forest and wetlands. The channel likely was braided, or several parallel channels existed. Figure 52 is a photograph of the Perkins St. bridge over the Russian River. Groundwater likely filled the pools in the river in summer during years of average or above average rainfall.

Historically summer flows in the Russian River depended on groundwater inputs typically creating low to no flow conditions (NMFS 2008, USGS 1913). An 1851 journal from the expedition of Colonel Redick M'Kee, a U.S. Indian Agent, observed the Russian River on August 24-25 as *"a completely dry channel"*. The river in Ukiah Valley is described as *"Above here the river during the dry season runs chiefly under the sand and gravel only to be obtained in occasional pools"* (Gibbs 1852). Rainfall records in San Francisco for 1851 show a dry year.

Oral histories recorded in the early 1990s of long-time Ukiah Valley residents describe conditions in the river and its floodplain (Chocholak 1992). Agricultural development began between 1850 to 1860 with hay, grain, hops, and livestock. Hops require a large labor force and families came to the area and stayed for several months.

One resident remembered, *"Everybody would get their chores done in the morning and they would go down to the river and play and dive and swim underwater... Those were great days when we had all these people enjoying the river" (David Sagehorn)* (Chocholak 1992*)*. This account indicates there were deep pools in the river in summer.

Another interview describes the river bed as 8 to 12 feet higher than today, *"we used to be able to drive across it almost any place you wanted" (Morgan Ruddick)*.

Figure 52. Historic photograph of the Perkins St. Bridge over the Russian River. Note the wide, shallow channel. Date unknown.

The floodplain held many sloughs *"...with large bunch grasses and climbing wild grapevines up in the oak trees and ash trees" (Nelson Redding). "The farmers had to farm around the sloughs, they didn't have the machinery to level the land. Even in those years the farmers would work on the river banks. They would cut the trees and make barriers to stop erosion."…there was a lot of land between the agricultural crops and the river" (Nelson Redding).*

Native Cultural Practices

A number of native California Indian tribes live in the Ukiah and Redwood Valleys. These tribes are well known for the beautiful baskets they weave from certain riparian plants such as willow, basket sedge and others. Upland plants such as redbud are also used. The basket makers tend to the plants to provide straight growing roots for the baskets. Plants are tended and collected at specific time in the season. Baskets were used for food gathering and cooking, fish traps, carrying infants and religious ceremonies. The cultural practice of tending and collecting plants and creating baskets was a central and important part of tribal life and continues today.

HISTORIC CHANGES

With development of the Ukiah and Redwood Valleys for agriculture and housing starting in the 1850's, local native California Indian tribes lost access to their tribal lands including riparian corridors essential to basket making.

Figure 53. The Ukiah Valley in the late 1800's

The Potter Valley Project changed summer flows in the Russian River. Warmer water and elevated summer flow velocities have degraded the habitat quality of the main stem for salmonid species (Steiner 1996). Although changed by the Potter Valley Project, the Russian River continued to have riffles, pools, and gravel bars and a floodplain with sloughs into the 1940s. However, with the availability of heavy machinery such as bulldozers, a variety of bank stabilization and channel clearing activities occurred in the post World War II years.

"They didn't think about cleaning the river up like they do now, go down there with a cat and pick out all the little islands in the river and what not. In some ways it was a good deal and, in some ways, it was a bad deal. Those little islands out in the river slowed the water down some on the banks. When they took those all out, of course, that made the river kind of speed up quite a bit and it ate more at the banks. I think that's one thing that caused a lot of erosion of the river banks" (Marjorie Hetzel) (Chocholak 1992*).*

"If you look at it now, you'll find the river doesn't have the vegetation it used to have...it's all fast water. There's nothing to bump up against...there used to be holes. They cleaned out the debris that makes those things"(Clarence White) (Chocholak 1992*).*

"In our valley the river will run from a mile to four or five miles in width and the river is very crooked. It will first hit one bank and then hit the other, and it is very hard for a person to control the banks. The greatest danger we have is in a crooked stream, when it hits one side, it diverts directly back to the other. After a while it gets deep enough in the turn, it is very apt to go directly over and isolate a large piece of land" (Leslie Crawford 1938) (Kaplan 1979).

"*Practically each and every farmer on the Russian River has his own particular fight with that old monster* (river)*, because she has shown herself to be a monster. Our ranches are going downstream and we haven't the finances or the strength or the intuition or anything else to combat them alone; we need help" (Edward Dutton 1938)* (Kaplan 1979).

The Army Corps of Engineers constructed the Russian River Channel Improvement Project between 1956 and 1963. The project involved dredging the river channel to create a trapezoidal channel with a uniform bottom width, side slopes and bottom slope (Figure 54). Creation of the channel involved straightening the river and removing riparian vegetation, gravel bars, stumps, wood, snags and brush (Pace 1949). The channel was then stabilized with the installation of metal jacks on erodible banks, flexible fence training structures where banks were undercut, and gravel and wire mesh bank revetment to maintain the new alignment. The purpose of the channel improvement project was " to stabilize stream flow and to reduce the tendency of the stream to meander" (Pace 1949).

A series of floods in the 1930s and 40s and a growing demand for urban and agricultural water supply prompted the construction of the Coyote Dam on the East Fork Russian River in 1959 creating Lake Mendocino. The maximum storage capacity of Lake Mendocino is 122,000 AF. Dam operations reduce peak flood flows, prolong high flows in the winter and augment summer baseflows increasing water temperatures in the river (Steiner 1996).

The combination of Coyote Dam reducing sediment supply to the river, gravel extraction directly removing bedload, and the clearing, straightening, and stabilization of the river channel by the Army Corps of Engineers brought about significant channel entrenchment (Figures 55 and 56).

"Relative to 1965, I am a firm believer that the level of the water course is lower than it was earlier... We've noticed that our gravel bar, we do have a gravel bar which we've never extracted from, it is now scoured very badly in the last few winters. The reason for that is, it was high ground and it is now being cut and deposited someplace downstream" (Malcolm King) (Chocholak 1992*).*

Florsheim & Goodwin (1993) compared surveys of the Russian River channel done by the Army Corps in 1940, a 1979 FEMA survey, and a 1985 Mendocino County survey and concluded that at least 18 ft. of incision in the main river channel and 10 ft. in the West Fork had occurred. Channel entrenchment reduced the bed formations (pools, riffles, gravel bars) in the main stem and created a deep channel with steep vertical banks and limited riparian canopy. The former floodplain, the valley floor, became disconnected from the river channel. The drop in base level in the main stem migrated up alluvial tributary channels such as the West Fork causing further incision, loss of bedforms and resulting in impacts to infrastructure and loss of riparian habitat.

The California Department of Water Resources (1984) surveyed a number of tributary streams between 1980 and 1982 and found channel incision in Hensley, Ackerman, and Robinson Creeks. Between 1970 and 1990, the river incised about 5 feet at the City of Ukiah well (Philip Williams & Associates 1997). Grade control structures were installed in Ackerman and Hensley Creeks in Ukiah to protect road bridges from undercutting as the main stem entrenchment moved up tributaries. The Willow Water District rubble dam was installed to increase the water level in a near-channel well field. Due to entrenchment of the channel, the rubble dam has a vertical depth of over 7 feet (Florsheim and Goodwin 1993).

Flood control operations of Coyote Dam can exacerbate channel erosion. The reservoir reduces releases during periods of intense rainfall and then once the storm has passed the flood pool is emptied through a release of up to 6,500 cfs that will not cause downstream flooding (Kaplan 1979, USACE 1965a). Studies have shown that bank erosion occurs at 6,500 cfs (Entrix 2000). There are sections of the main stem river which no longer have gravel bars and where bank erosion occurs frequently.

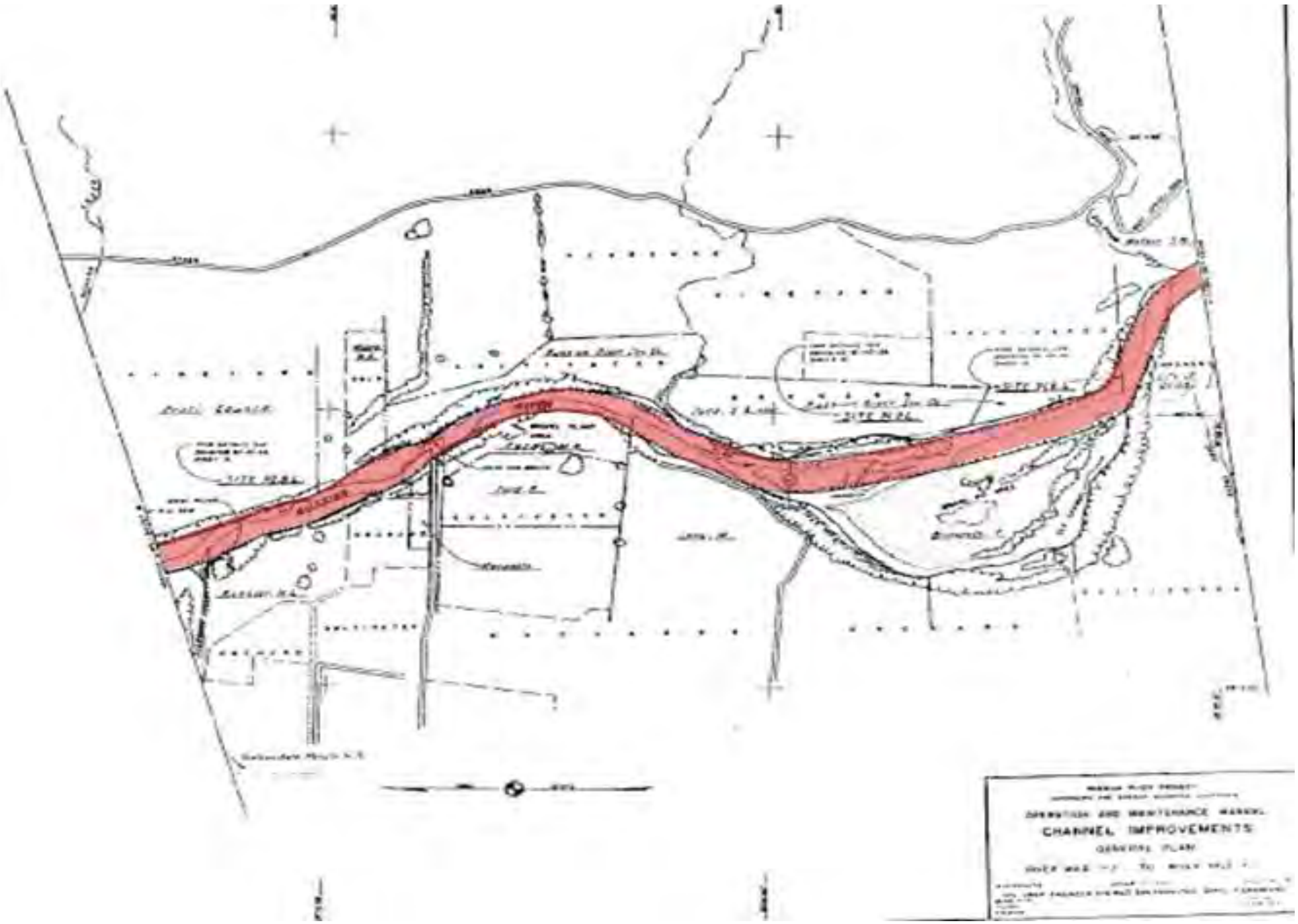
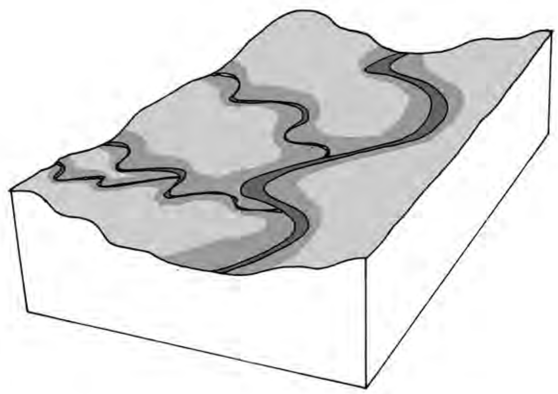


Figure 54. Drawing of pilot channel portion of Russian River Channel Improvement Project in Ukiah Valley subarea. Note the difference in width between the pilot channel (shaded in red) and the natural meandering channel. Once the pilot channel was created the wetland and riparian habitats on the floodplain were changed to agricultural and residential uses



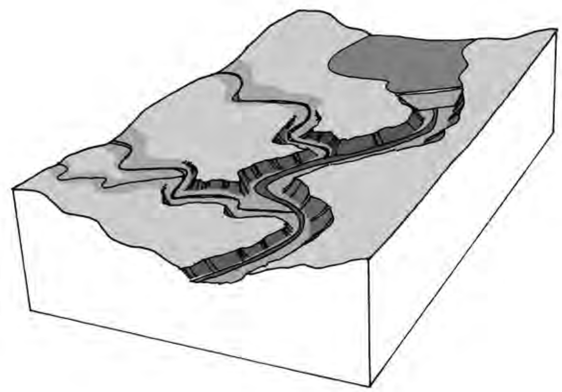


Figure 55. Depiction of Russian River before and after the construction of the Coyote Dam. As the main stem entrenches the change in base level cuts back up tributaries.

Figure 56. Channel incision on the Russian River downstream of Coyote Dam after a wet year.

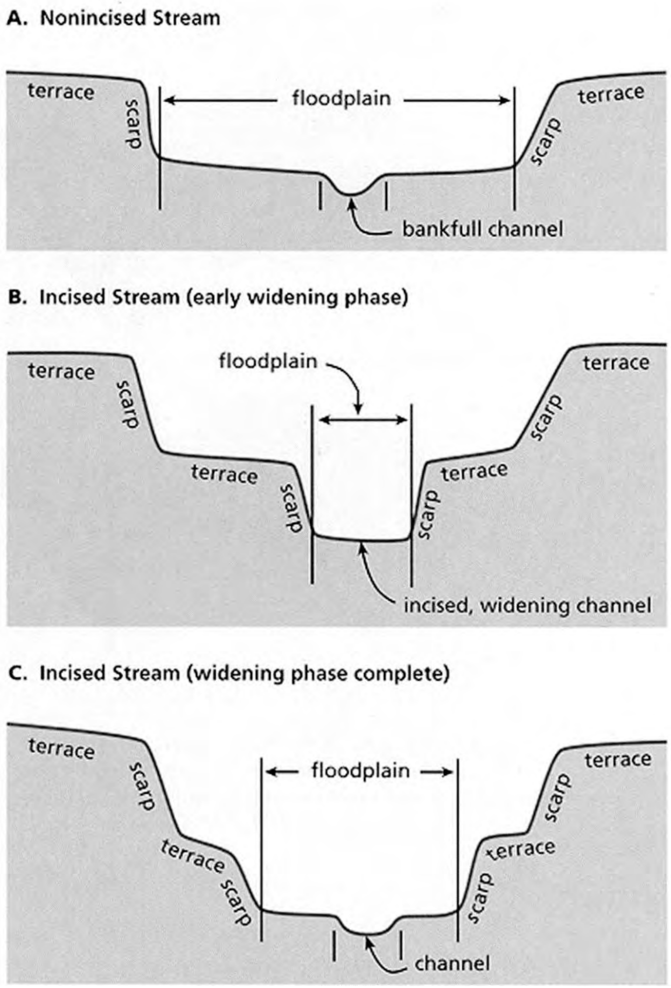


Figure 57. The incision process in unconfined alluvial channels

Figure 58. Post incision channel showing newly formed floodplain within the incised channel

THE INCISION PROCESS

Entrenchment of the Russian River has occurred through flood events which erode and transport more sediment from the channel than is provided from the watershed. As the channel entrenches and deepens into its floodplain, flood flows are confined within the channel increasing erosion and further deepening the channel. Eventually the riverbanks, made of sand, gravel and silt, become too tall and fail during a flood, thus widening the channel. The deepening and widening of the channel will continue until a new lower elevation floodplain is formed where flood flows spread out and slow down reducing erosion of the channel (Figures 57 and 58).

The Russian River channel in its alluvial valleys is still undergoing the incision process. As deepening and widening occurs, landowners and agencies typically install rock riprap or other hard materials to reduce channel widening. Rock riprap increases the velocity of flood flows resulting in increased erosion of banks downstream. There is less clearing and straightening of the river channel now than in prior years.

Eighteen to twenty feet of incision of the main river channel has occurred in the Ukiah Valley. Incision in the West Fork of the Russian River in Redwood Valley has also occurred as the drop in base level in the main stem river has migrated upstream into the West Fork. Many tributaries to the river are incised in their alluvial channels in the valleys. It is likely that the river channel will continue to deepen and widen at high flows and will continue to experience a lack of adequate sediment supply due to the long-term effects of Coyote Dam. The continued incision in the main stem will continue to affect tributary streams as incision propagates upstream, undercutting infrastructure, and eroding acres of private land and habitat.

Effects of Channel Incision on Groundwater Levels

Incision lowers the elevation of the river bottom. The low point in the channel defines the dry season elevation of the groundwater table in unconfined alluvial aquifers such as occur along the Russian River (Figure 59). In the dry season, the elevation of the surface of the groundwater table will correspond to the low flow channel or roughly the bottom of the incised river channel. If there is significant flow in the channel, the elevation of the surface of the groundwater table will match the water surface elevation in the river channel. The effects of channel incision on groundwater levels in alluvial aquifers has been documented for numerous other rivers and streams.

Effects of Channel Incision on Habitats

Incision of the Russian River channel has disconnected the channel from its floodplain and concentrates flood flows into the channel. Riparian and aquatic ecosystems depend upon equilibrium channel conditions with frequently inundated floodplains for seed germination, ecological succession and recruitment of large wood into the channel. The formation of pools and riffles in alluvial channels, important to salmonids, requires meandering and sinuosity in the channel. Straightened, incised channels often have flow velocities that scour out riffles, gravel bars and riparian trees. With no floodplain next to the channel, the riparian trees lack flat locations for germination. Collapse of the tall vertical banks covers spawning gravel with fine sediment and can fill pools further impacting salmonid habitat. Natural adjustment of the current Russian River channel to an equilibrium condition could require hundreds of years given likely continued bank stabilization efforts and scour-inducing dam operations.

Changes to groundwater levels associated with changes in river stage also affect the growth of riparian trees and flow in tributary streams in the Ukiah/Hopland area. Jackson and Marcus (2004) studied Morrison and Parsons Creeks to determine factors limiting establishment of riparian vegetation along these creeks. One of these factors is depth to groundwater. Incision in the main stem lowers the spring water table and riparian trees may not produce roots fast enough in spring to reach the lowered groundwater level. This study installed several monitoring wells along the length of the unconfined alluvial channel of each creek. Measured groundwater levels were correlated to stage in the main stem as recorded at the USGS Hopland gage. Additionally, three series of paired four- and eight-foot-deep trenches were dug along Parsons Creek and dormant willow poles were installed during winter. All the willows leafed out, but those closest to the river channel all died. Willows farthest from the river channel all survived. Figures 60 and 61 depict the creek groundwater measurements and Russian River stage at the Hopland gage. This particular study was done in a year with little spring runoff and demonstrates the problem of disconnected flows between the entrenched main stem river and tributary streams.

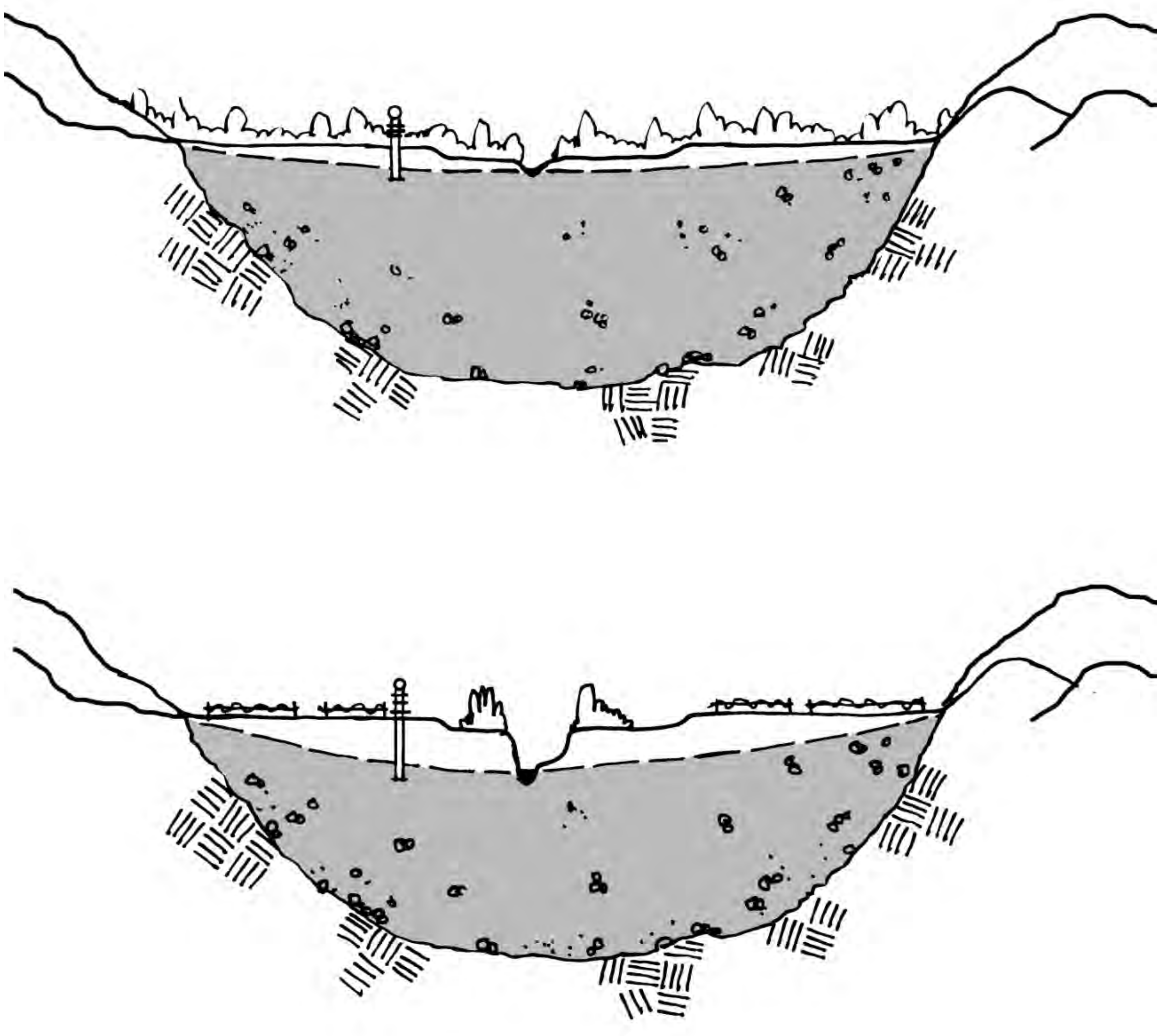


Figure 59. Decrease in the level of the groundwater table in an alluvial valley with entrenchment of the river channel.

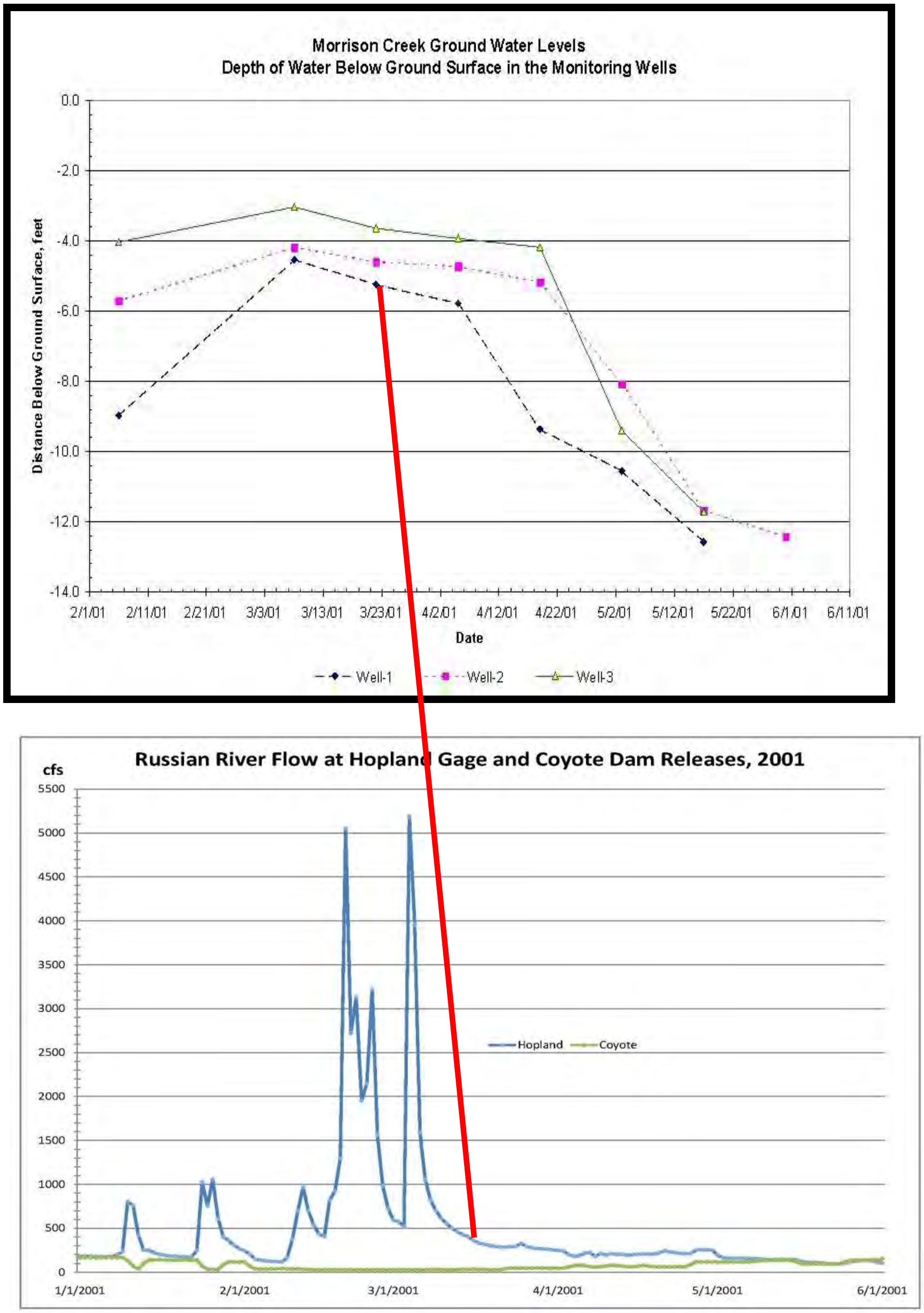
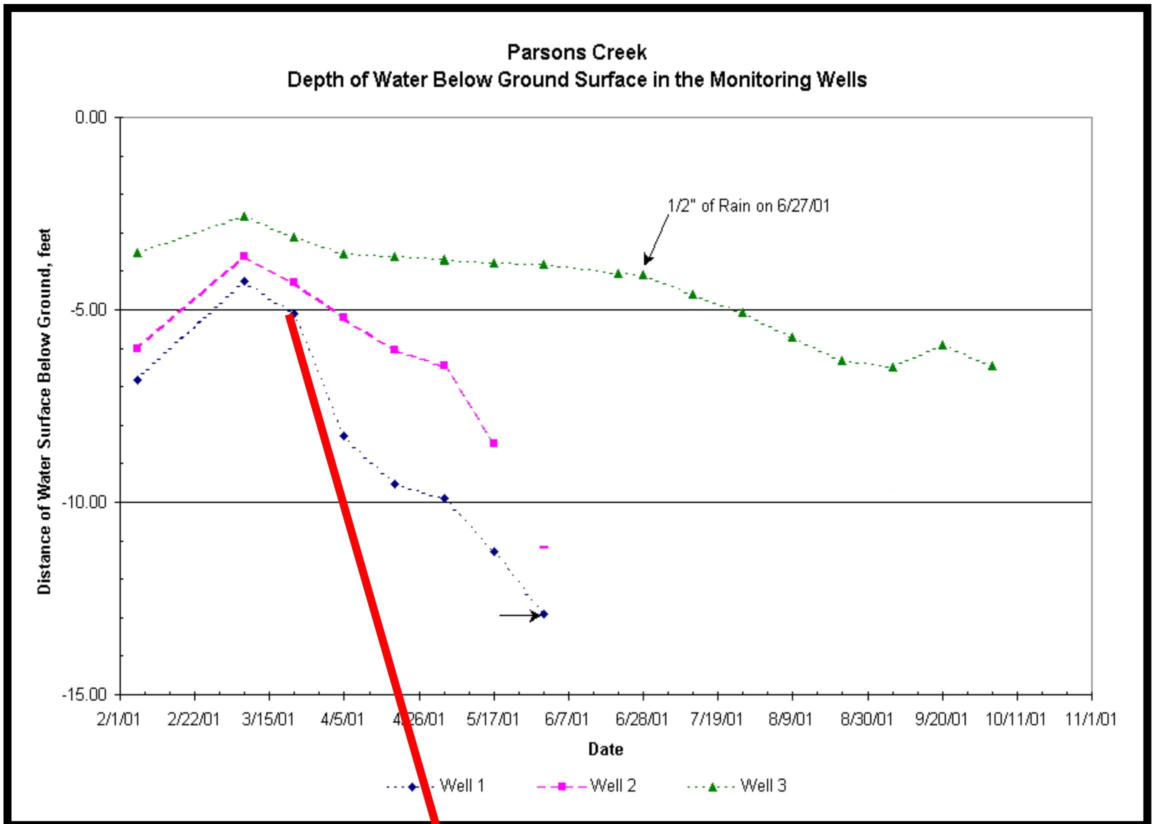


Figure 60. Morrison Creek groundwater level and water flow (cfs) in the Russian River. The March 2001 drop in groundwater levels in Morrison and Parsons Creeks coincides with the drop in flow levels in the main river channel and is the greatest in the well located closest to the Russian River (well 1). Surface flow in both Morrison and Parsons Creeks went subterranean as the water level in the river dropped. No juvenile steelhead could have migrated out of these creeks in late March.



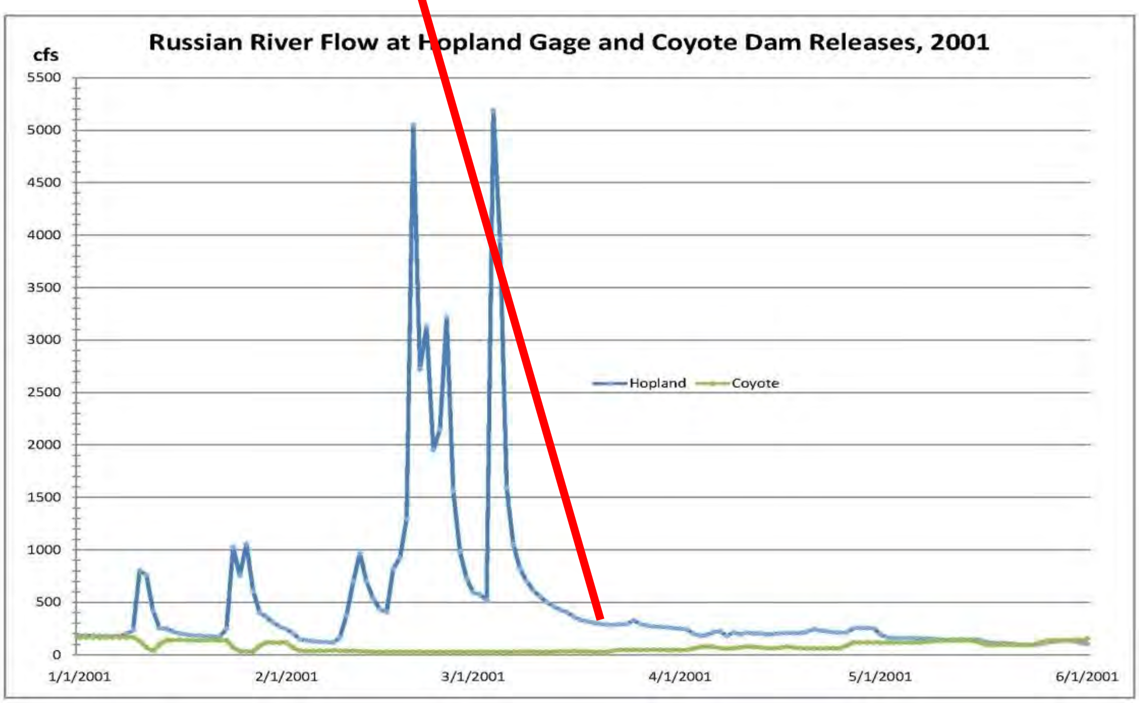


Figure 61. Parsons Creek groundwater level and water level in the Russian River. Well 1 is closest to the river.

Tributary Creeks

Streams tributary to the Russian River have been altered to a varying extent. The unconfined alluvial reaches of many tributaries were straightened or confined by levees, and riparian vegetation was removed to conform to property boundaries and maximize arable or buildable land. Many alluvial reaches that were historically meandering, or had distributary channels, were straightened, rerouted, and/or confined by levees (for example Morrison Creek, Figure 62). Some streams have been impounded by small dams. Although they do not alter hydrology at the scale of the large water projects, these small dams can act as barriers to fish migration and sediment deposition areas.

Figure 62. Aerial of Morrison Creek in the 1950s showing the creation of a single creek channel on the alluvial fan.

<u>FISH</u>

Listed Salmonid Species

The Russian River supports approximately 32 species of freshwater and anadromous fish species, about half of which are native and one endemic (Russian River tule perch) (Cook et al. 2010). There are two federally-listed threatened salmonid species: Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) in the watershed of the Ukiah Valley Groundwater Basin (National Marine Fisheries Service 1995 and 1996). These salmonid species are anadromous, meaning they incubate, hatch and rear in freshwater streams for a period of time that varies by species before descending downstream into estuaries and the ocean to feed and mature.

Salmon and steelhead trout are cold water fish and need water temperatures of less than 65-70^{o} F. Juvenile steelhead remain in the watershed for at least a year after emergence. They rear in tributary creeks where there is cold well-oxygenated water. Riparian shade is part of maintaining cold water during summer along with groundwater inflow and adequate streamflow to provide oxygen. Chinook salmon juveniles leave the river in spring and spend time in the estuary prior to entering the ocean.

Tributaries demonstrate a flow regime typical of Mediterranean streams with high flows in the winter receding to low-flow or dry conditions in the summer and early fall. Stream flow in tributaries is strongly affected by surface and groundwater interactions; flow may be perennial in bedrock reaches, but intermittent, or dry, in alluvial reaches due to seepage into the highly permeable alluvial substrate (Deitch et al. 2009a, Merenlender et al. 2010). Many of the alluvial reaches of tributaries are passable by migrating salmonids for only a short period in the rainy season when there is sufficient runoff to provide needed water depths (Grantham 2011a). In drier months flow may be subsurface in alluvial channels. In the winter months groundwater levels are high enough to sustain surface water flow until upstream contributions and groundwater levels decline and flow again goes subsurface.

REVEGETATION/RESTORATION PRACTICES FOR RIPARIAN CORRIDORS

Removal and Control of Invasive Nonnative Species

Invasive nonnative species are a major concern in riparian corridors (Figure 63). Invasive species may negatively affect the stream corridor in the following ways:

- Replacement of native species due to competition with invasives and loss of native riparian forest
- Increased water temperature as most invasives do not provide adequate shade canopy
- No contribution of large wood into the stream for fish habitat
- Ineffective for bank protection
- High level of transpiration of water may reduce stream flow
- Reduction in wildlife habitat values

Prior to replanting native species, the invasive species should be removed. Invasive plants typically spread from upstream to downstream and should be removed starting from the upper watershed or channel. In almost all trials and studies of invasive plant removal, herbicide has proven more effective than mechanical removal methods. However, hand removal performed several times a year consistently for a decade or more can completely eradicate invasive plants if no re-infestations occur from upstream.

Giant reed (*Arundo donax*) - This is a very difficult plant to remove once established and needs to be controlled as soon as found. There are several approaches to eradication - lasso the Arundo clump and spray the foliage with herbicide in the fall. Herbicide application must avoid overspray onto native trees. Another method involves cutting the Arundo to remove the biomass in the summer, then spraying the re-growth with herbicide in the fall. A third method involves a two-person crew: one person cuts the Arundo just above the ground and the other person paints the cut stem with full strength herbicide within 30 seconds of cutting in the fall. All cut Arundo should be moved to an area outside the floodplain and be burned or chipped into pieces less than 1 inch in length as soon as possible.

Blue periwinkle (*Vinca major*) **-** Spray foliage with herbicide when plant is green and growing vigorously during any periods in January or February, being careful to avoid other plants and any drift. Don't spray when plant is wilted. Re-spray all survivors. This understory plant provides little to no erosion control and soil can be washed out from underneath without notice. This plant will dominate the understory of established riparian areas and reduce or eliminate the germination of native tree seedlings and shrubs. Over time, as the riparian trees age and die, the corridor will have no replacement trees and a monoculture of Vinca is created. Hand removal can be done, but must be repeated several times a year.

Himalayan blackberry (*Rubus discolor*) - This is the blackberry that has big leaves, big thorns and big berries and is found along both streams and roadsides. It is an invasive plant that will take over native areas and provide little erosion protection for banks. Spray foliage with herbicide in the fall. Cutting and painting stems with herbicide is also effective. If it is interspersed with natives or if mechanical methods are preferred, cut and pull by hand using really thick gloves and follow up with removal several times a year.

Tamarisk (*Tamarix ssp*.) - This is a desert species of tree that is becoming established in California and is tough to eradicate. Cut the tree before it has a chance to flower and paint with herbicide immediately following cutting. Remove duff with seeds to the greatest extent possible. Pull out all seedlings and retreat any re-sprouting stumps.

Tree of heaven (*Ailanthus altissima*) and Acacia (*Acacia sp.)* **-** These invasive trees should be cut and then painted with herbicide in the fall to kill the root system. They can also be cut continuously several times a year and all seedlings removed. Root sprouts can be sprayed with herbicide in the fall.

Scotch (*Cytisus scoparius*) or French (*Genista monspessulana*) broom - There are a number of invasive brooms that can be cut and painted with herbicide and seedlings hand pulled. Hand removal requires all parts including roots and the seed bank be removed. There are areas in the riparian corridor that may have broom, although it is more common on hillsides. A weed wrench works well for removal of this species because broom generally does not re-sprout from roots.

Cape (*Delairea odorata*) and English (*Hedera helix*) ivy - These very invasive species spread by runners. Spray with herbicide and remove and re-spray all survivors until it is gone. Cape ivy will climb trees and smother them resulting in the dead tree falling and often taking the stream bank or slope with it. If it is interspersed with natives, cut and pull by hand.

It is important to note that any use of herbicides should be done in full accordance with label directions and restrictions. In general, if the area to be treated is next to water, the herbicide needs to be a formulation safe for use near to water. Consult with the County Agricultural Commissioner for details on herbicide use. For most projects in the riparian corridor a 1600 Streambed Alternation Permit from the California Department of Fish and Wildlife is required. If a large area of invasive plants is removed, a plan for revegetation of the area should be completed. Native plant sprigs or container stock from local genetic stock should be on order when the eradication is done, as these species are not readily available from nurseries.

General Replanting Approach

Native plants are not the same as ornamental garden plants. They need to be purchased from a native plant nursery (Appendix 5) and should be grown from bulbs, seeds or propagules collected in the same watershed as where the new seedling will be planted. This approach gives these plants a genetic advantage in adapting and responding to the environmental conditions in the watershed.

Native plants are installed in the winter after the ground has saturated with rain. For a successful project native plants are installed as small seedlings, not 1–5-gallon stock. Root growth and development is the primary focus

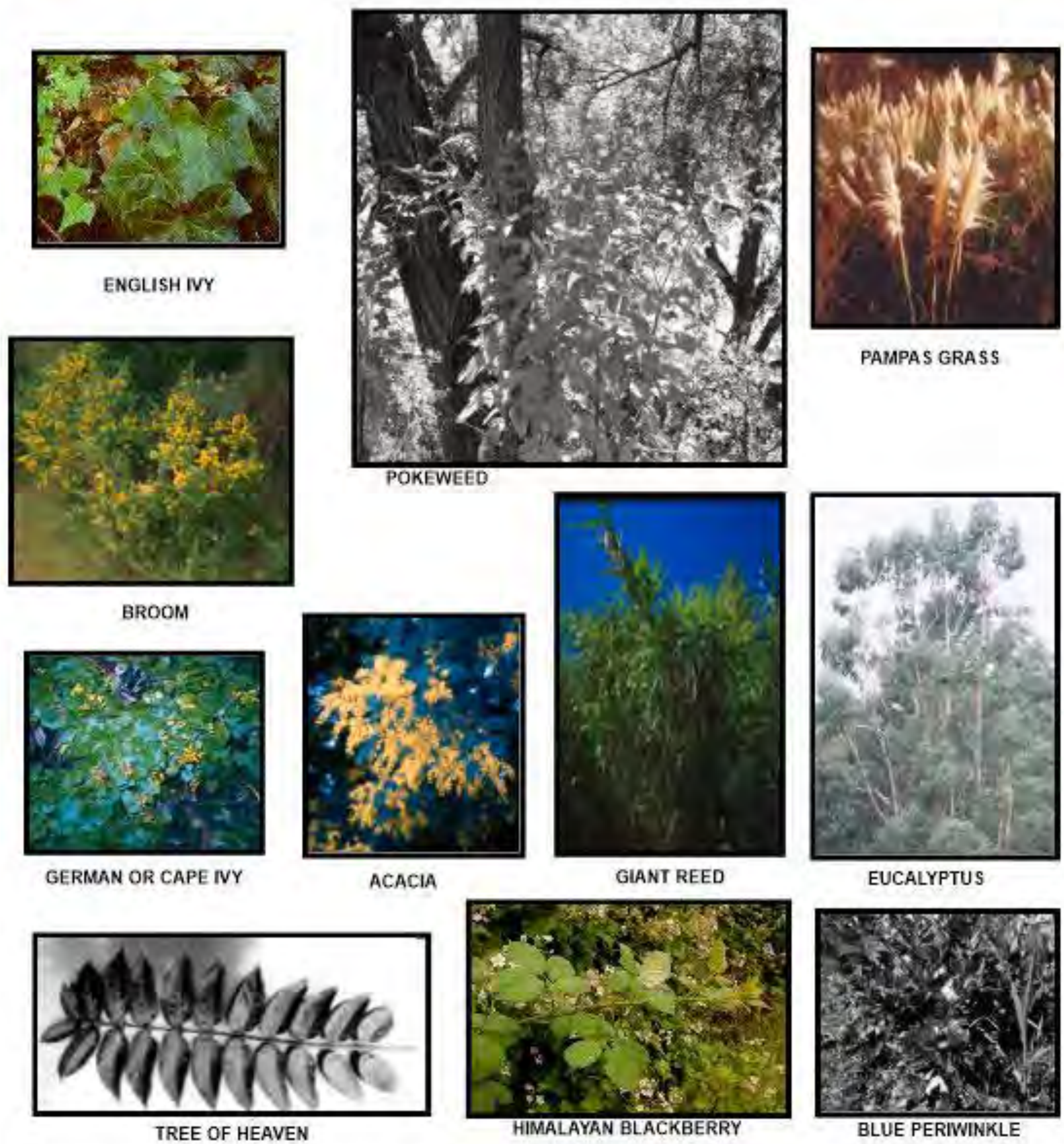


Figure 63. Invasive plants in Russian River riparian habitats

of new seedling growth for the first 3-5 years following installation. Development of an extensive root system provides needed water during summer and mechanical strength to withstand high velocity flow.

Native trees also need to be planted at fairly large distances from each other such as 15-25 ft. depending on the species and site. This spacing allows the trees enough root space to grow well and enough canopy space to obtain adequate sun.

Some pioneer species (willow and cottonwood) can be planted through sprigging rather than planting nursery stock. Pioneer species are planted adjacent to the bankfull or scour channel. Willow sprigging can be an effective and inexpensive way to revegetate along streams. Willow must be planted in sunny areas where plants can establish roots and reach summer groundwater. Sprigs should be collected and planted when willows are dormant in January. Some willows, such as the sandbar willow, do not sprig well and should not be used. Cottonwoods also work well for sprigging.

Sprigs should be at least one-half inch in diameter and 18 inches long. Sprigs two to three inches in diameter and three to four feet long work the best. Cuttings should be planted on the same day they are cut. If this is not possible then the entire cutting should be placed in water in a cold area until used.

Plant the willow with the buds up after sharpening the bottom end of the sprig with an axe or pruners. Sprigs should be driven into the soil 75 to 80 percent of their total length at a slight angle downstream to decrease the resistance to water flows. In hard soil, an iron bar, or auger, can be used to bore planting holes. After placing the cutting in the hole, tamp firmly around the cutting to remove any air pockets in the soil. In soft soils, sprigs can be driven in with a wooden mallet or sledgehammer. Cut off the tops of the sprigs if they split while hammering. Leave only one or two buds exposed.

Along stream banks spacing of the sprigs may be as close as 2-4 inches on eroding banks or 1 ft apart in other sites. Cattle tend to browse on young willow; the revegetated areas may need protection with exclusionary fencing.

Managed Bank Retreat

Incremental improvements in highly incised channels have the potential to result in long-term riparian restoration. When a flood occurs in an incised channel it will erode banks at the outer edges of meanders and in locations where vegetation is sparse or bank materials are particularly prone to erosion. Following a flood, the eroded bank can be addressed with the following practices:

1) Vines, trellis and any other infrastructure needs to be removed from the failed bank.
2) If needed, large trees should be relocated to be parallel to the bank rather than transverse across the channel. Hand tools can be used to shape the surface of the failure if needed to allow for planting. Himalayan blackberry, blue periwinkle, poison hemlock, and other invasive plants on the failure site need to be removed and hauled offsite. Do not dispose of any vegetation in the creek.
3) Dormant willow or cottonwood sprigs should be harvested from nearby stands, being careful to take no more than one-third of any one tree. The downward end of each cutting needs to be sharpened and make each cutting about 36”-48” in length. The sprigs should be installed with the sharpened end into the base of the eroded bank to a depth where at least two-thirds of the sprig is below the soil surface. Sprigs should be installed densely with 2-4 inches between sprigs. The bank failure needs to be planted from the base of the bank up 3-4 ft. of the lower bank (lowest 5-7 ft.).
4) The mid-bank (5-7 ft. between the channel and top of bank), and upper bank should be seeded with grass as a temporary erosion control measure. Larger trees such as live oak, valley oak, Ca. walnut, Oregon ash, box

elder, California bay laurel, and California buckeye should be installed in the mid and upper bank using seedlings grown by a native plant nursery from local genetic stock. Tree seedlings should be planted 15-20 ft. apart to avoid overcrowding when they grow. Alternatively, acorns can be planted at 10 for every 1 tree needed.

5) The planting area will need to be periodically weeded and inspected for the health of the plantings and need for replants. Protective hardware such as grow tubes should only be used at the top of the bank where flood waters are less likely to move them downstream.
6) The mid and upper bank plants will need to be drip irrigated approximately once every 10 days for 8-10 hours, during the dry season from April to November depending on rainfall. This irrigation schedule provides for less frequent deep watering to encourage root growth.
7) In a revegetation zone adjacent to the eroded bank, the same trees as the upper bank should be planted in the winter with summer irrigation and weed control provided.
8) For the first three summers following planting of native riparian plants, each plant will require irrigation. Dormant willow or cottonwood sprigs do not require irrigation. Unlike many ornamental plants, natives need deep infrequent watering. In April, the project will need to install a drip irrigation system for the native plants and irrigate for an eight-hour period at least once a week. Irrigation should extend from late April if rains have ended to the beginning of the next rainy season. If a drip system cannot be installed the trees can be hand watered.
9) When native plants are put in, weeds around the plant should be removed and a square of weed mat installed. As part of spring or summer maintenance, weeds should be removed next to the new plant. Dormant willow or cottonwood sprigs should have weeds removed if appropriate as well, but not have weed mat installed. There are a variety of protective tubes used for native plants to reduce browsing by rodents and deer for the first several years of growth. These are placed around or over the plant and should not be used near the actively flooding portion of the channel. All tubes and protective hardware should be removed after 2-3 years.
10) Native plants should only be pruned when they become so successful that they are extending into a road or vineyard. Only those trees causing a problem should be cut. Pruning should be done in the winter and early spring months. Within the corridor area no pruning or trimming is needed and in fact is detrimental to the wildlife values in the corridor.

Most banks fail in a horizontal zone that is three times the height of the bank. For example, for a 15 tall bank the failure zone will be 45 ft from the prior location of the top of bank. Added to this failure zone is a new riparian zone of 20 or more feet and a new vineyard road zone if needed (Figures 64-65). Since bank erosion only occurs occasionally this approach incrementally improves channel geomorphology without affecting large areas of land. This approach is not useful for urban areas with structures located close to the bank top.

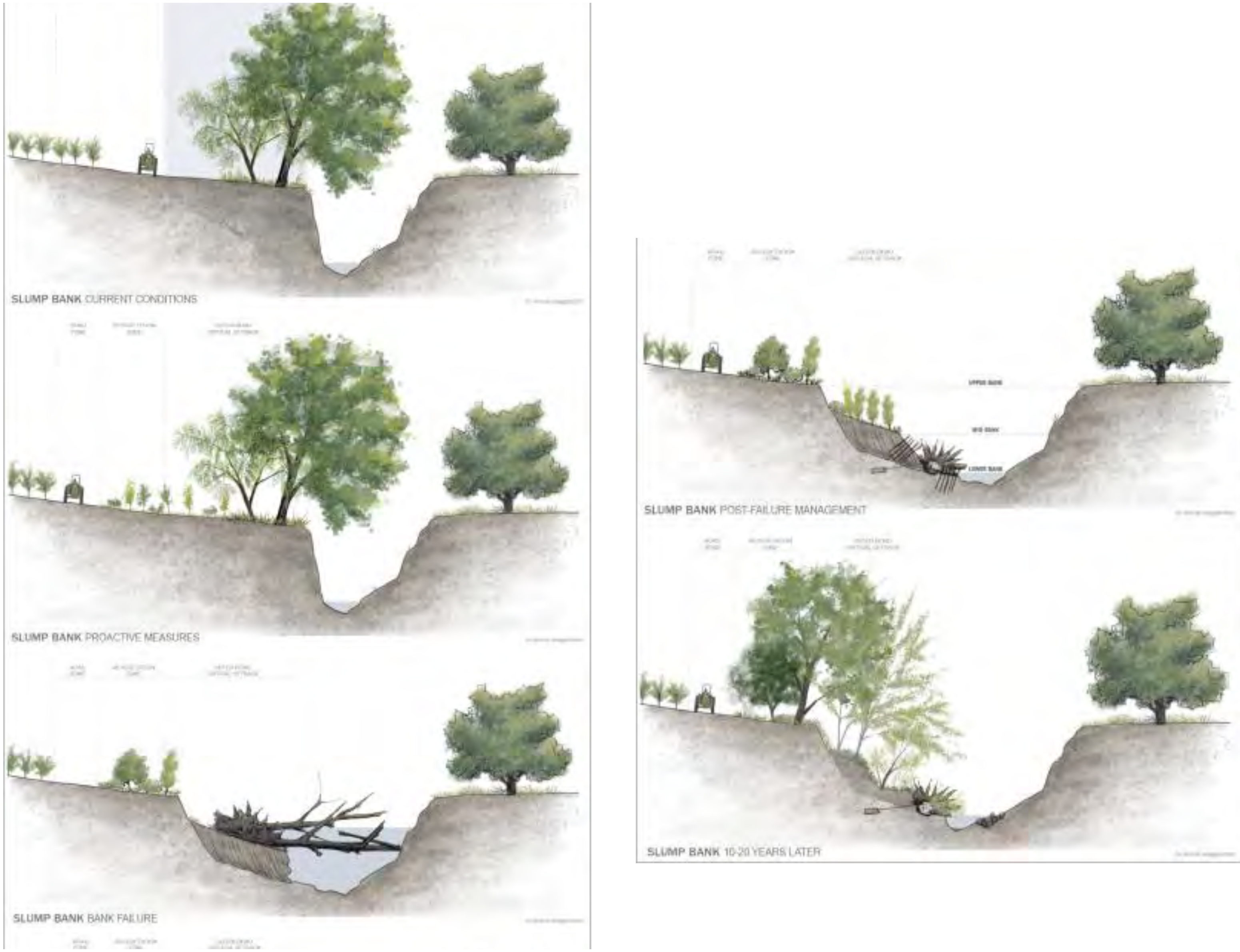


Figure 64. Managed Bank Retreat for slump bank

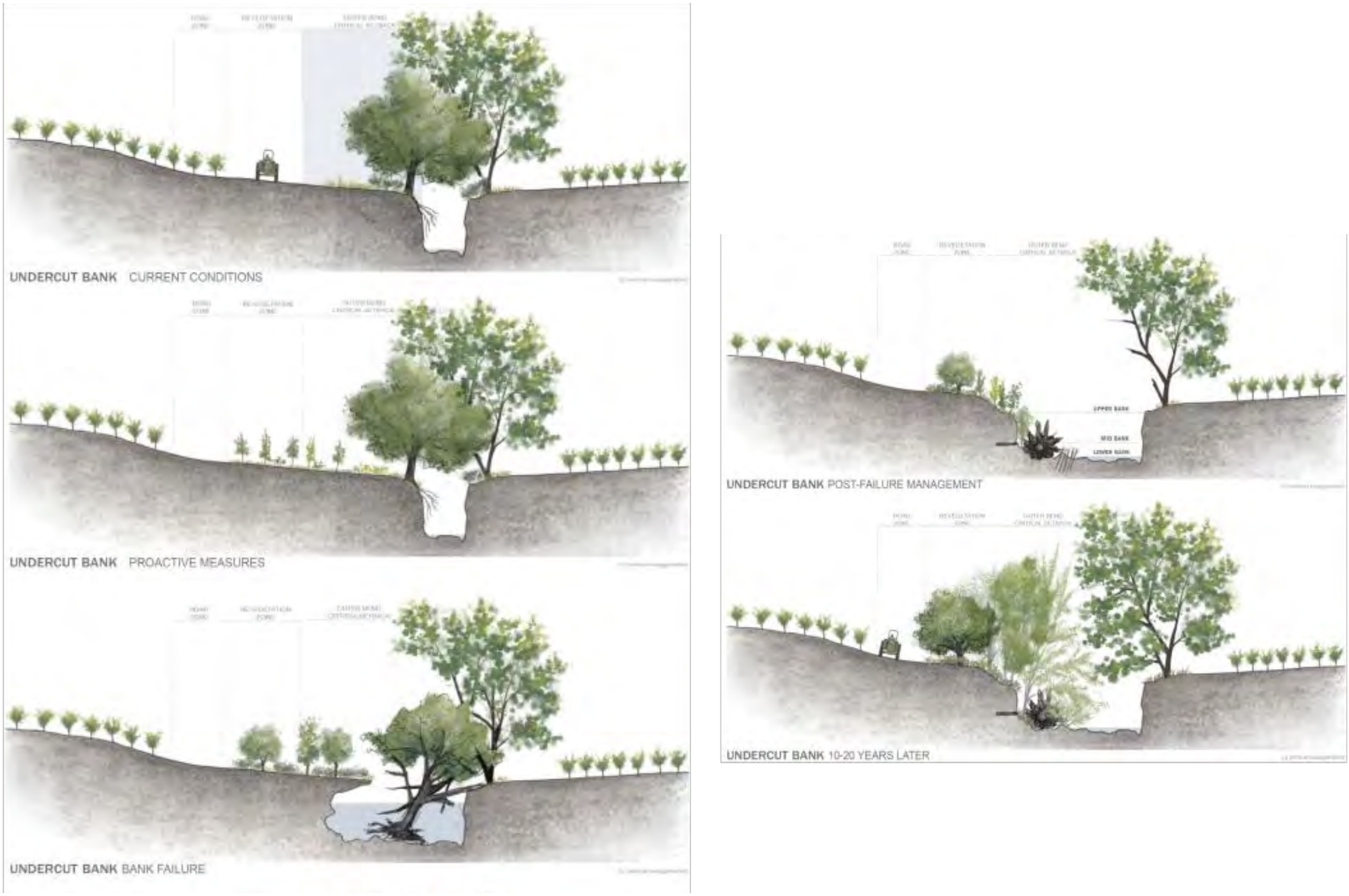


Figure 65. Managed Bank Retreat for undercut bank

Use of Large Rock
Many property owners stabilize bank erosion with large rock and sometimes sprigs of willow in between the rocks. The willow is not planted in a location where it can provide much habitat and is just an add on make the rock look less environmentally destructive. The rock will accelerate flows in the channel and likely promote increased erosion of the opposite bank and deepening of the channel. This approach provides no long-term sustainable riparian or aquatic habitats.

Alluvial Fan Channels
Alluvial fans differ significantly from low slope (<1%) meandering channels. The fan has multiple channels which change location in flood events. The main channel may fill in with bedload during a flood and a new channel form in another location. Alluvial fans are dry much of the time as stream flow percolates through the cobble, gravel and sand. Alluvial fans may not support extensive riparian vegetation as valley streams do. Because of their higher slope and more porous features the entire surface of the fan supports widely-distributed, drought tolerant plants such as live oak, valley oak, Ca. bay laurel, grey pine. Willow, white alder, big leaf maple and box elder are riparian species sometimes found along the fan channels rather than the fan surface. Restoration and management measures for alluvial fans must take into account the processes in these high slope, multi-channeled systems.

Semi-confined Alluvial Channels
Semi-confined channels can be revegetated starting from the edge of the bankfull channel to the outer extent of the floodplain. Pioneer species can be sprigged first and if successful then tree seedlings can be installed a few years later.

Confined Bedrock Channels
A few trees can be installed along the edges of the confined channel but these can be scoured out in a flood. For burned hillslopes along these channels replanting forest may be needed to keep the hillslope stable and create shade over the stream.

Dissected Alluvium Channels
These channels have deposits of gravel in the channel bottom and banks of highly competent clay. Sprigs or tree seedlings can be installed along the outer edges of the gravel bars in the channel to the edge of the scour. channel. The base of the clay banks may be able to be sprigged in winter when saturated. However, tree roots may not be able to extend very far into this material and the tree may not grow.

HIGH PRIORITY STREAMS IN UKIAH VALLEY GROUNDWATER BASIN WATERSHED
CLSI reviewed Fish and Game creek survey reports and the National Marine Fisheries Service Recovery Plan (2016) for steelhead trout for the watershed. We evaluated creeks that support steelhead for the need for riparian revegetation (Figure 66). These creeks are:

Mariposa Creek
Salt Hollow Creek
Forsythe Creek I, II, III
Ackerman Creek
McClure Creek
Mill Creek
North Fork Mill Creek
Robinson Creek

Morrison Creek
McNab Creek
Parsons Creek

Figure 67 shows the reaches of these creeks that are unconfined alluvial channels, semi-confined alluvial channels, dissected alluvium channels and alluvial fans. These reaches are the most appropriate for revegetation. As previously described revegetation in bedrock channels is difficult and less likely to be successful.

Using recent aerial photographs, we digitized the riparian corridor along each creek within a 100-foot corridor on each side of the blueline of the stream on the map. The area incorporates the scour channel of the stream and the adjacent riparian corridor. Unvegetated areas were also digitized in the same 100-foot width corridor. For each creek reach we measured corridor acreage (vegetated and unvegetated), length, watershed area draining into the upstream area of the creek reach. We also developed a table of landowners for the parcels along each creek. Appendix 4 contains creek reach maps with parcels and tables of ownership. We did not include the parcels that were primarily housing as these sites typically do not have the room to create riparian habitat. We used the USGS stream stats program to define the average annual precipitation in the watershed and the size of floods with recurrence intervals of 2, 5 and 10 years.

For each creek reach we reviewed the need for revegetation, the ease of implementation, constraints to success of the project and provided an overall ranking for the reach.

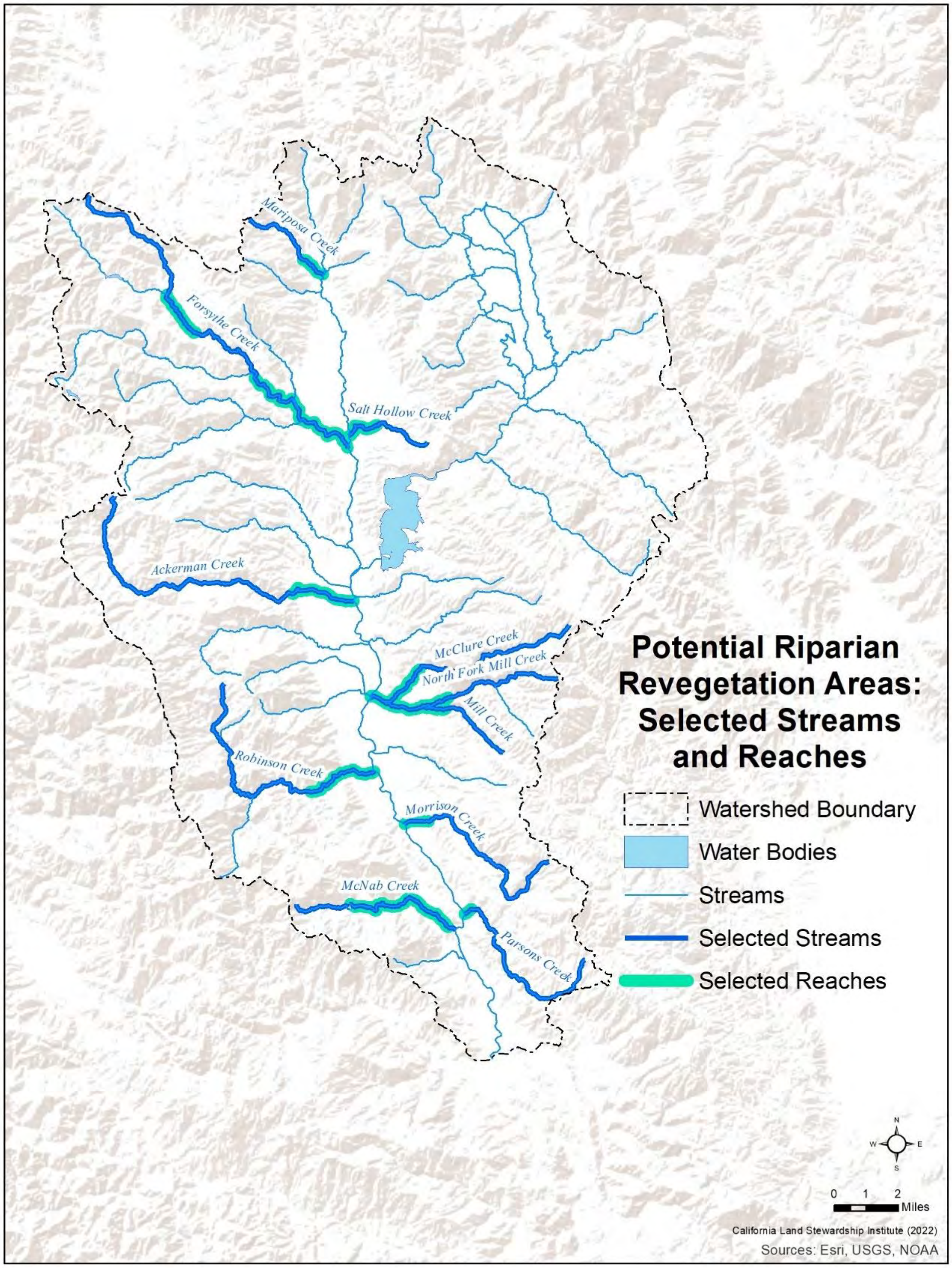


Figure 66. Selected streams

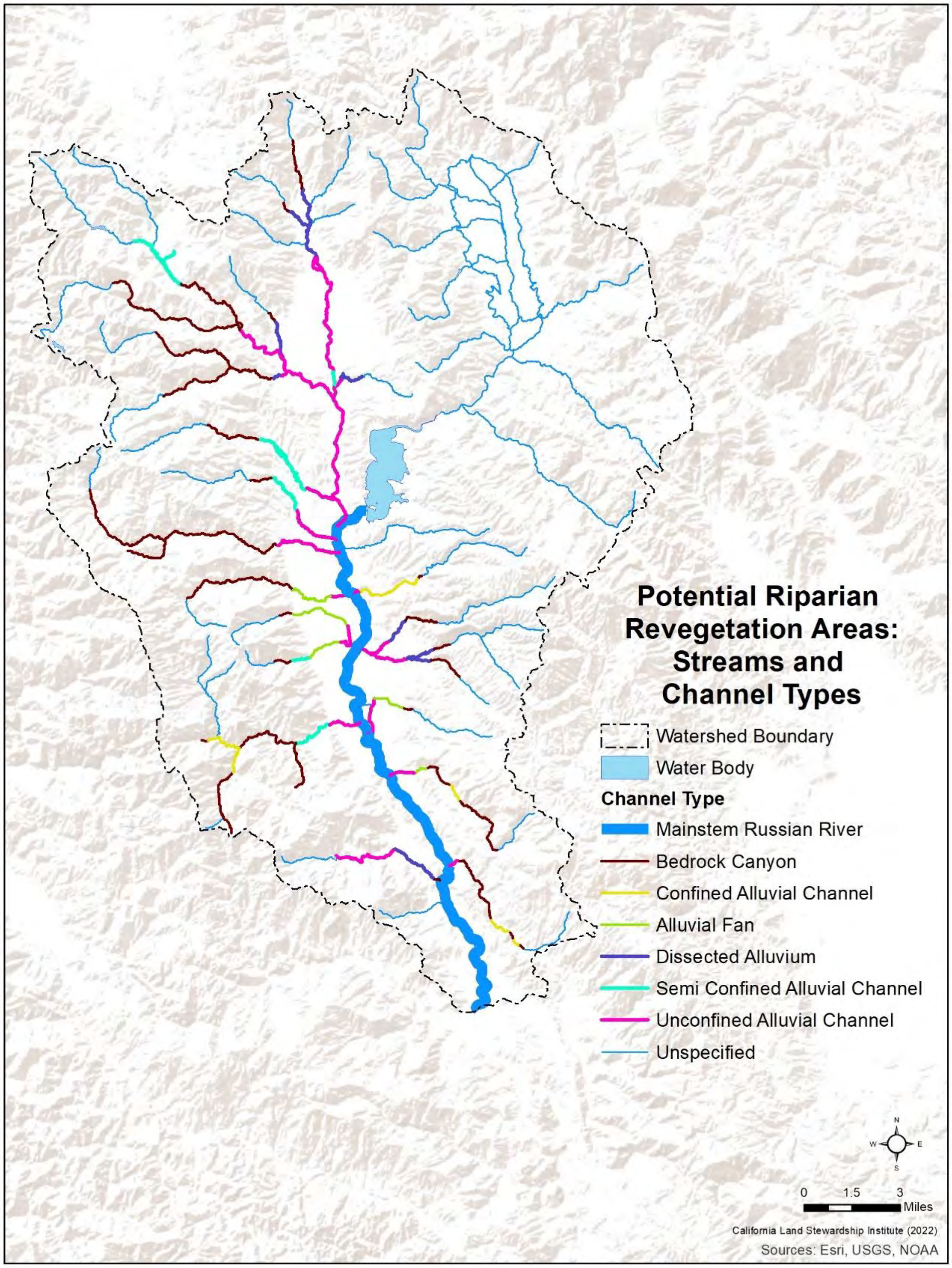


Figure 67. Channel types

Mariposa Creek
Mariposa creek is a tributary to the West Fork Russian River. Table 13 lists the length and slope class of Mariposa Creek along with the watershed area draining into the creek, annual precipitation, and estimates of various frequency flood flows.

Channel Type: Dissected alluvium

Watershed Vegetation and Land Use
Mixed conifer and hardwood forest dominate the watershed of Mariposa Creek. Land uses are irrigated agriculture, forestry and grazing.

Revegetation Opportunities
Mariposa Creek has a dense vegetative cover (15.13 acres) over most of this reach of the creek. Approximately 24% (4.78 acres) of the corridor is unvegetated. The portion of the creek downstream of the onstream pond would benefit from revegetation (Figure 68).

Revegetation Constraints
The unvegetated section of Mariposa Creek is close to the confluence with the West Fork Russian River and is incised with 18 ft tall banks and will need bank setbacks for revegetation. An on-stream dam blocks salmonid passage up Mariposa Creek limiting the value of revegetation for fish habitat. Additionally, there are a number of residential parcels near the confluence with the West Fork Russian River which could make revegetation difficult.

Rank: Low

Table 13. Features of Mariposa Creek

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
Mariposa	Dissected Alluvium	4587.08	0.87	<1%	2.70	53.80	225.00	424.00	568.00	15.13	4.78	24%

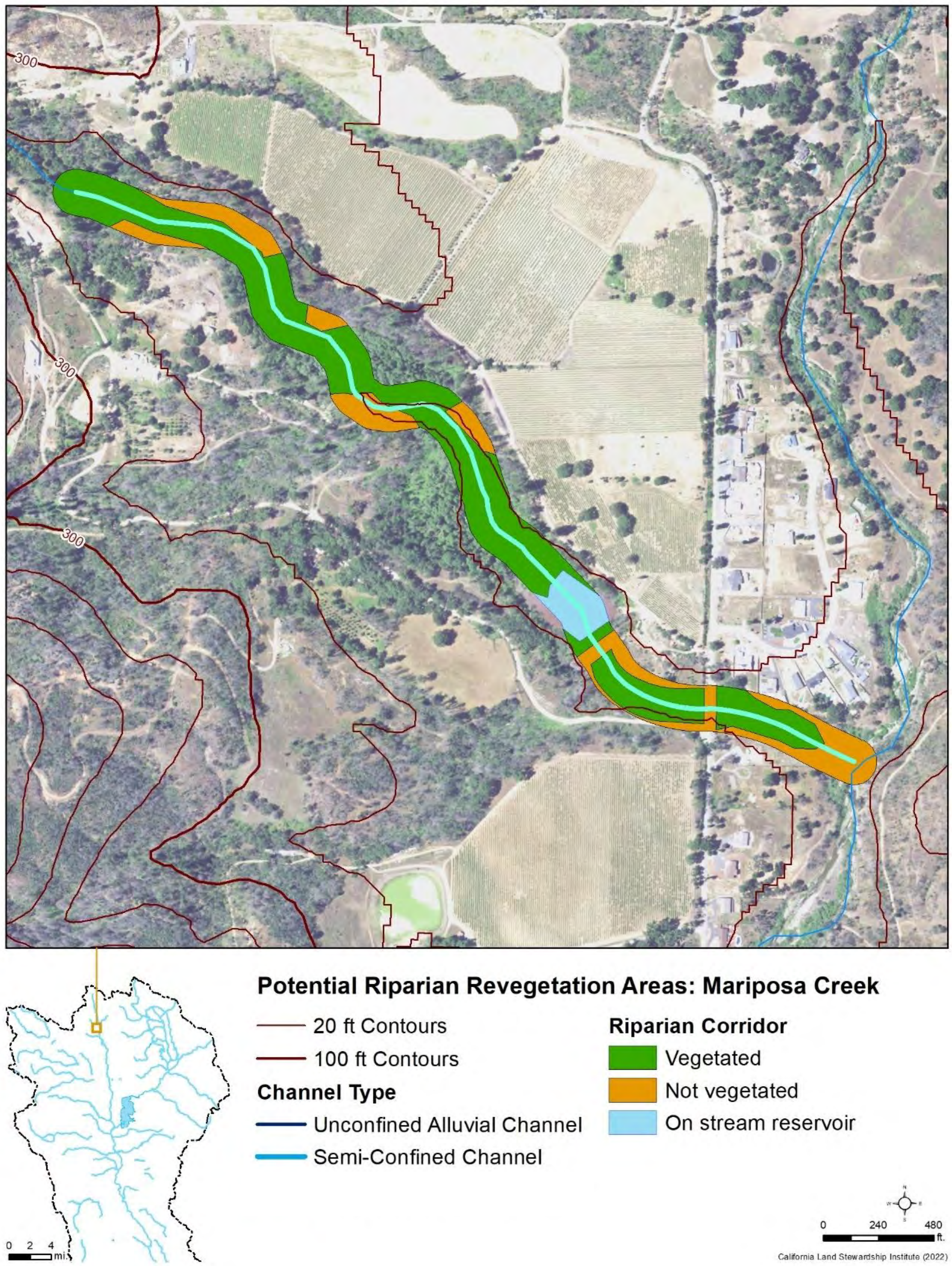


Figure 68. Potential revegetation areas on Mariposa Creek

Salt Hollow Creek
Salt Hollow Creek is a tributary to the West Fork Russian River. Table 14 lists the length and slope class of Salt Hollow Creek, the size of the watershed, average annual precipitation and estimates of flows for various frequency floods.

Channel type: Dissected alluvium (upstream 0.77 miles), Unconfined alluvial (downstream, 0.47 miles).

Watershed Vegetation and Land Use
Hardwood forest and grassland dominate the Salt Hollow Creek watershed. Land uses include grazing and irrigated agriculture.

Revegetation Opportunities
About 44% of the riparian corridor of this reach of Salt Hollow Creeks is not vegetated (8.7 acres). The vegetated area is 11 acres. The downstream section of the creek is the least vegetated while the upstream section has a few areas that could be planted (Figure 69).

Revegetation Constraints
The downstream reach is unconfined alluvial and is highly incised due to the upstream migration of the incision in the West Fork. Revegetation of this downstream reach would require the setback of banks to create adequate space for the trees. The dissected alluvium channel may have limited riparian vegetation in some locations due to the high banks this material forms.

Rank: High

Table 14. Features of Salt Hollow Creek

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
Salt Hollow	Dissected Alluvium	4042.08	0.77	<1%								
Salt Hollow	Unconfined Alluvial	2476.94	0.47	<1%								
Total		6519.02	1.24	<1%	2.50	40.60	159.00	319.00	436.00	11.00	8.70	44%

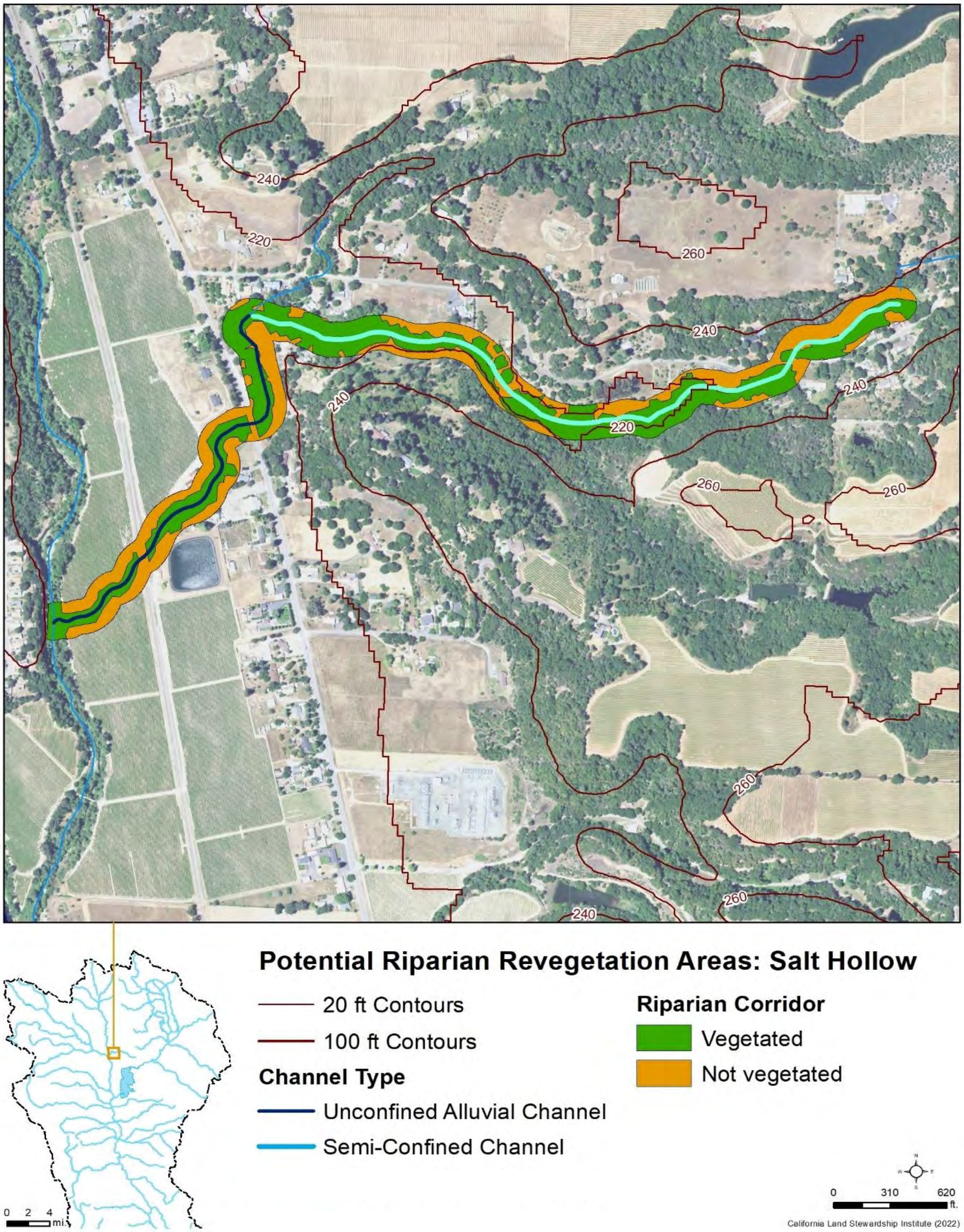


Figure 69. Potential revegetation areas on Salt Hollow Creek

Forsythe Creek I
This reach is located in the upstream area of Forsythe Creek. Table 15 lists the length and slope class of Forsythe Creek I along with the watershed area draining to this creek reach, average annual precipitation and estimates of various size flood flows.

Channel type: Semi-confined alluvial

Watershed Vegetation and Land Uses
The watershed of Forsythe Creek I is covered in mixed conifer/hardwood forest with hardwood forest, chaparral and grassland. Land uses are primarily grazing.

Revegetation Opportunities
The riparian corridor of Forsythe Creek 1 is well vegetated with 33.2 acres of habitat (Figure 70). Twenty-four percent of the corridor is unvegetated (10.5 acres). The unvegetated areas are on the outside edges of the corridor.

Revegetation Constraints
There are a large number of owners of the unvegetated areas and coordinating a continuous project could be difficult.

Rank: Low

Table 15. Features of Forsythe Creek I

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
Forsythe I	Semi-Confined Alluvial	9604.01	1.82	<1%	12	52.1	838	1550	2060	33.2	10.5	24%

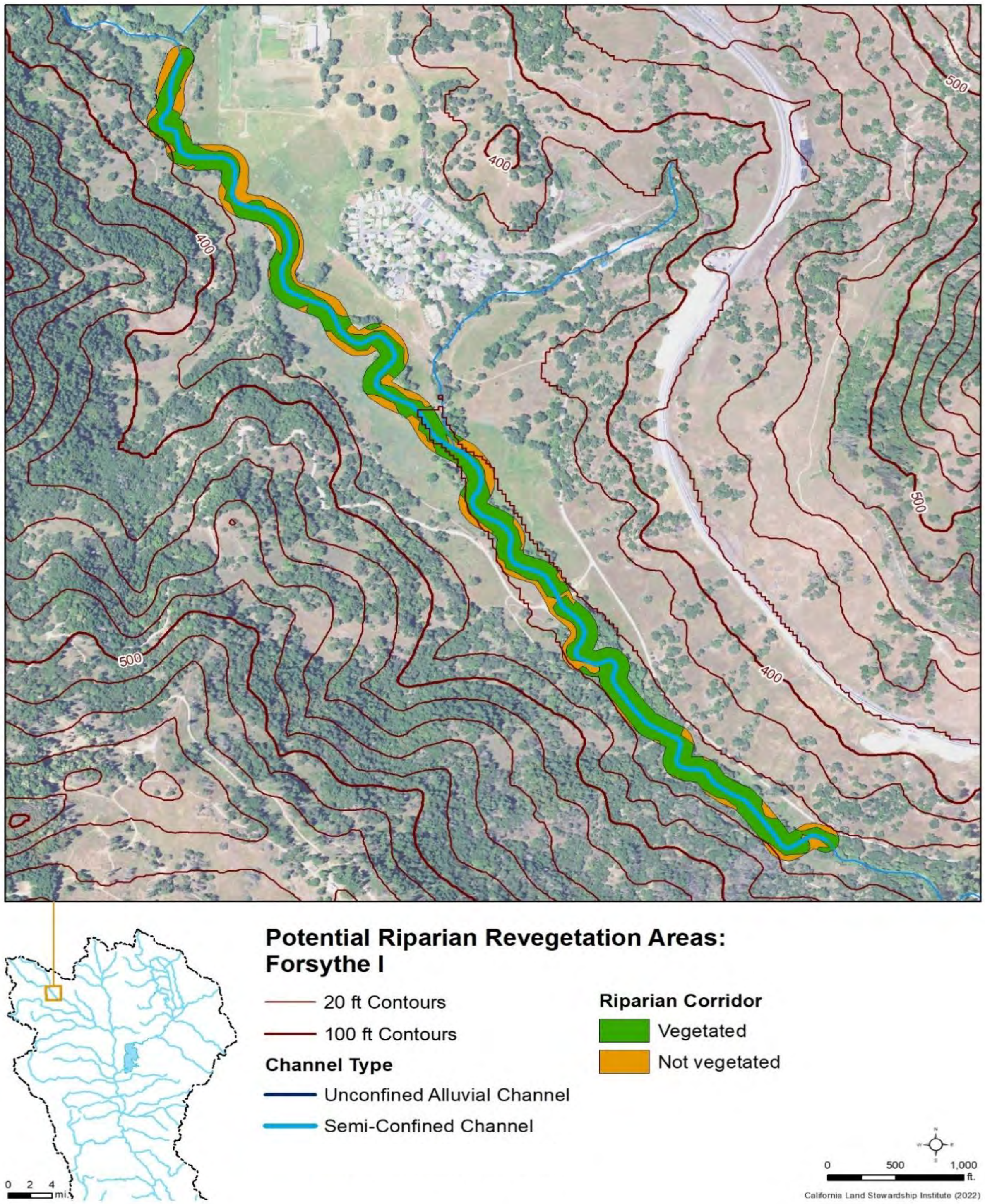


Figure 70. Potential revegetation areas on Forsythe Creek I

Forsythe Creek II
Reach II of Forsythe Creek extends downstream from the confluence with Mill Creek and ends just upstream of the confluence with Seward Creek. Table 10 lists the length and slope class of Forsythe Creek II along with the watershed area draining to this creek reach, average annual precipitation and estimates of various size flood flows.

Channel type: Unconfined alluvial

Watershed Vegetation and Land Uses
The watershed that drains to this reach of Forsythe Creek II is covered in mixed conifer/hardwood forest, chaparral with conifer forest in the headwaters. Land uses area grazing, forestry and some irrigated agricultural lands.

Revegetation Opportunities
The Forsythe Creek II reach has significant unvegetated areas in the riparian corridor (48%, 28.4 acres). Many of these unvegetated areas encompass long lengths along one bank or the other or both (Figure 55).

Revegetation Constraints
Due to the many parcels along this creek reach a great deal of coordination would be needed to assure landowner support and participation in revegetation of the corridor.

Rank: High

Table 16. Features of Forsythe Creek II

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
Forsythe II	Unconfined Alluvial	13754.88	2.61	<1%	29.50	50.60	1840.00	3380.00	4460.00	30.57	28.42	48%

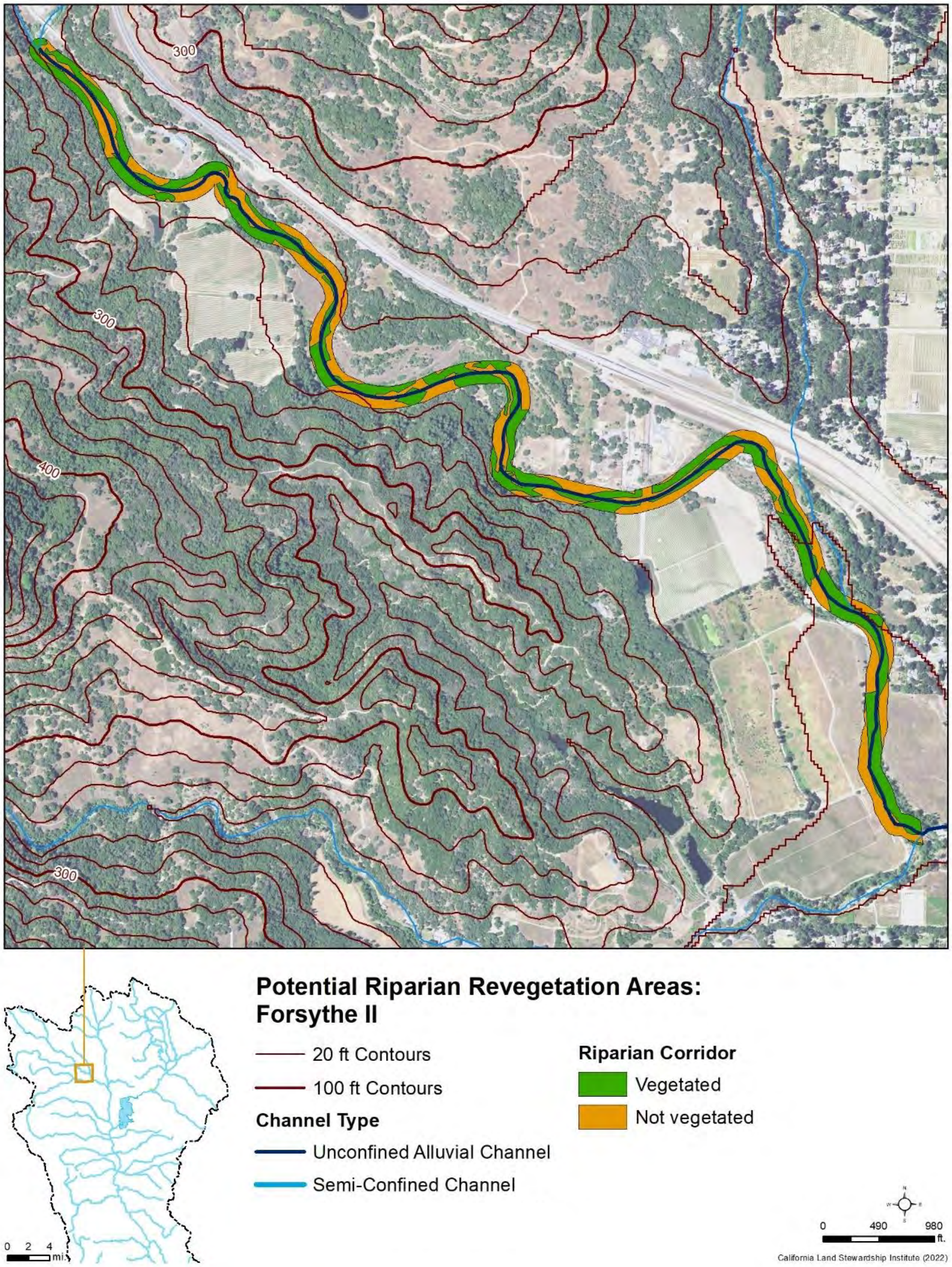


Figure 71. Potential revegetation areas on Forsythe Creek II

Forsythe Creek III

This reach of Forsythe Creek is located downstream of the confluence with Seward Creek and extends to the confluence with the West Fork Russian River. Table 17 lists the length and slope class of Forsythe Creek III along with the watershed area draining to this creek reach, average annual precipitation and estimates of various size flood flows.

Channel type: Unconfined alluvial

Watershed Vegetation and Land Uses

The watershed of this reach includes all of the Forsythe Creek drainage. Conifer forest Mixed hardwood/conifer forest and hardwood forest are the primary vegetation types with both chaparral and grassland in some locations. Land uses are primarily grazing and forestry with some irrigated agriculture and rural residential uses.

Revegetation Opportunities

This reach is primarily vegetated with 30% unvegetated or 12.1 acres compared to 27.8 acres of vegetated area (Figure 72). The unvegetated areas are on several different parcels.

Revegetation Constraints

This reach of Forsythe Creek is incised with 13 ft. banks. Some of the unvegetated areas are adjacent to vineyards and urban development and there may be conflicts which restrict the area that could be planted.

Rank: High

Table 17. Features of Forsythe Creek III

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
Forsythe III	Unconfined Alluvial	10823.21	2.05	<1%	46.50	49.60	2720.00	4980.00	6570.00	27.87	12.13	30%

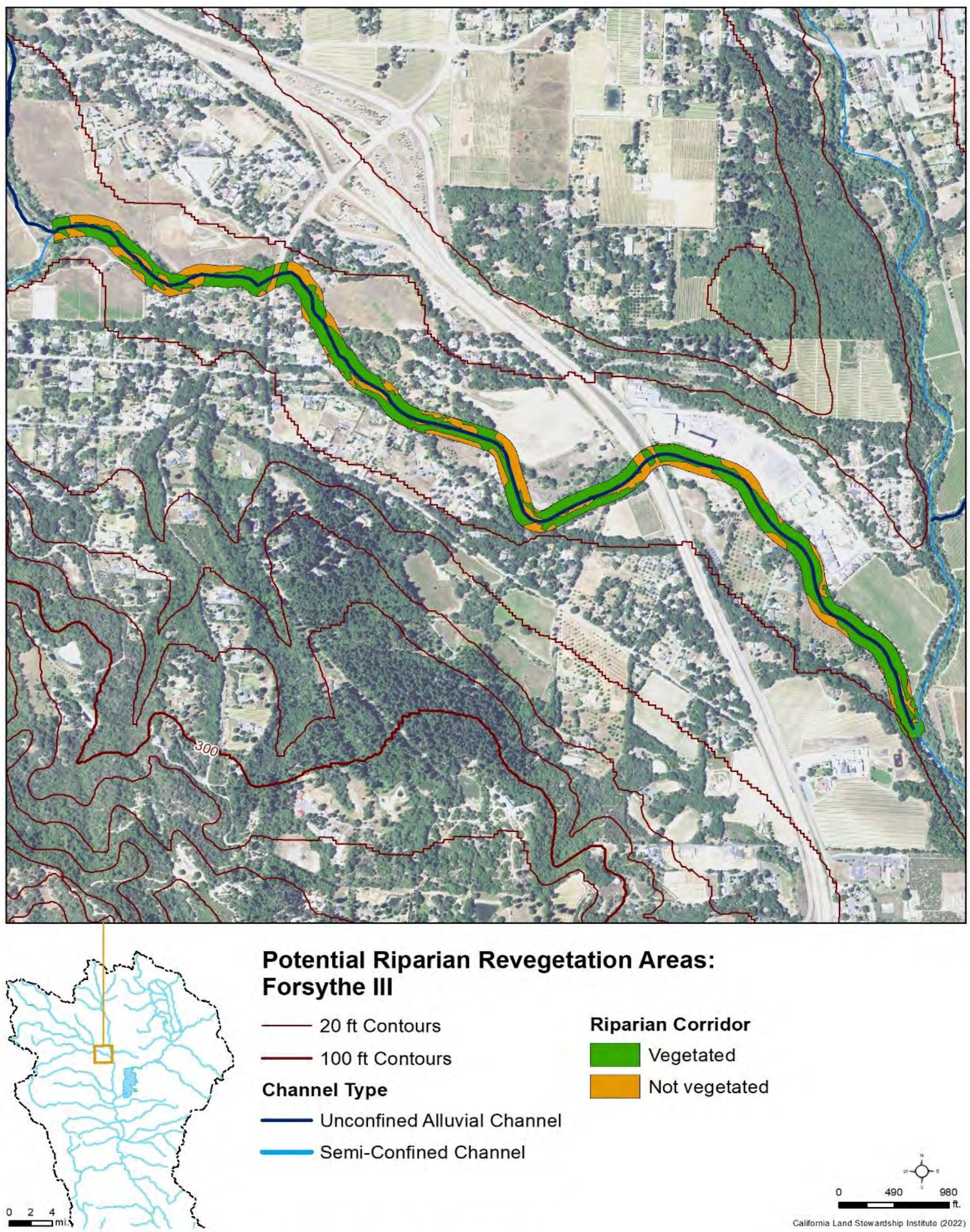


Figure 72. Potential revegetation areas on Forsythe Creek III

Ackerman Creek
The most downstream reach of Ackerman Creek was evaluated. Table 18 lists the length and slope class of Ackerman Creek along with the watershed area draining to this creek reach, average annual precipitation and estimates of various size flood flows.

Channel type: Unconfined alluvial

Watershed Vegetation and Land Uses
The Ackerman Creek watershed has mixed conifer/hardwood forest in its headwaters and large areas of hardwood forest, grassland and chaparral over the remainder of the drainage. Land use is grazing along with agriculture and urban land in the lower watershed.

Revegetation Opportunities
The riparian corridor of Ackerman Creek has a high level of vegetation (32.8 acres) with just 28% unvegetated (12.9 acres) (Figure 73). Here are some locations near Highway 101 and near the confluence with the Russian River that could benefit from revegetation.

Revegetation Constraints
There are numerous owners along most of the reach making it difficult to complete large multi-owner project. Additionally in some locations buildings are located close to the creek corridor. This reach of Ackerman Creek is highly incised. Recently the Pinoleville Pomo Nation, an owner on Ackerman Creek, received funding to complete a revegetation project on their lands along the creek.

Rank: Low

Table 18. Features of Ackerman Creek

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
Ackerman	Unconfined Alluvial	11587.01	2.19	<1%	18.60	50.40	1210.00	2240.00	2970.00	32.88	12.93	28%

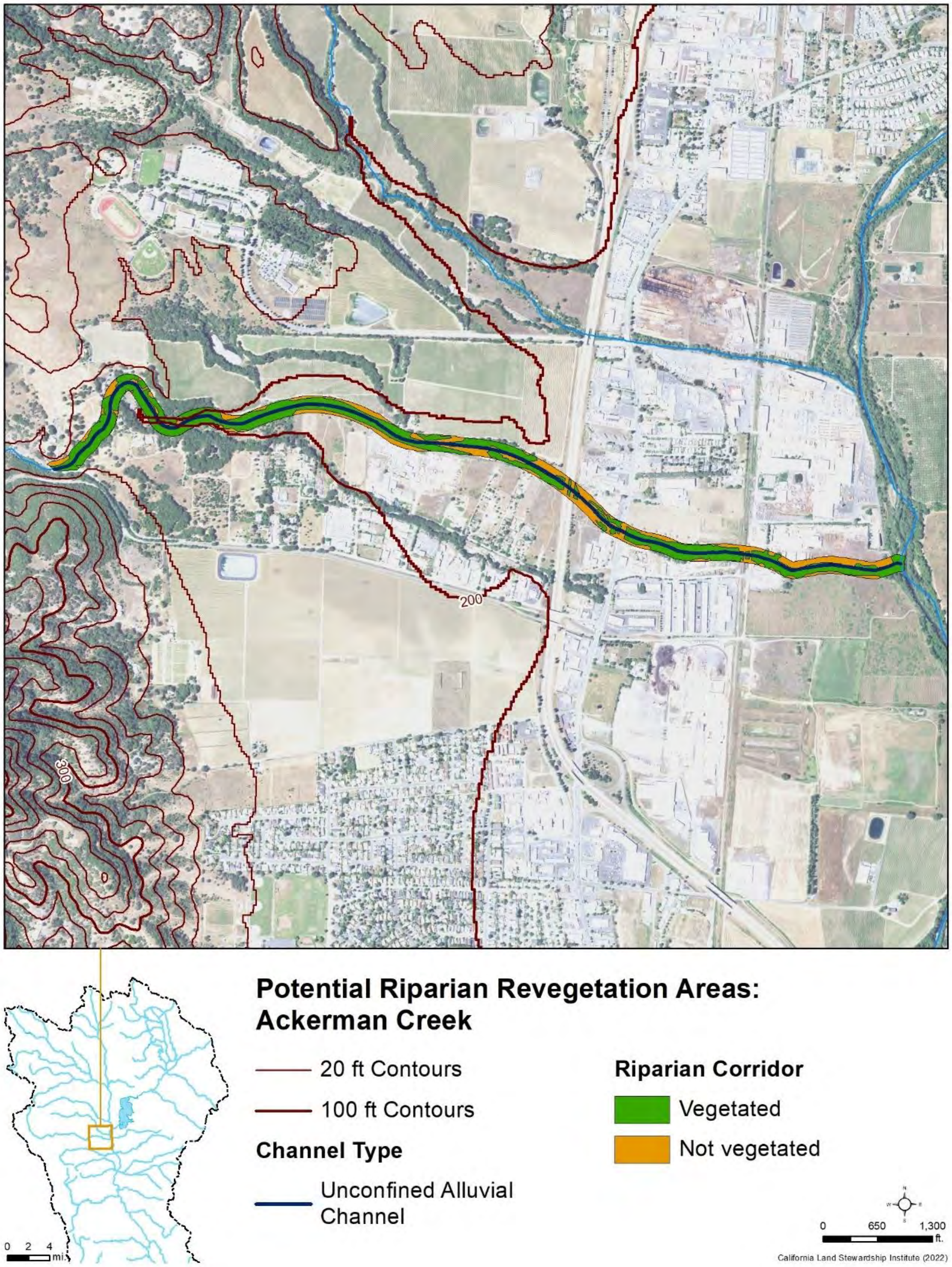


Figure 72. Potential revegetation areas on Ackerman Creek

McClure Creek
McClure Creek is a major tributary to Mill Creek on the east side of the Russian River. Table 19 lists the length and slope class of McClure Creek along with the watershed area draining to this creek reach, average annual precipitation and estimates of various size flood flows.

Channel type: Dissected alluvium (upstream 0.91 miles), Unconfined alluvial (downstream, 0.71 miles)

Watershed Vegetation and Land Uses
The McClure Creek watershed s mostly chaparral with hardwood forest in canyons. Land uses include grazing irrigated agriculture and recreation at the Cow Mountain Recreation Area.

Revegetation Opportunities
About 51% of the McClure Creek riparian corridor is unvegetated (18.1 acres) and has 17.3 acres that is vegetated (Figure 73). McClure Creek needs planting along the uppermost reach and entire lower reach. The upper reach has many characteristics of an alluvial fan where the creek exits its bedrock canyon.

Revegetation Constraints
Revegetating the lower reach would require removal of vineyard and possibly bank setbacks. A portion of the downstream reach is lined with houses also restricting the area for habitat improvements.

Rank: High

Table 19. Features of McClure Creek

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
McClure	Dissected Alluvium	4811.97	0.91	<1%								
McClure	Unconfined Alluvial	3758.80	0.71	<1%								
Total		8570.77	1.62		5.90	47.00	399.00	765.00	1030.00	17.38	18.17	51%

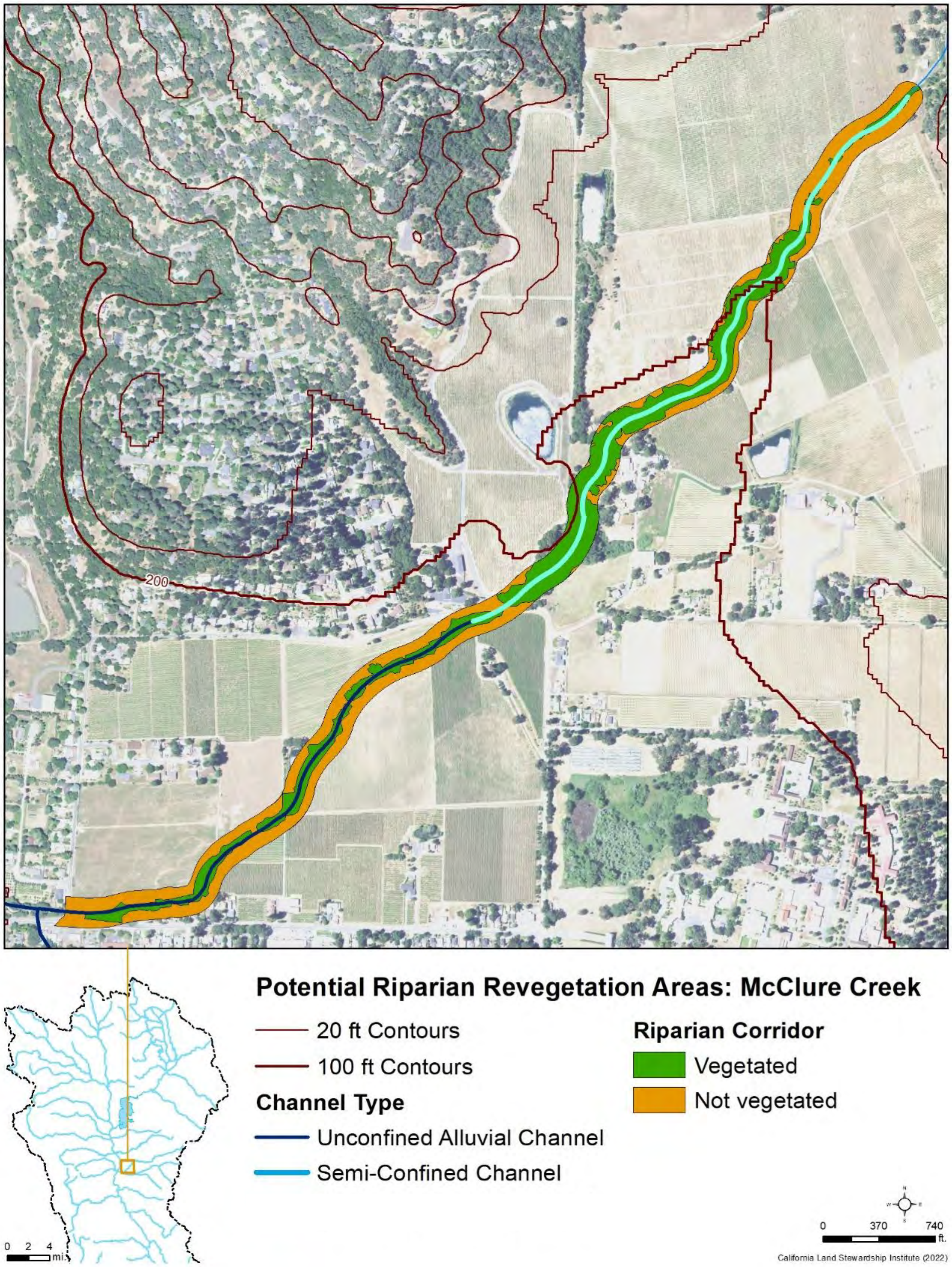


Figure 73. Potential revegetation areas on McClure Creek

Mill Creek
We separated Mill Creek into three sections (A, B and C) extending from where the creek exits its bedrock canyon to its confluence with the Russian River. Table 20 lists the length and slope class of Mill Creek along with the watershed area draining to this creek reach, average annual precipitation and estimates of various size flood flows.

Channel type: Dissected alluvium (upstream, 0.82 miles), Unconfined alluvial (downstream, 1.88 miles)

Watershed Vegetation and Land Uses
The Mill Creek watershed is primarily chaparral with hardwood forest in canyons. Grazing, irrigated agriculture, rural residences and recreation at Cow Mountain Recreation areas are uses occurring in the watershed. There are a series of public reservoirs on Mill Creek that provide recreation.

Revegetation Opportunities
The most upstream reach of Mill creek is well vegetated but downstream there is very little riparian vegetation and plantings will benefit the habitat (Figure 74). Vegetated areas are 26 acres and unvegetated area are 21.9 acre (46% unvegetated).

Revegetation Constraints
Revegetation along many areas of Mill Creek could be difficult due to the proximity of numerous houses and vineyards. Additionally, the downstream section of Mill Creek is highly affected by the adjacent gravel mining.

Rank: High

Table 20. Features of Mill Creek

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
Mill	Dissected Alluvium	4325.68	0.82	<1%								
Mill	Unconfined Alluvial	9943.51	1.88	<1%								
Total		14269.19	2.70	<1%	3.80	46.60	266.00	514.00	694.00	26.04	21.92	46%

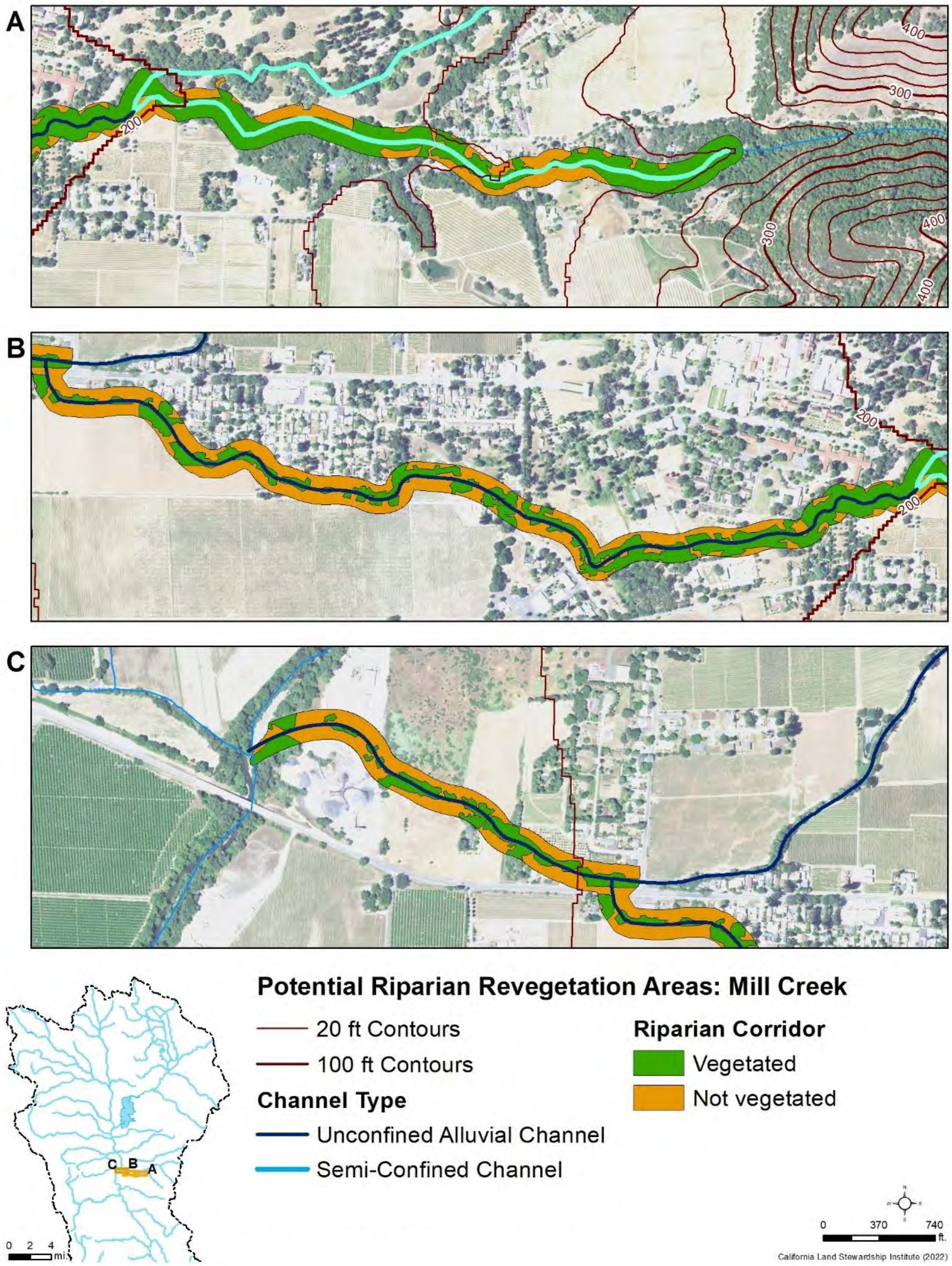


Figure 74. Potential revegetation areas on Mill Creek

North Fork Mill Creek
North Fork Mill Creek extends form where the creek exits its bedrock canyon to the confluence with the mainstem Mill Creek. Table 21 lists the length and slope class of North Fork Mill Creek along with the watershed area draining to this creek reach, average annual precipitation and estimates of various size flood flows.

Channel type: Dissected alluvium

Watershed Vegetation and Land Uses
Chaparral dominates the watershed of the North Fork Mill Creek with hardwood and mixed conifer forest in the canyon. The primary land uses are grazing and recreation in the Cow Mountain Recreation Area.

Revegetation Opportunities
The North Fork Mill Creek has a well vegetated riparian corridor with 16.6 acres of vegetated habitat and 4.7 acres, or 22% not vegetated (Figure 75). These unvegetated areas are small and on the outer edges of the riparian corridor.

Revegetation Constraints
Some of the larger unvegetated areas are adjacent to oak savannah while others are next to vineyard. The sites near the oak savannah likely do not need additional plantings as these two habitats are connected. The areas near vineyard may require removal of vines to widen the riparian corridor.

Rank: Low

Table 21. Features of North Fork Mill Creek

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
North Fork Mill	Dissected Alluvium	5407.73	1.02	<1%	4.7	49.8	344	654	877	16.636	4.759	22%

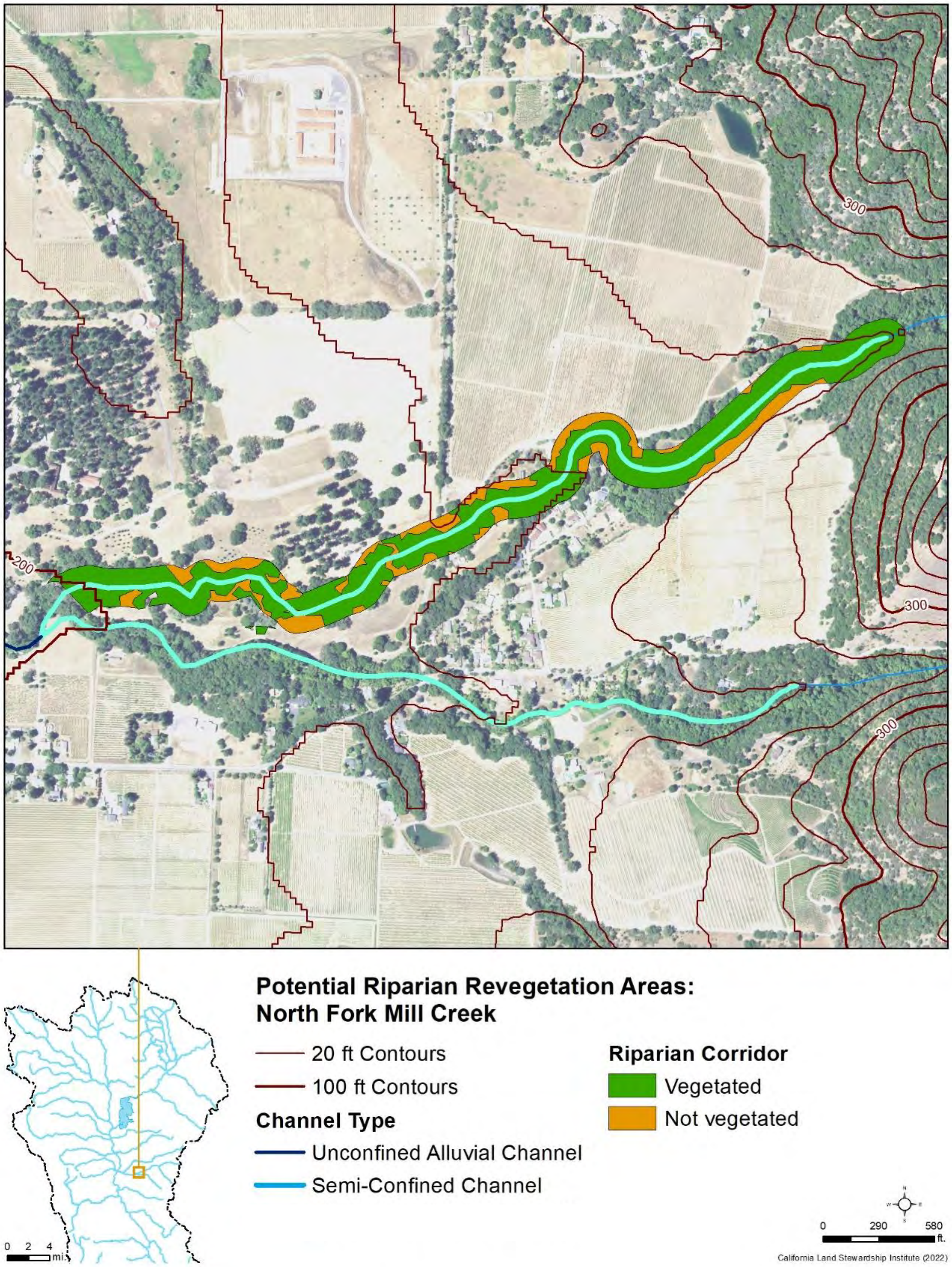


Figure 75. Potential revegetation areas on North Fork Mill Creek

Robinson Creek

Robinson Creek was evaluated from the crossing of Boonville-Ukiah Road to the confluence with the Russian River. Table 22 lists the length and slope class of Robinson Creek along with the watershed area draining to this creek reach, annual precipitation and estimates of various size flood flows.

Channel type: Semi-confined alluvial (upstream, 1.36 miles), Unconfined alluvial (downstream, 1.09 miles)

Watershed Vegetation and Land Uses

The watershed of Robinson Creek is a mix of conifer and hardwood forest in its headwaters and chaparral and hardwood forest in the mid and lower area of the drainage. Land use is primarily grazing with irrigated agriculture along the downstream reach of the creek.

Revegetation Opportunities

Overall Robinson Creek has 31.9 acres of vegetated corridor and 17.7 acres (36%) is unvegetated (Figure 76). The upstream reach of Robinson Creek is well vegetated with just a few areas large enough to warrant planting. On the downstream reach of Robinson Creek; however, the riparian corridor is not well vegetated in several areas and needs to be revegetated.

Revegetation Constraints

The lower reach of Robinson Creek is incised with banks heights of 15-25 ft. due to incision in the main Russian River. Additionally, the creek corridor is adjacent to vineyard so some vines would likely have to be removed for revegetation to occur. As the incision progresses the channel will deepen and banks will fail. Use of the Managed Bank Retreat is a good option for this lower reach.

Rank: Moderate

Table 22. Features of Robinson Creek

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
Robinson	Semi-Confined Alluvial	7181.68	1.36	<1%								
Robinson	Unconfined Alluvial	5728.86	1.09	<1%								
Total		12910.54	2.45	<1%	23.7	50.1	1490	2760	3660	31.907	17.765	36%

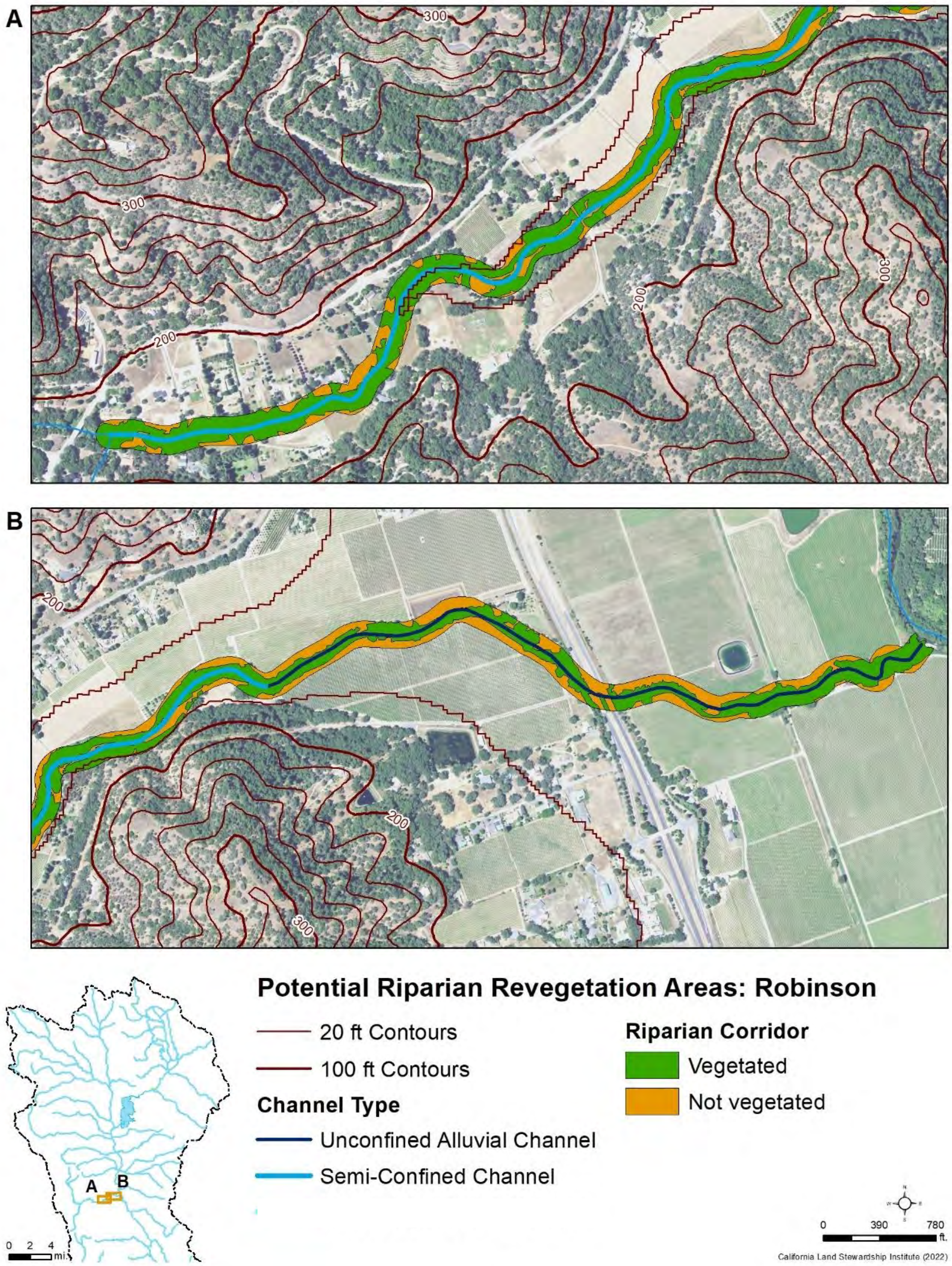


Figure 76. Potential revegetation areas on Robinson Creek

Morrison Creek

Morrison Creek was evaluated from where it exits its bedrock canyon to the confluence with the Russian River. Table 23 lists the length and slope class of Morrison Creek along with the watershed area draining to this creek reach, average annual precipitation and estimates of various size flood flows.

Channel type: Alluvial fan

Watershed Vegetation and Land Uses

Chaparral and hardwood forest dominate the Morrison Creek watershed. Land uses include grazing and recreation in the Cow Mountain Recreation Area in the upper watershed along with irrigated agriculture in the lower end of the watershed.

Revegetation Opportunities

Much (79%) of the Morrison creek riparian corridor is unvegetated (15.1 acres) (Figure 77). This creek likely always supported oak savannah rather than a dense riparian woodland. Planting widely spaced valley oaks and irrigating the oaks is the best approach to revegetation in this reach.

Revegetation Constraints

CLSI completed some revegetation experiments on Morrison Creek by creating a deep trench near the scour channel and putting long willow poles in the trench during winter. We also monitored shallow groundwater levels. This study along with one on Parsons Creek (p 77) showed that the incision in the main stem Russian River affects the spring groundwater level and limits the ability to revegetate Morrison Creek downstream of the Old River Road bridge.

Rank: Moderate

Table 23. Features of Morrison Creek

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
Morrison	Unconfined Alluvial	8307.04	1.58	<1%	9.30	45.40	581.00	1120.00	1500.00	4.00	15.16	79%

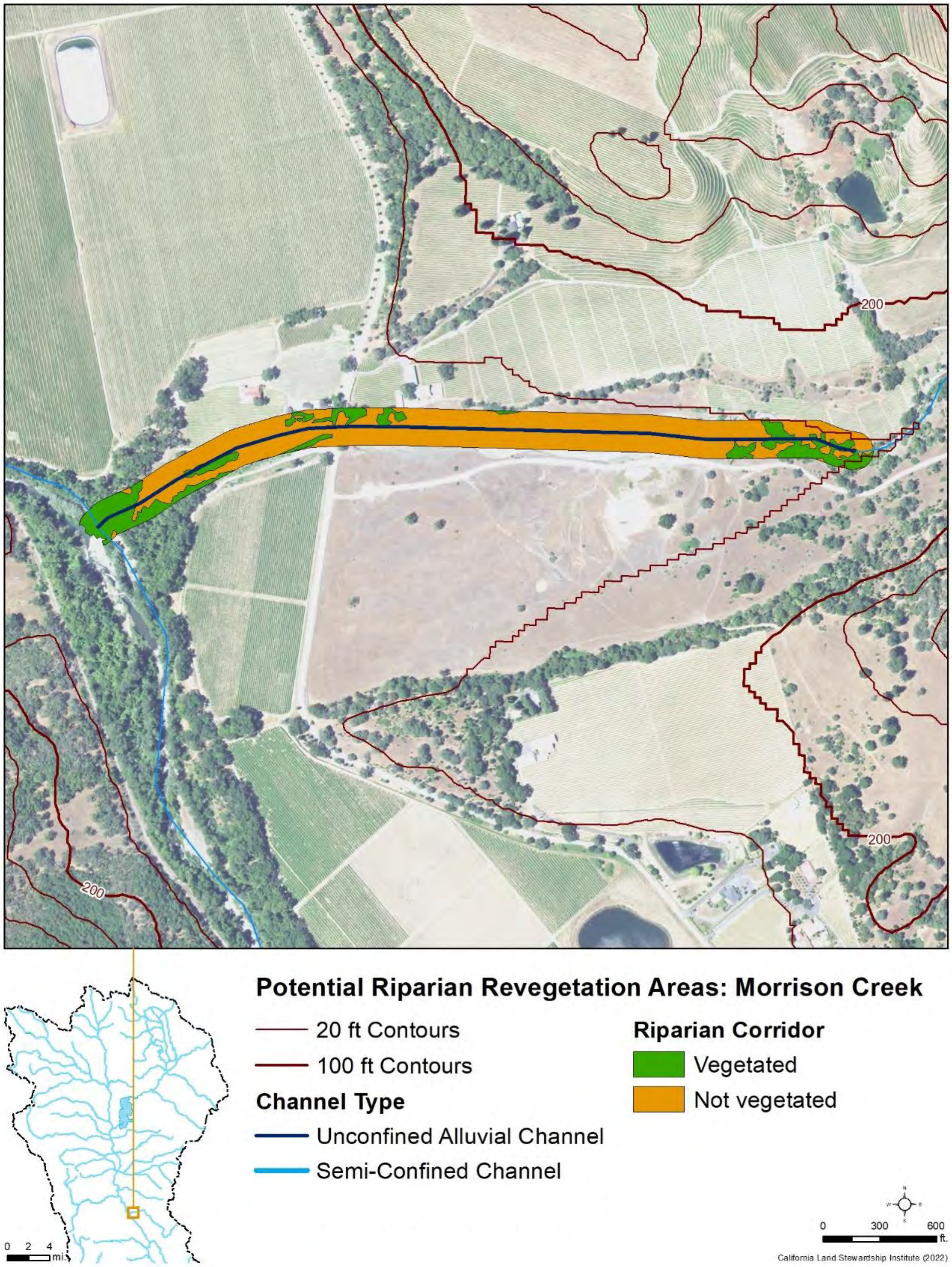


Figure 77. Potential revegetation areas on Morrison Creek

McNab Creek
McNab Creek was evaluated from the onstream reservoir in the upstream area to the confluence with the Russian River. Table 24 lists the length and slope class of McNab Creek along with the watershed area draining to this creek reach, average annual precipitation and estimates of various size flood flows.

Channel type: Unconfined alluvial – (upstream 2.36 miles), Dissected alluvium – (downstream, 1.78 miles)

Watershed Vegetation and Land Uses
Hardwood forest and grassland dominate the watershed of McNab creek. Land uses are grazing and irrigated agriculture

Revegetation Opportunities
Unvegetated areas of the McNab Creek riparian corridor make up 47% (45.1 acres) (Figure 78). Vegetated areas of the corridor total 50.8 acres. There are a large number of areas that need revegetation along McNab Creek.

Revegetation Constraints
McNab Creek is highly incised with 15-20 ft. banks along much of its length restricting the area where riparian trees can be planted. Revegetation will require that vineyard be removed and banks be set back. The Managed Bank Retreat method could also be used in collaboration with the farmers along the creek.

Rank: Low

Table 24. Features of McNab Creek

Creek	Channel type	Length of creek reach in ft	Length of creek reach in miles	Slope classification	Watershed area draining to upstream end of creek reach (square miles)	Average annual precipitation in watershed (inches)	Stream flow for 2-year return interval flood (CFS)	Stream flow for 5-year return interval flood (CFS)	Stream flow for 10-year return interval flood (CFS)	Acres of riparian corridor with vegetation	Acres of unvegetated area in riparian corridor	Percentage of riparian corridor without vegetation
McNab	Dissected Alluvium	9392.5	1.78	<1%								
McNab	Unconfined Alluvial	12484.	2.36	<1%								
Total		21876.9	4.14	<1%	2.9	50.2	224	429	577	50.80	45.10	47%

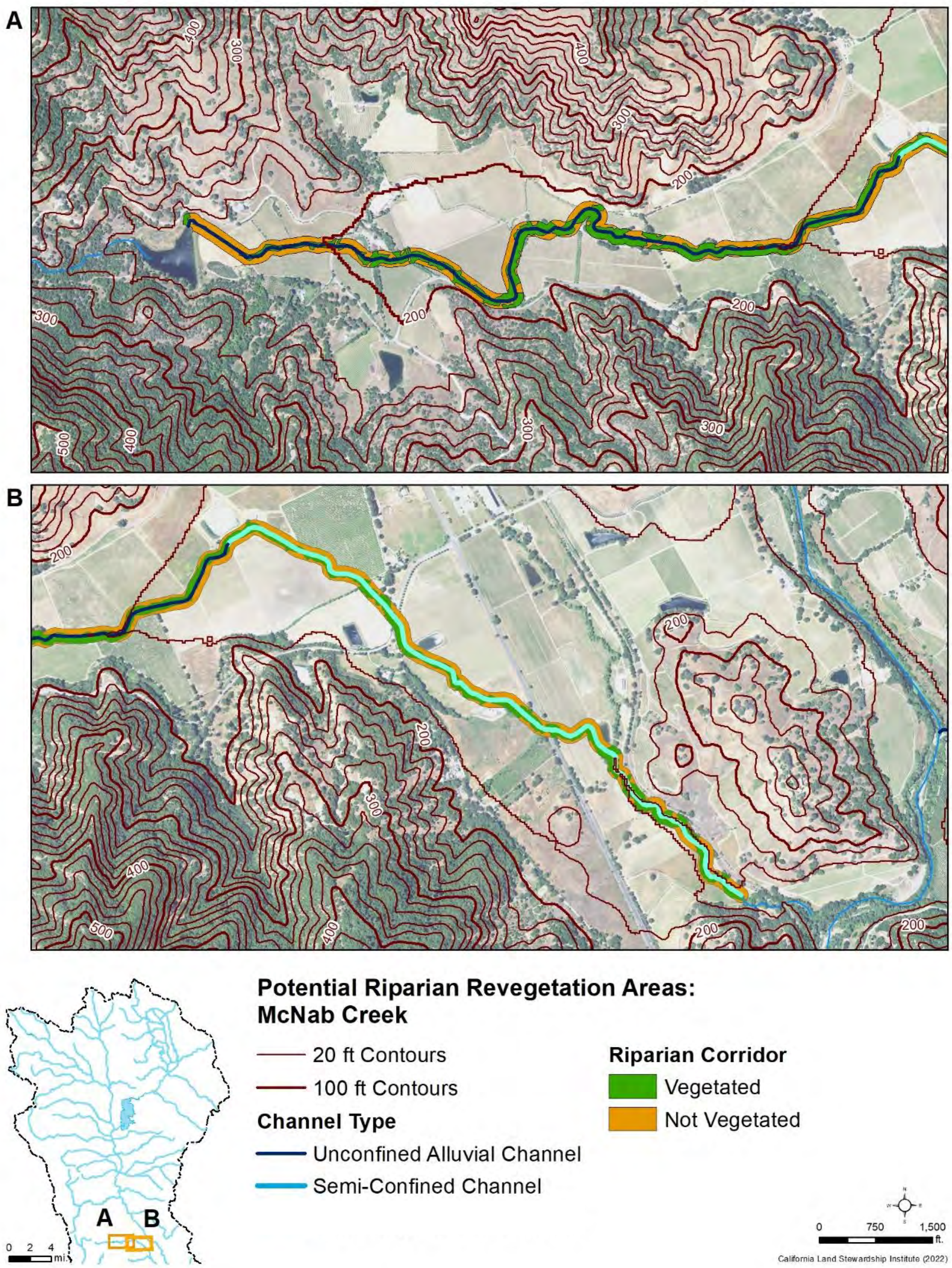


Figure 78. Potential revegetation areas on McNab Creek

Parsons Creek
Parsons Creek was evaluated from where the creek exits from its confined canyon to the confluence with the Russian River. Table 25 lists the length and slope class of Parsons Creek along with the watershed area draining to this creek reach, annual precipitation and estimates of various size flood flows.

Channel type: Unconfined alluvial

Watershed Vegetation and Land Uses
Hardwood forest and grassland dominate the Parsons Creek watershed. Land uses include grazing and recreation at the Cow Mountain Recreation Area.

Revegetation Opportunities
Unvegetated areas of the Parsons Creek riparian corridor make up 55% of the total area (3.7 acres) (Figure 79). Vegetated areas of the corridor total 3.1 acres. There are a number of areas that would benefit from revegetation along Parsons Creek; however, establishing riparian plants may be difficult in the mid to downstream area of this reach.

Revegetation Constraints
CLSI completed some revegetation experiments on Parsons Creek by creating 4 pairs of deep trenches from upstream of the Old River Road crossing to the confluence with the Russian River (p 77). These trenches were also located near the scour channel of Parsons Creek. Long willow poles (6-8 feet) were placed in the trenches during winter. The idea behind this method was to bring the willow poles closer to the groundwater. We also monitored shallow groundwater levels. This study along with one on Morrison Creek showed that the incision in the main stem Russian River affects the spring groundwater level and limits the ability to revegetate Parsons Creek downstream of the Old River Road bridge.

Rank: High

Table 25. Features of Parsons Creek

Creek	**Channel type**	**Length of creek reach in ft**	**Length of creek reach in miles**	**Slope classification**	**Watershed area draining to upstream end of creek reach (square miles)**	**Average annual precipitation in watershed (inches)**	**Stream flow for 2-year return interval flood (CFS)**	**Stream flow for 5-year return interval flood (CFS)**	**Stream flow for 10-year return interval flood (CFS)**	**Acres of riparian corridor with vegetation**	**Acres of unvegetated area in riparian corridor**	**Percentage of riparian corridor without vegetation**
Parsons	Unconfined Alluvial	0.29	1516.53	<1%	8.50	40.50	479.00	943.00	1280.00	3.11	3.74	55%

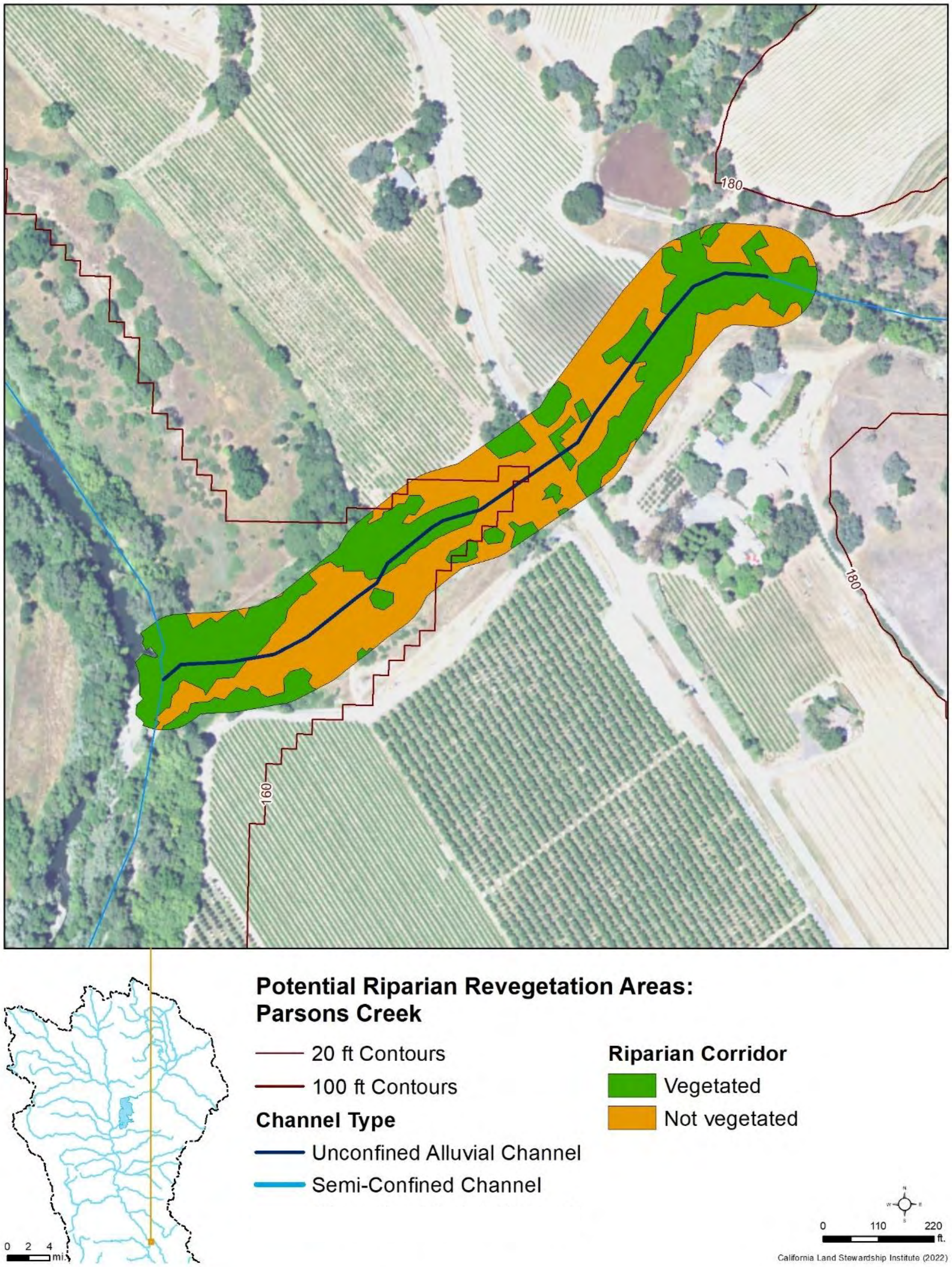


Figure 79. Potential revegetation areas on Parsons Creek

Summary

Table 26 Summarizes the review of each creek. We recommend that the creeks rated high (marked in bold) and possibly moderate be the focus of revegetation projects

Table 26. Summary of information on priority creeks

Creek	**Percentage of riparian corridor unvegetated**	**Ranking**
Mariposa	24%	Low
Salt Hollow	44%	High
Forsythe I	24%	Low
Forsythe II	48%	High
Forsythe III	30%	High
Ackerman	28%	Low
McClure	51%	High
Mill	46%	High
North Fork Mill	22%	Low
Robinson	36%	Moderate
Morrison	79%	High
McNab	47%	Low
Parsons	55%	High

REVEGETATION PROJECTS

Salt Hollow Creek

Revegetation plans were prepared for two sections of Salt Hollow Creek.

Revegetation zones 1 and 2 are located in the downstream reach of Salt Hollow Creek at the confluence with the West Fork Russian River. The incision in the mainstem Russian River has migrated up into the West Fork and Salt Hollow Creek. The creek channel is very narrow and deep and over the next 10 years will start to widen as the tall banks can no longer stand up at 15-20 ft tall. Due to the proximity of vineyard to the creek the easiest way to implement a creek revegetation project is to implement Managed Bank Retreat with the owners on each side of the channel.

Dormant willow sprigs should be installed at the lower 2 ft. of the bank once it erodes. The willows should be installed during winter months (see page 81). The sprigs should be installed 5 feet apart. The mid and upper banks should be revegetated with a variety of riparian seedling trees planted 15 ft apart.

Revegetation zones 3 and 4 are upstream and are an opportunity to widen the riparian corridor with seedling trees. The trees should be installed 20 ft. apart.

Table 27 provides the details of the revegetation for each project.

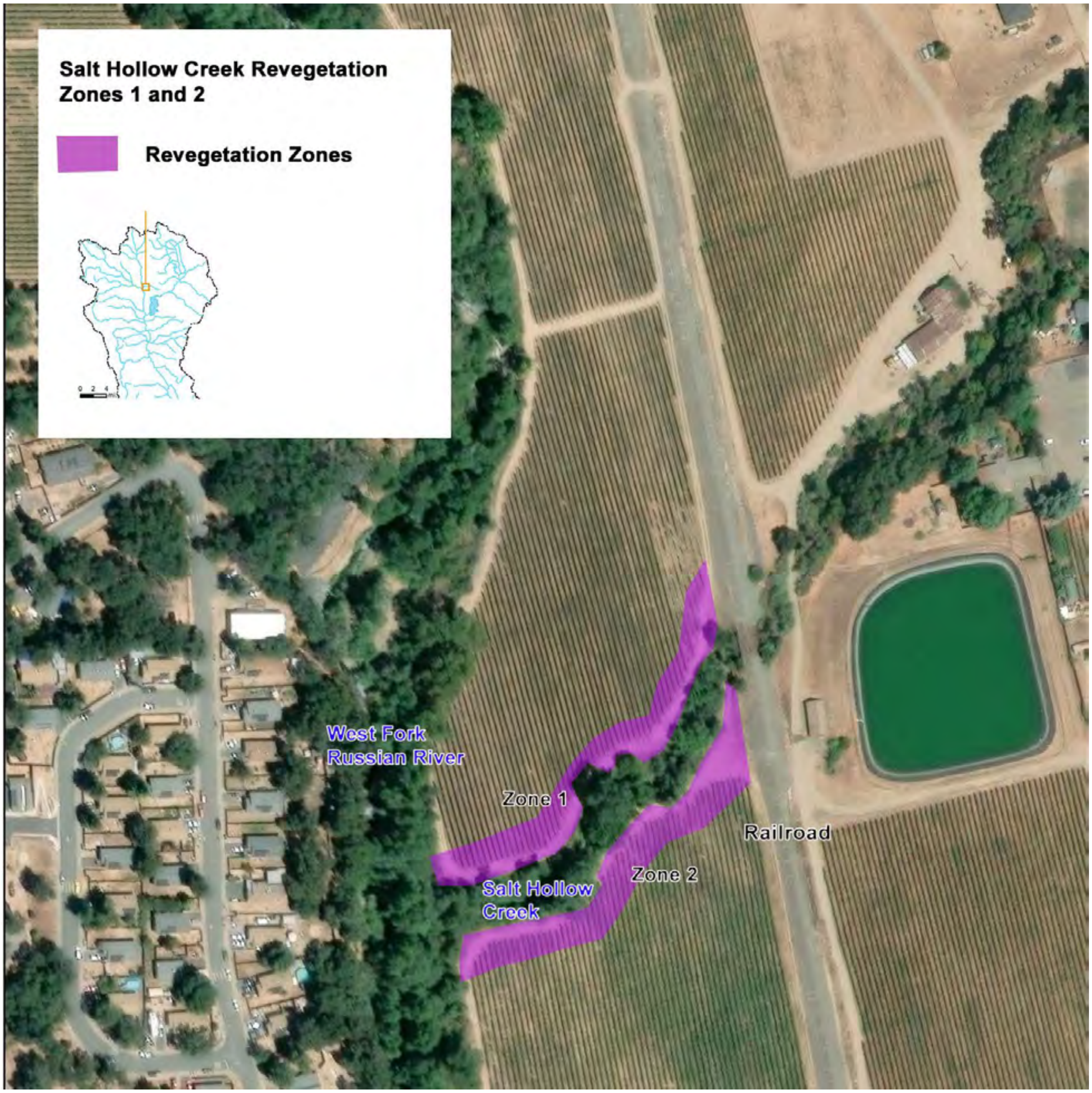


Figure 80. Revegetation plan for Salt Hollow Creek Parcels 7 and 49 (see Appendix 4).

Figure 81. Revegetation plan for Salt Hollow Creek Parcel 41 (see Appendix 4)

Table 27. Revegetation Plant List for Salt Hollow Creek

Scientific Name	Common Name	Number of plants					
		Zone 1	Zone 2	Zone 3	Zone 4	Total	Plant type
		0.77 acres	0.77 acres	0.93 acres	0.46 acres		
Trees							
Aesculus californica	Ca buckeye	25	25	20		70	Dee pot or tree band container, plant on 20 ft spacing
Quercus lobata	Valley oak	15	15	40	35	105	Dee pot or tree band container plant on 20 ft spacing
Quercus agrifolia	Live oak	25	25	40	35	125	Dee pot or tree band Container, plant on 20 ft spacing
Fraxinus latifolia	Oregon ash	25	25	40		90	Dee pot or tree band Container, plant on 20 ft spacing
Dormant Cuttings							
Salix sp.	Willow	75	75			150	Dormant cutting, plant on 5 ft spacing at base of bank only
TOTALS		**165**	**165**	**140**	**70**	**540**	

Forsythe Creek II

We identified four large areas along the Forsythe Creek II reach. These projects would transform grassland into riparian corridor. Table 28 lists the plants for each zone on Figures 82 and 83

Figure 82. Revegetation plan for Forsythe Creek II Parcels 4 and 128 (see Appendix 4).

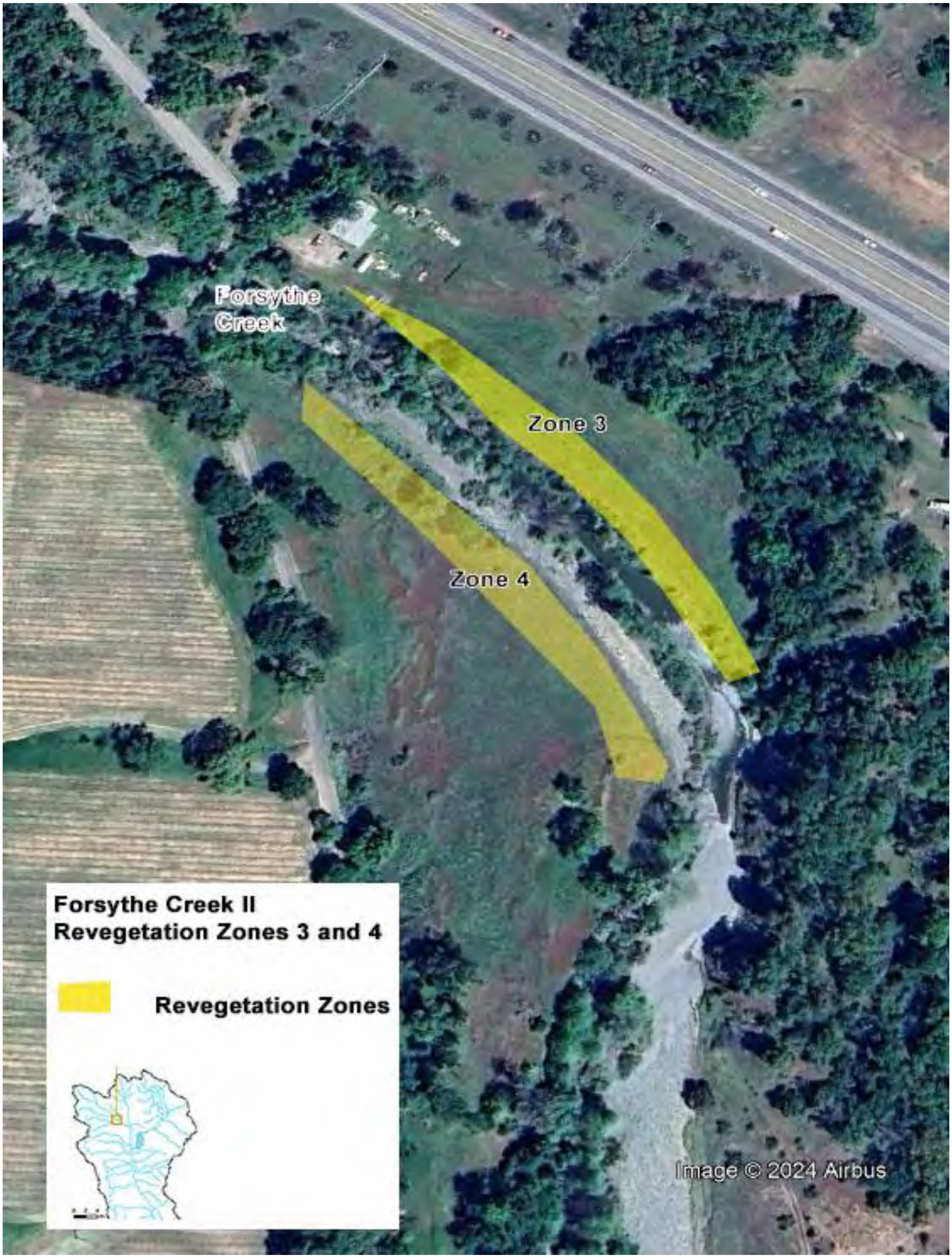


Figure 83. Revegetation plan for Forsythe Creek II Parcels 26 and 23 (see Appendix 4).

Table 28. Revegetation Plant List for Forsythe Creek II.

Scientific Name	Common Name	Number of plants					
		Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**Total**	**Plant type**
		1.6 acres	**1.8 acres**	**1.8 acres**	**1.4 acres**		
Trees							
Aesculus californica	Ca buckeye	25	25	20	10	80	Dee pot or tree band container, plant on 20 ft spacing
Acer negundo	Box elder		6	26	10	42	Dee pot or tree band container, plant on 20 ft spacing
Quercus lobata	Valley oak	15	15	40	7	77	Dee pot or tree band container plant on 20 ft spacing
Quercus agrifolia	Live oak	25	25	40		90	Dee pot or tree band Container, plant on 20 ft spacing
Fraxinus latifolia	Oregon ash	25	25	40	30	120	Dee pot or tree band Container, plant on 20 ft spacing
Populus fremontii	Fremont Cottonwood		25	30	20	75	Dee pot or tree band container, plant on 20 ft spacing
Dormant Cuttings							
Salix sp.	Willow		75		75	150	Dormant cutting, plant on 5 ft spacing at base of bank only
TOTALS		**90**	**196**	**196**	**152**	**634**	

Forsythe Creek III

In this area of Forsythe Creek there are numerous rural residences and many pathways next to the creek. In order to have successful revegetation project on these sites it will be necessary to have several neighborhood meetings and establish pathways and educate local residents of the value of revegetating the creek. Forming a creek group that can help with planting, replanting and maintenance could provide ownership of the project and improve local stewardship. Table 29 lists the plants for each zone. Several zones have some trees already and this has been taken into account in the planting plans.

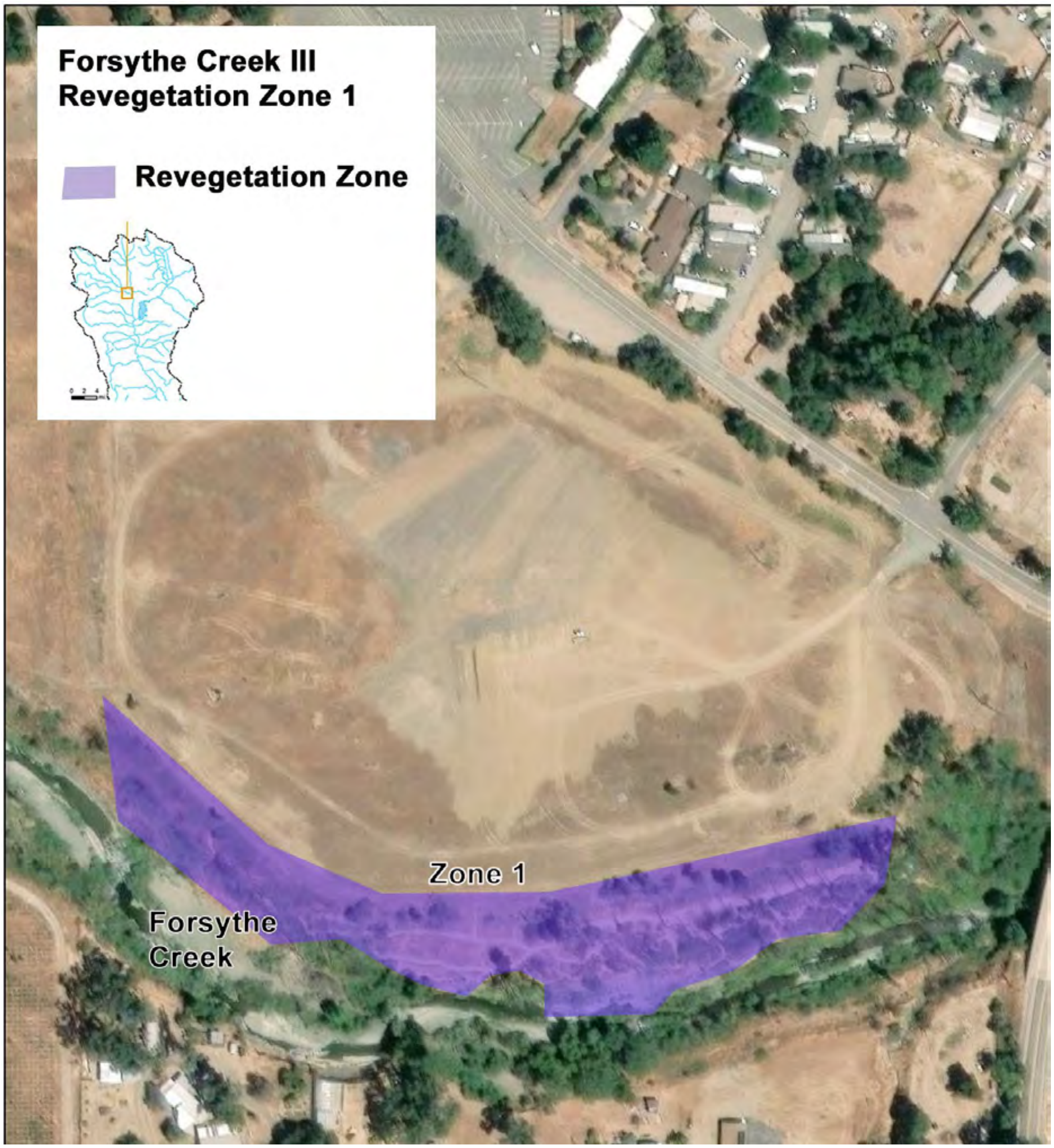


Figure 84. Revegetation plan for Forsythe Creek III Parcel 108 (see Appendix 4).

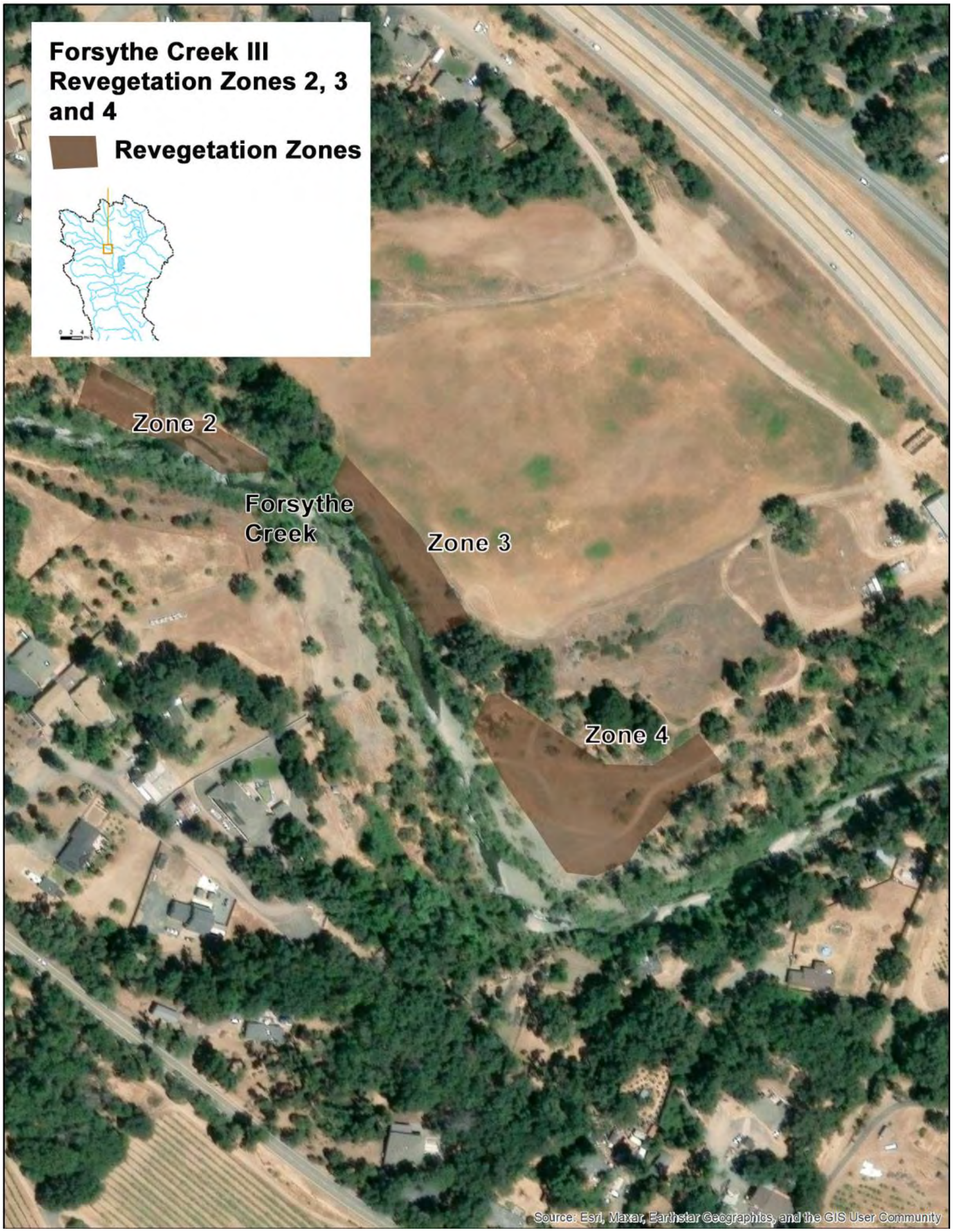


Figure 85. Revegetation plan for Forsythe Creek III Parcel 125 (see Appendix 4).

Table 29. Revegetation Plant List for Forsythe Creek III.

Scientific Name	Common Name	Number of plants					
		Zone 1	Zone 2	Zone 3	Zone 4	Total	Plant type
		1.0 acres	0.3 acres	0.4 acres	1.6 acres		
Trees							
Aesculus californica	Ca buckeye	9	5	10	30	54	Dee pot or tree band container, plant on 20 ft spacing
Acer negundo	Box elder		5	10	40	55	Dee pot or tree band container, plant on 20 ft spacing
Quercus lobata	Valley oak	10	13	4	10	37	Dee pot or tree band container plant on 20 ft spacing
Quercus agrifolia	Live oak	10	5			15	Dee pot or tree band Container, plant on 20 ft spacing
Fraxinus latifolia	Oregon ash	10	5	10	30	55	Dee pot or tree band Container, plant on 20 ft spacing
Populus fremontii	Fremont Cottonwood	20		10	30	60	Dee pot or tree band container, plant on 20 ft spacing
Dormant Cuttings							
Salix sp.	Willow	50			13	63	Dormant cutting, plant on 5 ft spacing at base of bank only
TOTALS		**109**	**33**	**44**	**153**	**339**	

McClure Creek

We have identified 5 zones for revegetation along McClure Creek. Zones 1-3 are in the alluvial fan portion of the creek and will be revegetated as oak savannah the natural habitat of these creek types. Revegetation Zones 4 and 5 are located in the downstream reach of McClure Creek. The creek channel is very narrow and deep and over the next 10 years will start to widen as the tall banks collapse. Due to the proximity of vineyard to the creek the easiest way to implement a creek revegetation project is to implement Managed Bank Retreat with the owners on each side of the channel.

Dormant willow sprigs should be installed at the lower 2 ft. of the bank once it erodes. The willows should be installed during winter months (see page 81). The sprigs should be installed 5 feet apart. The mid and upper banks should be revegetated with a variety of riparian seedling trees planted 20 ft apart.

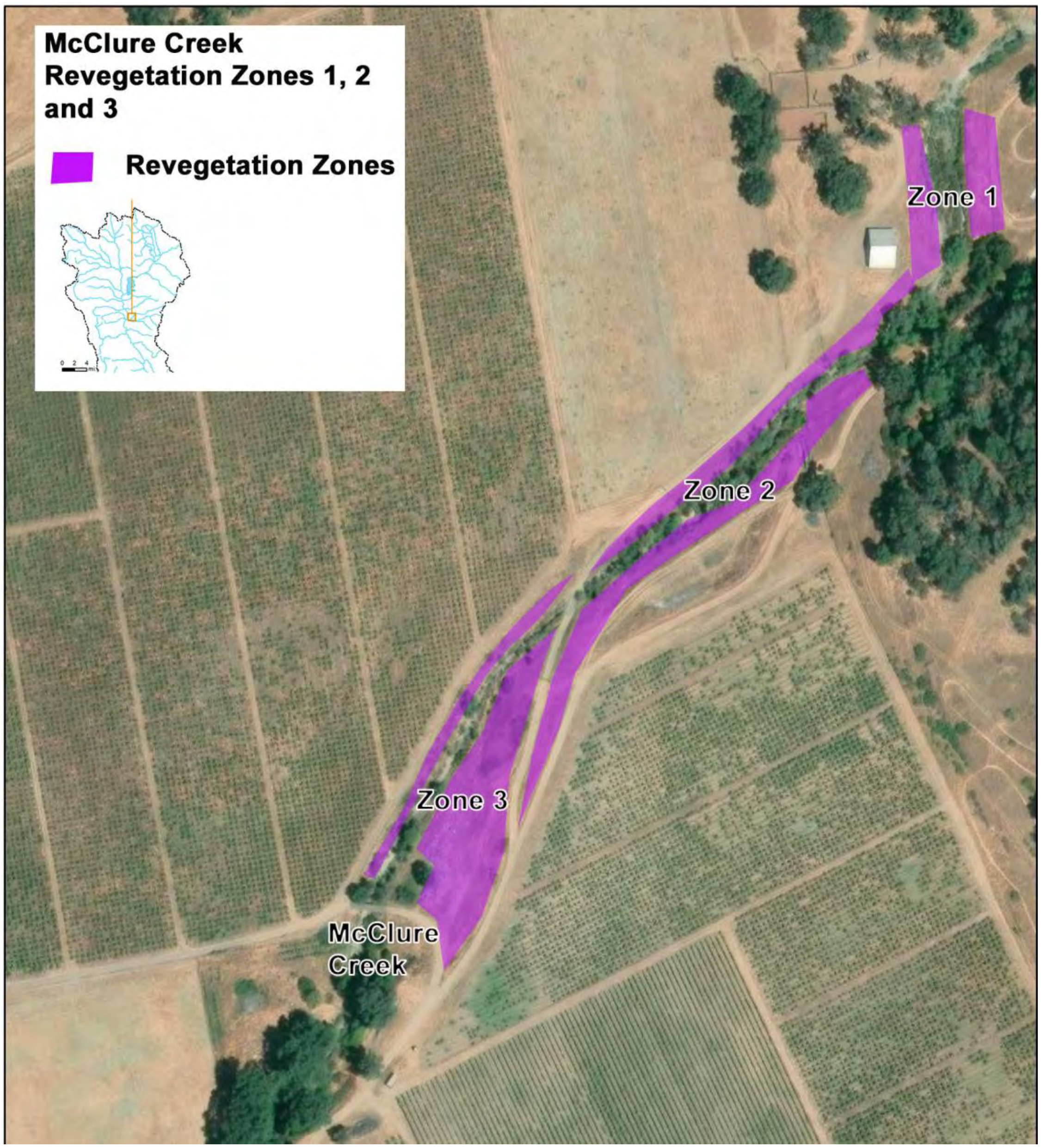


Figure 86. Revegetation Plan for McClure Creek Parcels 75 and 78 (see Appendix 4).

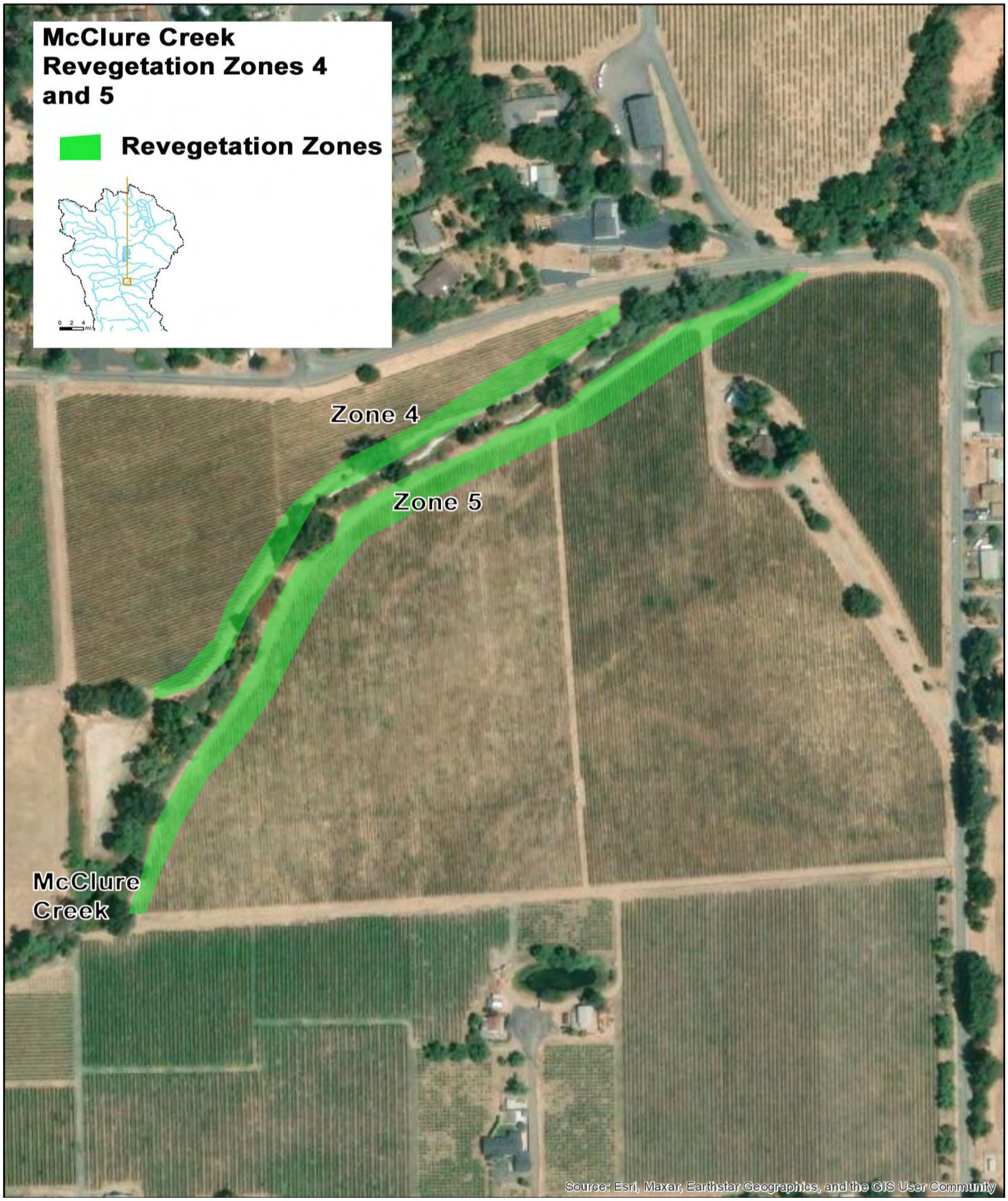


Figure 87. Revegetation Plan for McClure Creek Parcel 205 (see Appendix 4).

Table 30. Revegetation Plant List for McClure Creek.

Scientific Name	Common Name	Number of plants						
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total	Plant type
		0.3 acres	0.5 acres	0.7 acres	2.0 acres	3.0 acres		
Trees								
Aesculus californica	Ca buckeye		10	25	52	77	164	Dee pot or tree band container, plant on 20 ft spacing
Acer negundo	Box elder				52	78	130	Dee pot or tree band container, plant on 20 ft spacing
Quercus lobata	Valley oak	17	25	26	51	77	196	Dee pot or tree band container plant on 20 ft spacing
Quercus agrifolia	Live oak	16	20	25	52	78	191	Dee pot or tree band Container, plant on 20 ft spacing
Fraxinus latifolia	Oregon ash				51	78	129	Dee pot or tree band Container, plant on 20 ft spacing
Populus fremontii	Fremont Cottonwood				52	78	130	Dee pot or tree band container, plant on 20 ft spacing
Dormant Cuttings								
Salix sp.	Willow				697	1045	1742	Dormant cutting, plant on 5 ft spacing at base of bank only
TOTALS		**33**	**55**	**76**	**1007**	**1511**	**2682**	

Mill Creek

The downstream section of Mill Creek where it reaches the Russin River is highly impacted by a gravel mining operation. There is very little vegetation along this reach of the creek and no vegetative filter stirps to intercept sediment from the mining site. Under state regulations the filterstrips should be installed as part of the mining operation along with other management measures to protect water quality. As part of the post mining reclamation process the creek has to be revegetated and restored. For zones 3 and 4 only the unvegetated area will be planted.

Figure 88. Revegetation Plan for Mill Creek Parcels 201 and 202 (see Appendix 4).

Figure 89. Revegetation Plan for Mill Creek Parcel 272 (see Appendix 4).

Table 31. Revegetation Plant List for Mill Creek.

Scientific Name	Common Name	Number of plants					
		Zone 1	Zone 2	Zone 3	Zone 4	Total	Plant type
		0.52 acres	1.1 acres	0.98 acres	0.97 acres		
Trees							
Aesculus californica	Ca buckeye	20	20	20	20	80	Dee pot or tree band container, plant on 15 ft spacing
Acer negundo	Box elder	21	20	15	15	71	Dee pot or tree band container, plant on 15 ft spacing
Quercus lobata	Valley oak		13	25	25	63	Dee pot or tree band container plant on 15 ft spacing
Quercus agrifolia	Live oak			20	20	40	Dee pot or tree band container, plant on 15 ft spacing
Fraxinus latifolia	Oregon ash	20	20	15	15	70	Dee pot or tree band container, plant on 15 ft spacing
Populus fremontii	Fremont Cottonwood	40	40			80	Dee pot or tree band container, plant on 15 ft spacing
Dormant Cuttings							
Salix sp.	Willow		100			100	Dormant cutting, plant at base of bank only
TOTALS		**101**	**213**	**95**	**95**	**504**	

Robinson Creek

Revegetation Zones 1 and 2 are located in the downstream reach of Robinson Creek. The creek channel is highly incised and over the next 10 years will start to widen as the tall banks collapse. Due to the proximity of vineyard to the creek the easiest way to implement a creek revegetation project is to implement Managed Bank Retreat with the owners on each side of the channel. Dormant willow sprigs should be installed at the lower 2 ft. of the bank once it erodes. The willows should be installed during winter months (see page 81). The sprigs should be installed 5 feet apart. The mid and upper banks should be revegetated with a variety of riparian seedling trees planted 20 ft apart.

Figure 90. Revegetation Plan for Robinson Creek Parcels 313 and 170 (see Appendix 4).

Table 32. Revegetation Plant List for Robinson Creek.

Scientific Name	Common Name	Number of plants					
		Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**Total**	**Plant type**
		1.8 acres	**0.9 acres**				
Trees							
Aesculus californica	Ca buckeye	20	20			40	Dee pot or tree band container, plant on 20 ft spacing
Acer negundo	Box elder	20	20			40	Dee pot or tree band container, plant on 20 ft spacing
Quercus lobata	Valley oak	20	8			28	Dee pot or tree band container plant on 20 ft spacing
Quercus agrifolia	Live oak	10				10	Dee pot or tree band Container, plant on 20 ft spacing
Fraxinus latifolia	Oregon ash	20	10			30	Dee pot or tree band Container, plant on 20 ft spacing
Populus fremontii	Fremont Cottonwood	6				6	Dee pot or tree band container, plant on 20 ft spacing
Dormant Cuttings							
Salix sp.	Willow	100	40			140	Dormant cutting, plant on 5 ft spacing at base of bank only
TOTALS		**186**	**98**			**284**	

Morrison Creek

The revegetation plan for Morrison Creek focus on recreating oak savannah habitat. Thei section of Morrison Creek is an alluvial fan and oak savannah is the natural vegetation type for fans. This plan should be implemented over a number of years. This revegetation plan can be revised to accommodate the recharge pond if that project moves forward

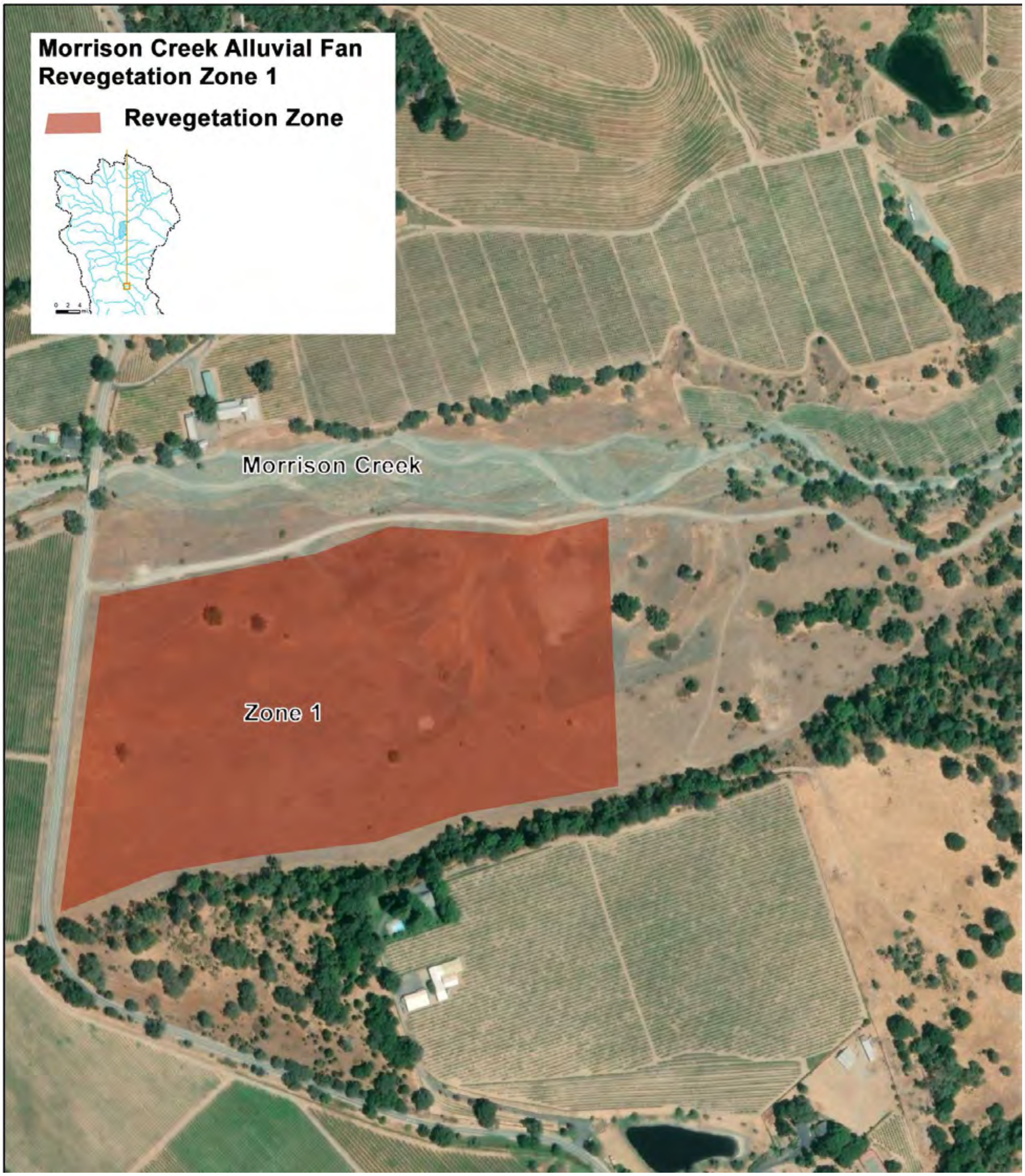


Figure 91. Revegetation Plan for Morrison Creek Parcels 92 and 82 (see Appendix 4).

Table 33. Revegetation Plant List for Morrison Creek.

Scientific Name	Common Name	Number of plants					
		Zone 1	Zone 2	Zone 3	Zone 4	Total	Plant type
		39.7 acres					
Trees							
Aesculus californica	Ca buckeye						Dee pot or tree band container, plant on 20 ft spacing
Acer negundo	Box elder						Dee pot or tree band container, plant on 20 ft spacing
Quercus lobata	Valley oak	600				600	Dee pot or tree band container plant on 40 ft spacing
Quercus agrifolia	Live oak	472				472	Dee pot or tree band Container, plant on 40 ft spacing
Fraxinus latifolia	Oregon ash						Dee pot or tree band Container, plant on 20 ft spacing
Populus fremontii	Fremont Cottonwood						Dee pot or tree band container, plant on 20 ft spacing
Dormant Cuttings							
Salix sp.	Willow						Dormant cutting, plant on 5 ft spacing at base of bank only
TOTALS		**1072**				**1072**	

Parsons Creek

This is a relatively small project that would increase the riparian corridor along Parsons Creek upstream of Old River Road.

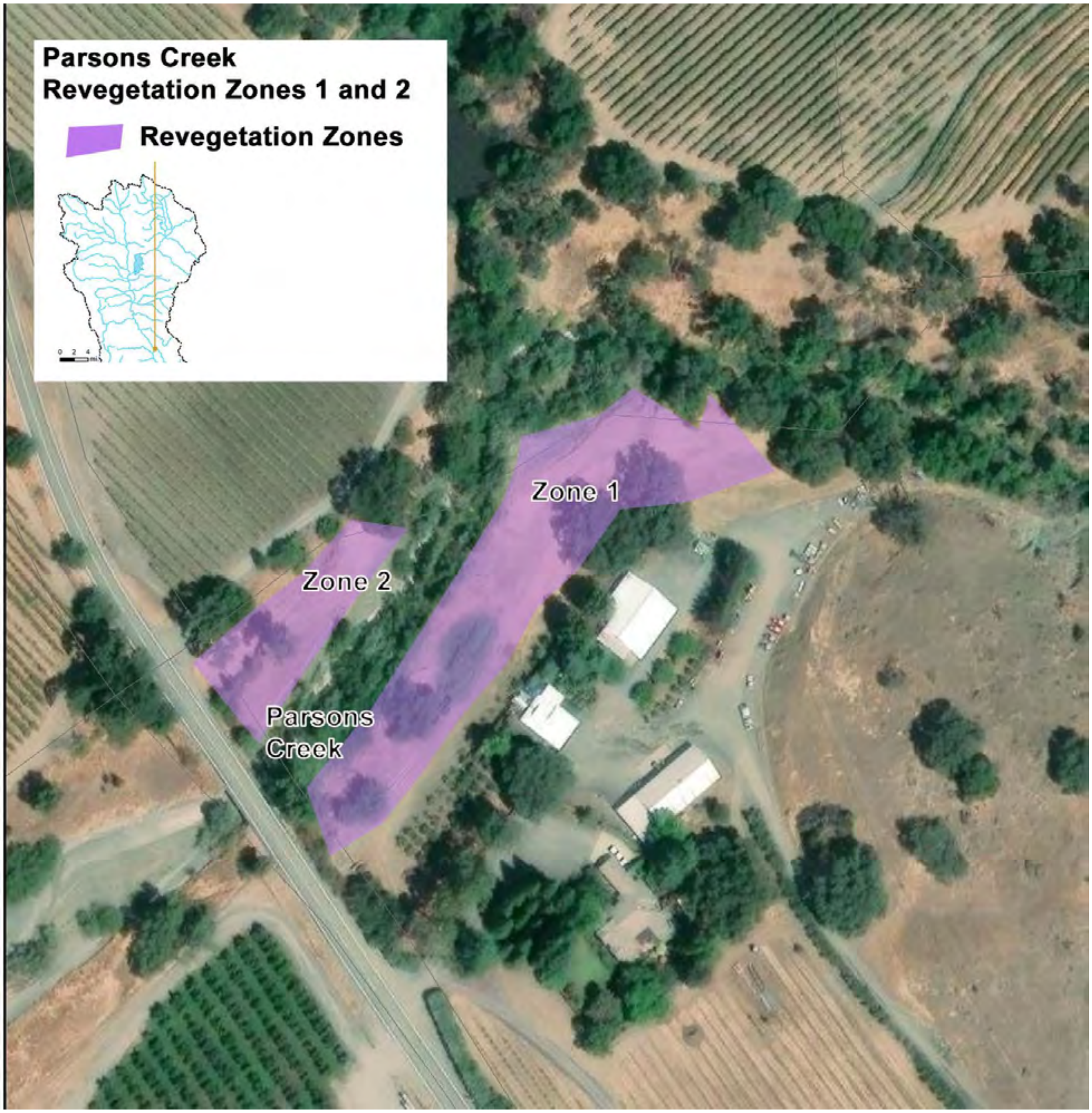


Figure 92. Revegetation Plan for Parsons Creek Parcels 62 and 80 (see Appendix 4).

Table 34. Revegetation Plant List for Parsons Creek.

Scientific Name	Common Name	Number of plants					
		Zone 1	Zone 2	Zone 3	Zone 4	Total	Plant type
		0.5 acres	0.56 acres				
Trees							
Aesculus californica	Ca buckeye	10	10			20	Dee pot or tree band container, plant on 20 ft spacing
Acer negundo	Box elder	10	10			20	Dee pot or tree band container, plant on 20 ft spacing
Quercus lobata	Valley oak	10	15			25	Dee pot or tree band container plant on 20 ft spacing
Quercus agrifolia	Live oak	10	15			25	Dee pot or tree band Container, plant on 20 ft spacing
Fraxinus latifolia	Oregon ash	15	11			26	Dee pot or tree band Container, plant on 20 ft spacing
Populus fremontii	Fremont Cottonwood						Dee pot or tree band container, plant on 20 ft spacing
Dormant Cuttings							
Salix sp.	Willow						Dormant cutting, plant on 5 ft spacing at base of bank only
TOTALS		**55**	**61**			**116**	

Implementation and Costs
The following planting details apply to all the revegetation plans.

Planting Notes:

1. Each Revegetation Plan is designed to enhance the riparian zone on the property. Selected plants are intended to create a riparian corridor of ecologically appropriate native plants to provide canopy cover, wildlife habitat, and to aid in bank stabilization. Willow cuttings are installed at the base of the bank. It should be noted that high flows may still cause bank erosion

2. Planting shall be installed in the winter months, once rainfall has moistened the soil to a depth of ten inches or greater. Planting shall be completed by March.

3. Planting technique shall be predominantly liner-sized seedlings (see Planting Details) propagated from seeds and cuttings collected as close as possible to the revegetation site. Plants will be installed with protective hardware and weed mats that are appropriate to the site conditions.

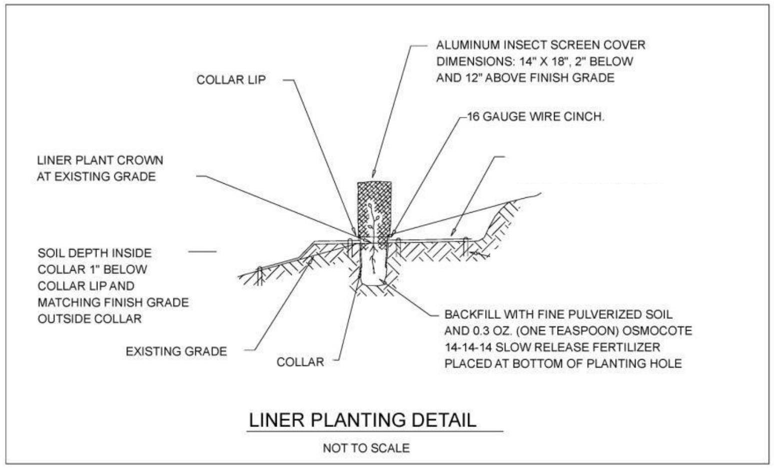
4. To ensure survival, plants will require frequent irrigation during the first dry season after planting. Irrigation should begin in April and continue into October. Approximately one to two gallons of water shall be applied directly to the plant during each irrigation visit. Watering interval shall be seven to ten days depending on weather conditions.

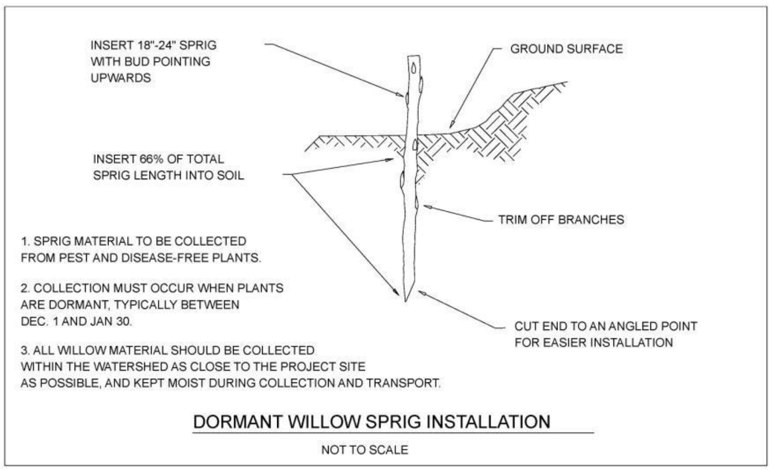
5. Weeds need to be removed around each plant for a period of three years – twice in the spring and once in the fall.

6. Invasive non-native plants such as Himalayan blackberry (Rubus armeniacus) and blue periwinkle (Vinca major) should be eradicated prior to planting native plants.

7. Cattle access to revegetation areas will need to be restricted either with a permanent fence or an electrical fence. Cattle will both trample and/or browse the installed plants.

8. Costs for revegetation plan vary widely. Based on several recent projects (2024) cost can vary from $30-$66/installed plant for purchase of the plants, installation and hardware to protect the plant and installation of drip irrigation lines for summer irrigation.





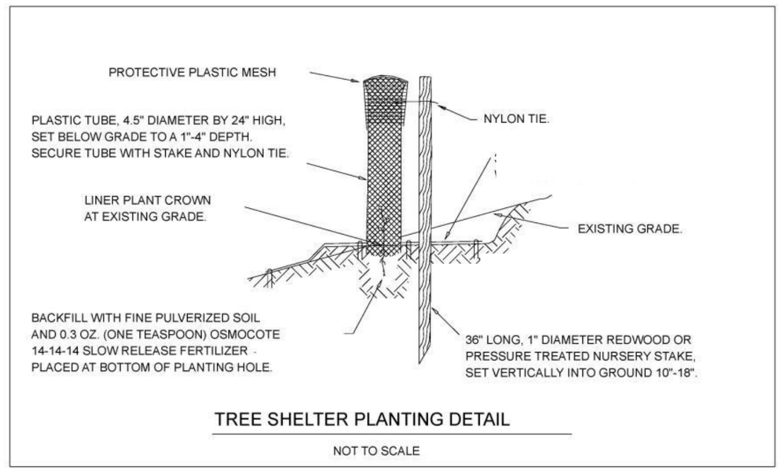


Figure 93. Planting Details

III. FIRE AND FUEL LOAD REDUCTION

INTRODUCTION

This report is the third section of the watershed plan and addresses fire and fuel reductions in the UVGBW. This report documents vegetation types, fire hazard severity zones and other analyses of fire risks as well as document parcels with structures and needed evacuation routes. Additionally future fire conditions with modeled climate changes are presented and how fire conditions will worsen in the future. Based on these future conditions the report recommends a number of actions.

VEGETATION

Figure 94 depicts the various types of vegetation in the UVGBW (U.S. Forest Service 2008). The eastern side of the basin is dominated by drought tolerant and fire adapted species. Table 35 lists the primary plant species in each vegetation type and their occurrence on the west, east side or both of Ukiah Valley. Figure 95 shows a graph of the acreage of each type of vegetation along the east side of the UVGBW. Chaparral, mixed hardwood, oak woodland and annual grassland are the most widespread vegetation types. Figure 96 graphs the acreage of each vegetation type along the west side of the UVGBW. There is far less chaparral on the west side and far more coniferous forest. Oak woodland is similar in coverage on both sides of the UVGBW. These vegetation types vary greatly in their response to wildfire and in their ability to recover following a burn.

Annual Grasses and Forbs

Annual grasslands in California are dominated by annual nonnative European grasses such as brome (Bromus sp.), wild oat (Avena sp.), dogtail (Cynosurus sp.), barley (Hordeum sp.), ryegrass (Lolium sp.) and others (Crampton 1974). Invasive plants such as yellow star thistle (Centaurea solstitialis) and black mustard *(*Brassica nigra) are common in grasslands.

In some locations native perennial bunchgrasses such as needlegrass (Nassella sp.), fescues (Festuca sp.), Ca. oatgrass (Danthonia sp.) can be found. Native forbs and wildflowers in grasslands include: wild hyacinth (Brodiaea sp.), mariposa lily (Calocortus sp.), Indian paintbrush (Castilleja sp.), tidy tips (Layia sp.), Ca. poppy (Eschscholzia californica) and others. Native forbs and grasses tend to germinate after fires when built up biomass is cleared away (Hervey 1949, Marty 2002). Some species have fire adaptations. For example, lupines and some clovers produce hard seeds that germinate after fire. Soap plant (Chlorogalum pomeridianum) can resprout from its bulb following fire The seeds of filaree species (Erodium) are awns that drill into the ground and withstand fires.

Mixed Chaparral

Chaparral is made up of evergreen, hard leaved and close growing shrubs and small trees. The leaves on the shrubs are oriented vertically to reduce overheating. Most shrubs in the chaparral are fire dependent. Chaparral is associated with Mediterranean climates and often grows on shallow rocky slopes at elevations of 900-4500 ft where 9 to 29 inches of rain falls yearly. Following a fire an ephemeral flora of annuals will grow int eh first year form the seed left in the litter of the chaparral form the last post fire bloom. Some of these species will spend 95% of their lifetime as a dormant seed waiting for a post fire bloom. About 20% of the post fire flora sprout form bulbs, corms or rhizomes and go dormant once the canopy of larger shrubs shades them out. In addition to these herbaceous plants

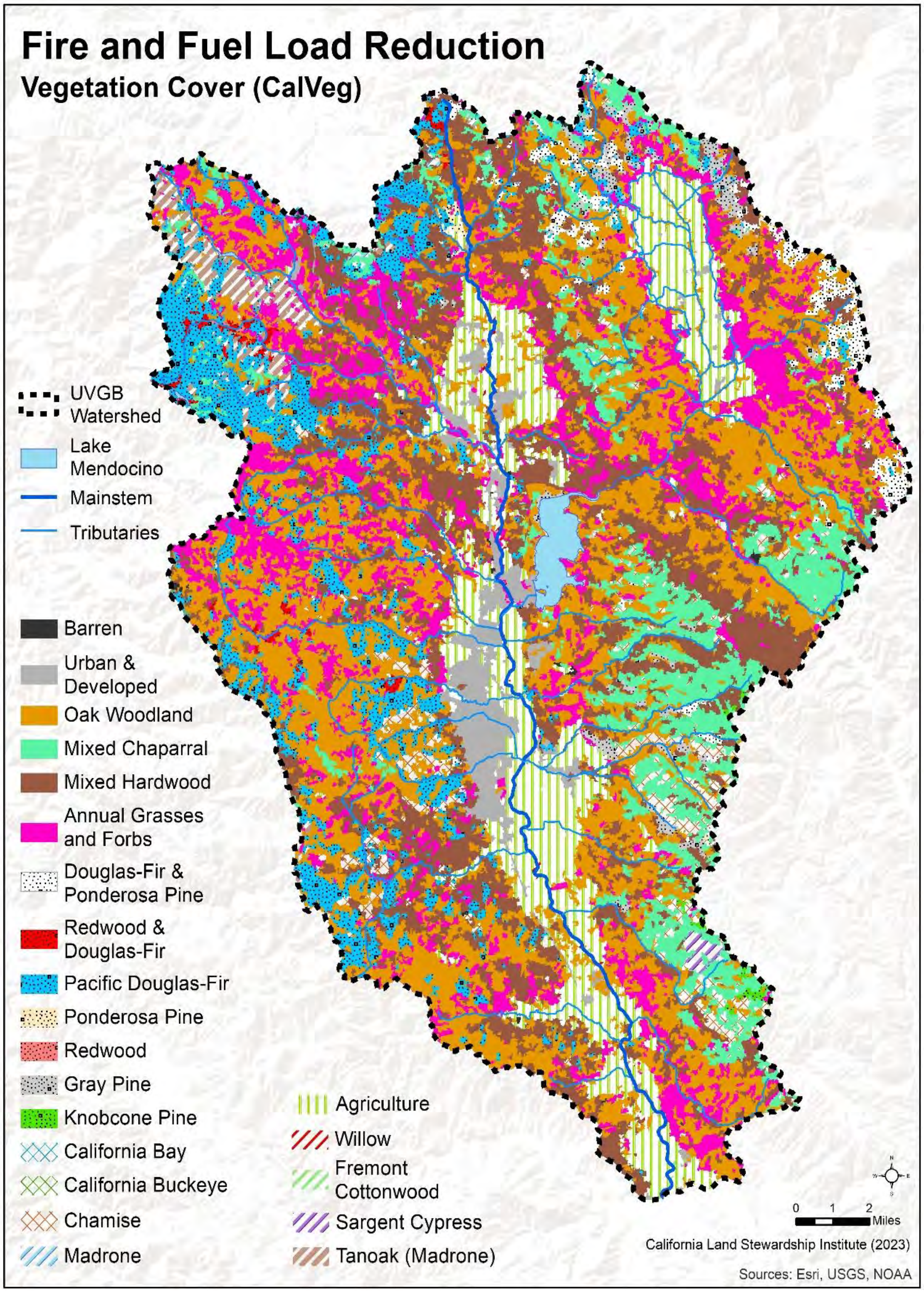


Figure 94. Vegetation types for the Ukiah Valley Groundwater Basin Watershed (UVGBW).

Table 35. Plant species associated with vegetation types in Figure 94. From: U.S. Forest Service. 2008.

General vegetation type	Specific vegetation type	Total acres	Likely species	East, or west side of valley or both
Agriculture	Agriculture	26,221.56	winegrapes, pears and olives	both
Annual Grasses and Forbs	Annual Grasses and Forbs	31,608.16	native: needlegrass, bluegrass, fescue, oatgrass, checker mallow, brodiaea, wild hyacinth, yampah, Mariposa lily and nonnative invasive: brome, wild oat, dogtail, barley	both
California Bay Laurel	California Bay Laurel	21.14	just Ca. bay laurel typically but may also have canyon live oak, coast live oak, ceanothus	east
California Buckeye	California Buckeye	42.96	just Ca. buckeye typically but may also have ca. bay laurel, canyon live oak, shrub oak, chamise and manzanita	west
Chamise	Chamise	4,716.08	just chamise typically but may also have wedgeleaf Ceanothus, canyon live oak, manzanita, knobcone pine and gray pine	both
Douglas-Fir – Pine	Douglas-Fir - Pine	4,232.16	Douglas fir, Ponderosa pine, knobcone pine, madrone, black oak, canyon live oak	both
Fremont Cottonwood	Fremont Cottonwood	251.67	just Fremont cottonwood or with willow	both
Gray Pine	Gray Pine	2,752.86	just gray pine typically but may also have blue oak, Oregon white oak, canyon live oak, madrone, chamise, white leaf and common wedgeleaf manzanita	both
Knobcone Pine	Knobcone Pine	286.75	just knobcone pine typically but may also have black oak, Oregon white oak, tanoak, shrub oak, canyon live oak, chamise and manzanita	east
Madrone	Madrone	275.18	just madrone typically but may also have Oregon white oak, chamise and manzanita	both

Table 35. (cont.) Plant species associated with vegetation types in Figure 94.

General vegetation type	Specific vegetation type	Total acres	Likely species	East, or west side of valley or both
Mixed Chaparral	Lower Montane Mixed Chaparral	19,214.12	chamise, wedgeleaf Ceanothus, birchleaf mountain mahogany, whiteleaf manzanita, Huckleberry oak, scrub oak, canyon live oak	both
	Upper Montane Mixed Chaparral	47.30	greenleaf manzanita, deerbrush, mountain whitehorn, Huckleberry oak, snowbush, hoary manzanita, canyon live oak, Fremont silktassel, pinemat manzanita	east
Mixed Hardwood	Interior Mixed Hardwood	42,139.00	blue oak, Oregon white oak, black oak, canyon live oak, coast live oak, Ca. bay laurel, Douglas fir	both
	Montane Mixed Hardwood	172.70	black oak, tanoak, tree chinquapin, madrone, canyon live oak, interior live oak, coast live oak, Oregon live oak, Ca. bay laurel, Ca. buckeye, blue oak, valley oak	east
Riparian Mixed Hardwood	Riparian Mixed Hardwood	16.92	willow, white alder, red alder, black cottonwood, Fremont cottonwood	east
Oak Woodland	Oak Woodland	72,291.67	black oak, blue oak, canyon live oak, coast live oak, Oregon white oak, scrub oak, valley oak, interior live oak	both
Pacific Douglas Fir	Pacific Douglas Fir	19,388.24	Douglas fir, sugar pine, tanoak, canyon live oak	both
Ponderosa Pine	Ponderosa Pine	236.14	just Ponderosa pine typically but may also have black oak, canyon live oak, Oregon white oak and whiteleaf manzanita	both
Redwood	Redwood	51.41	just coastal redwood typically but may also have tanoak, Pacific Douglas fir, Ca. hazelnut and Rhododendron	west
Redwood - Douglas-Fir	Redwood - Douglas-Fir	912.69	coast redwood, Douglas fir, tanoak, red alder, madrone, Ca. bay laurel, Oregon white oak, ca. hazelnut	both
Sargent Cypress	Sargent Cypress	409.31	Sargent cypress, McNab cypress, gray pine, Oregon white oak, coffeeberry, chamise, manzanita	east
Tanoak	Tanoak	3,402.22	tanoak with or without madrone	both
Willow	Willow - Alder	612.51	various species of willow and alder	both

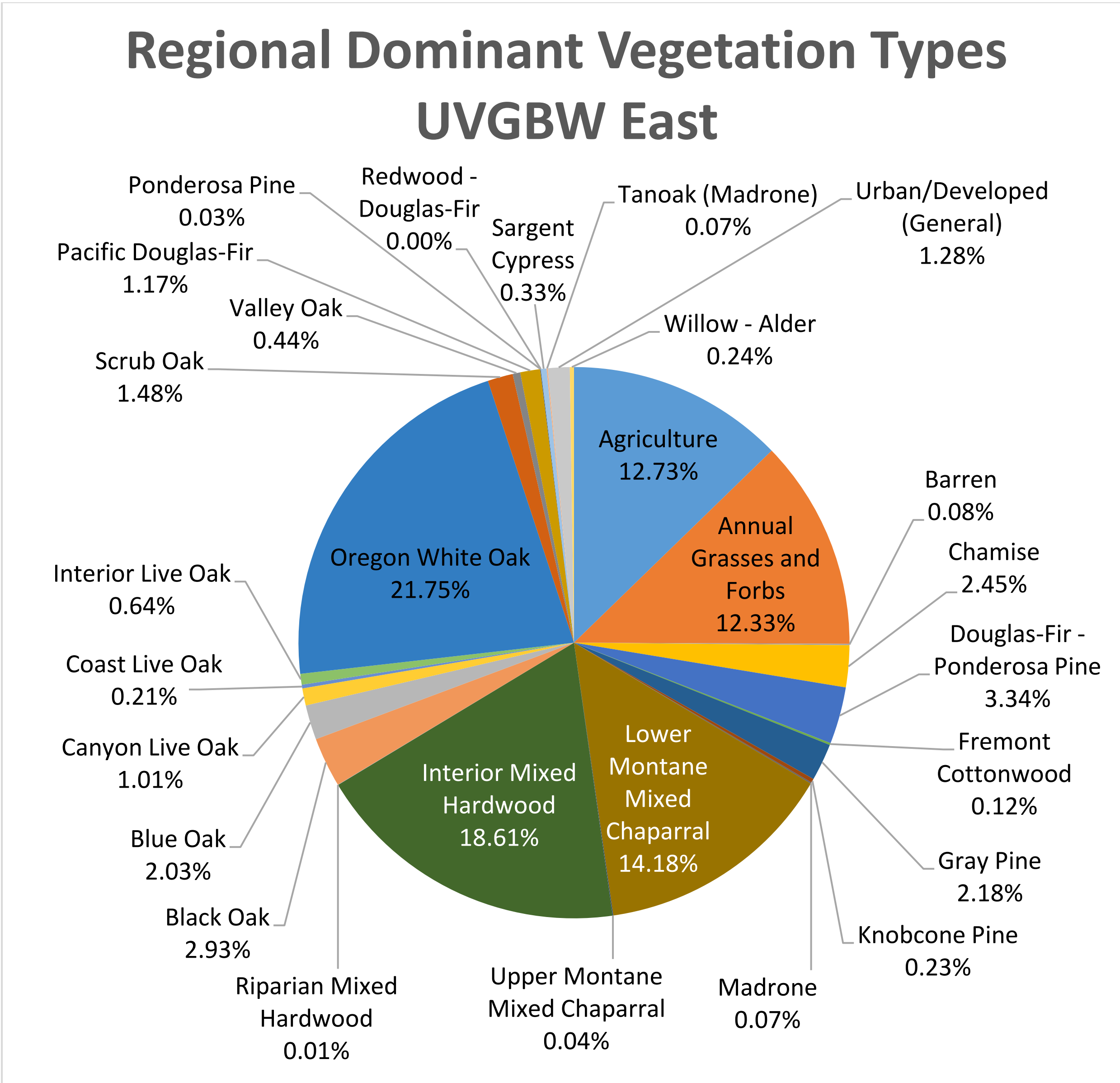


Figure 95. Vegetation types of the east side of UVGBW.

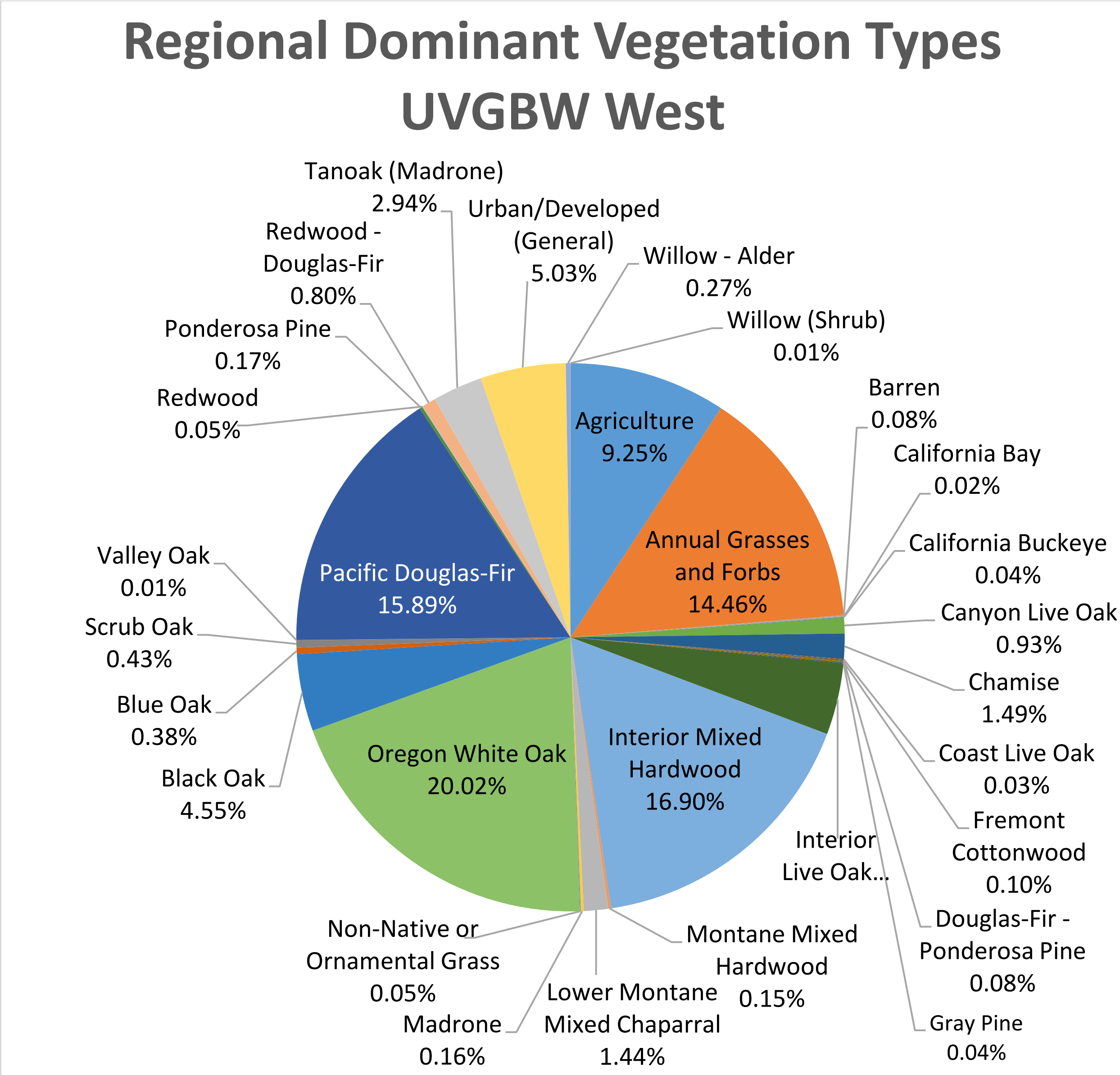


Figure 96. Vegetation types of the west side of UVGBW.

there are subshrubs such as toyon (Heteromeles arbutifolia), scrub oak (Quercus berberidifolia), mountain mahogany (Cerocarpus betuloides) and others that germinate post fire and will persist for up to 10 years, produce large amounts of seed and then die as they are shaded out by larger shrubs. The seed will remain viable until the next fire to grow again. Seed may stay dormant for up to 115 years and still germinate (Keeley et al 2003).

For the larger shrubs the fire will kill the above ground parts of the shrub. At soil level most shrubs will have a root crown or burl (Figure 97) The burl will start sprouting very soon after the fire (Figure 98). Chaparral shrubs also produce seeds which build up in the litter and will sprout after a fire. The seeds require a fire to break the hard seed coat and allow germination. These seedlings can tolerate severe summer conditions following a fire and need full sun. Looking across expanses of chaparral there are typically large patches of shrubs of the same age and size representing the regrowth following a fire intermixed with patches of much larger shrubs that are unburned. Figures 99-101 show a 2013 fire on Mt Diablo in Contra Costa County and the regrowth of chaparral and hardwood trees 10 years after the fire. There is no old growth chaparral as this vegetation type is fire dependent for seeds to germinate and established shrubs to resprout (Quinn and Keeley 2006, US Forest Service 2018, Reeves 2006, Fryer 2012, League 2005, Howard 1997, McMurray 1990, Howard 1993, Hauser 2007). In the absence of fire chaparral shrubs can get old enough to die creating large holes in the canopy and areas where invasive plants may get established. However frequent fires (2-10 years) can result in the transition of chaparral to grassland. The seedling and resprouting shrubs cannot grow enough to survive another fire.

Three types of shrubs dominate chaparral – chamise, manzanita and Ceanothus:
Chamise (Adenostoma fasciculatum) has small one-half inch or less dark green needlelike leaves (Figure 102). Chamise flowers in early February and resprouts quickly after fire. Chamise tends to grow at lower elevations and on south facing slopes (Quinn and Keeley 2006).

There are many species of Ceanothus, also called blue blossom or Ca. lilac, in California. This shrub flowers in winter and produces small fruits that explode in the summer heat and distribute seed. Some species do not stump sprout, but die following fire and regrow from seed; the majority of species resprout from root crowns (Quinn and Keeley 2006).

Manzanita (Arctostaphylos sp.) is widely distributed in California and is the longest-lived chaparral shrub. It tends to grow on higher slopes and ridgetops. Manzanita flowers in winter and produces fruits that are eaten by many types of wildlife. The digestive effects of the animal on the fruits makes the seed germinate better. Sprouting species are well adapted to frequent fires but still need 20 years or more between fires to fully recover (Sugihara et al. 2006).

Scrub oak (Quercus berberidifolia) termed “chaparra” by Spanish explorers is the primary tree species in the chaparral and is widely distributed in California. Scrub oak is evergreen with small leaves with spiny margins. This plant flowers from March to May and resprouts following fire. Often scrub oak will grow underneath the shrub canopy and stay as a stunted sapling. Then following a fire this species can resprout and reach the heights above or at the shrub canopy level.

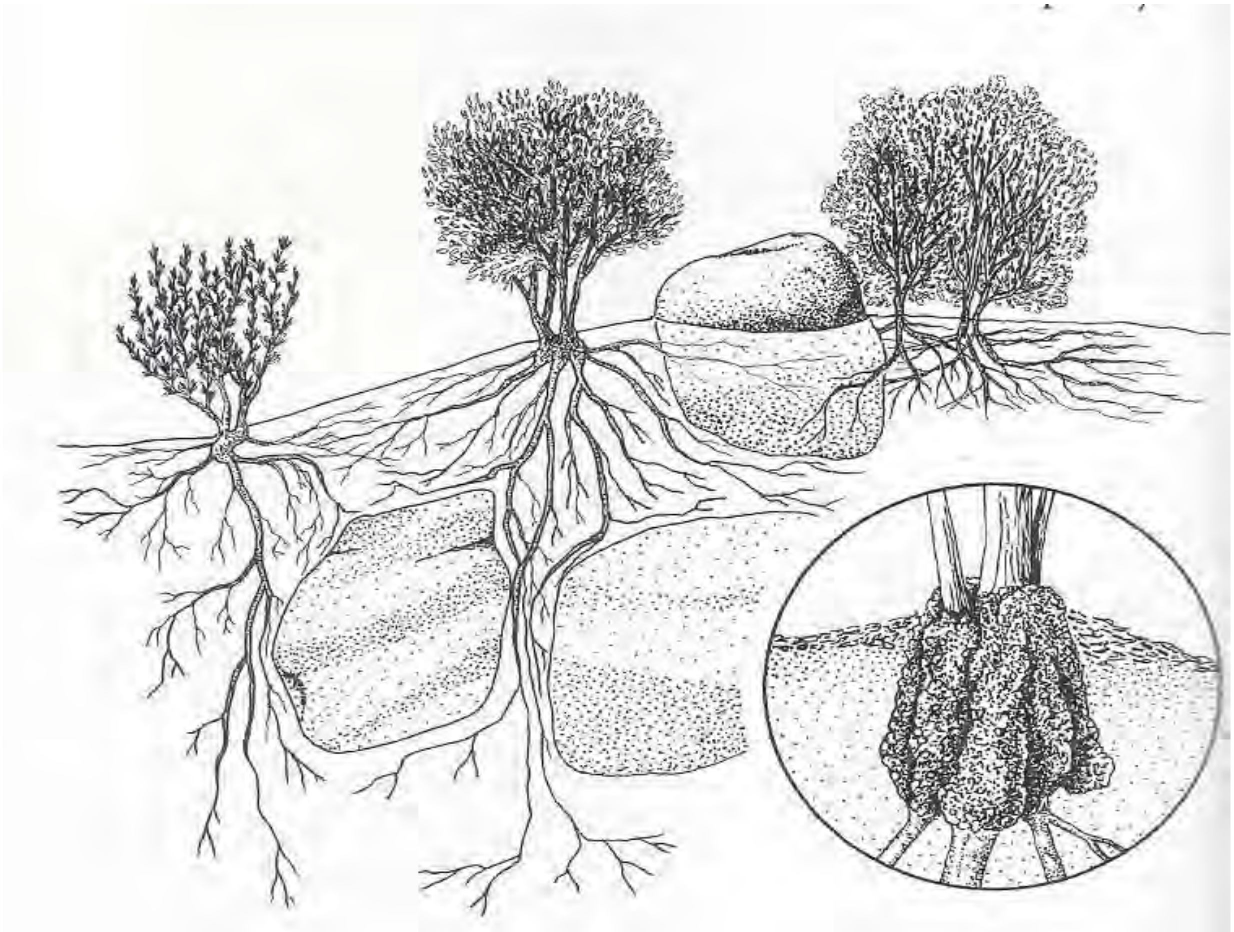


Figure 97. Root systems of chaparral plants hold the soil. Chamise (left), manzanita (middle) and Ceanothus (right). The inset is a root crown/burl in a chamise shrub. From: Quinn and Keeley 2006.

Figure 98. Post fire stump sprouting of chamise.


Figure 99. Chaparral shrubs and hardwoods following 2013 fire on Mt Diablo.


Figure 100. Resprouting and growth in an oak tree on Mt Diablo 10 years after fire.


Figure 101. Regrowth of scrub oak 10 years after fire on Mt Diablo.

Chamise flowering in the spring

Scrub oak

Ceanothus flowering in the spring

Greenleaf manzanita

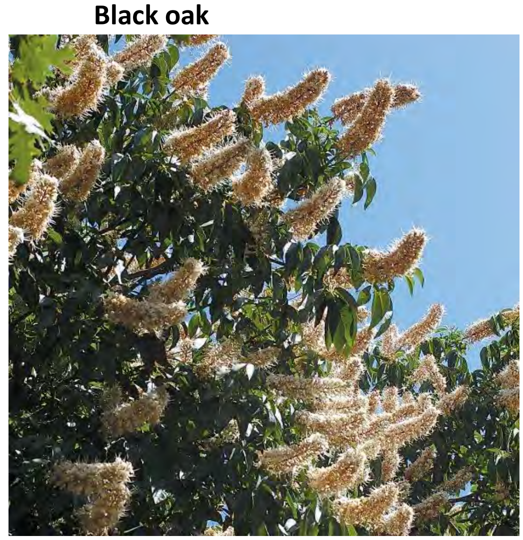
Ceanothus flower

Manzanita flower

Figure 102. Plants of mixed chaparral in the UVGBW.

Coast live oak **Canyon live oak**

Blue oak **Black oak**



Ca. bay laurel **Ca buckeye**

Figure 103. Plants of oak woodland and hardwood forest in the UVGBW

Figure 104. Stump sprouting oak with a post Redwood Valley fire infestation of invasive French broom.

Douglas fir cones

Ponderosa pine

Coastal redwood

Knob-cone pine

Grey pine cones

Grey pine

Sargent cypress

Sargent cypress

Figure 105. Conifer trees in the UVGBW.

Oak Woodland and Mixed Hardwoods

Oak woodland includes a variety of oak species that vary in distribution with slope, aspect, soil and water availability. All of these species are somewhat fire resistant and all resprout from their root crown (stump or burl) when fire kills above ground growth (Pavlik 1991, Fryer 2007a and b, Fryer 2012, Gucker 2007, Howard 1992a, c and d, Steinberg 2002, Tollefson 2008). Acorns germinate quickly and in large numbers on the burned mineral soil following a fire.

Oak woodland species in the UVGBW include (Figure 103):
Coast live oak (Quercus agrifolia) is an evergreen oak that favors north facing slopes, canyon bottoms, streams and locations with deep soils. Coast live oak has very hard bark that resists burning

Interior live oak (Quercus wislizeni) is also an evergreen oak and covers valley bottoms, canyons and hillsides.

Blue oak (Quercus douglasii) can be deciduous or evergreen depending on available soil moisture and is the most drought tolerant oak. It occurs in particularly hot and dry locations and is very slow growing.

Canyon live oak (Quercus chrysolepis), also called golden oak, is an evergreen oak that lives in ravines and along creeks.

Black oak (Quercus kelloggii) has large deciduous leaves and occurs in ravines along stream and on rich soils.

Oregon white oak (Quercus garryana) is widespread and deciduous with fairly large leaves.

Valley oak (Quercus lobata) needs abundant moisture and occurs on valley floors, ravines and along creeks. This species is deciduous.

Ca. bay laurel (Umbellularia californica) is the only native California tree in the avocado family and is evergreen with highly scented leaves. This species occurs along creeks, in ravines and on hillsides.

Ca. buckeye (Aesculus californica) has large sprigs of white flowers and segmented leaves. Buckeyes lose their leaves in late spring and become dormant to avoid the effects of summer drought.

Mixed hardwood forest consists of oak woodland species intermixed with Douglas fir, a conifer.

There are a number of invasive nonnative plants that invade burned lands particularly hardwood and conifer forests. Figure 104 shows a burned hardwood forest where French broom (Genista monspessulana) has invaded and is nearly as large as the stump sprouting growth of the oak trees. French broom is highly flammable and this invasion creates a dense understory of flammable vegetation in future fires. Broom produces abundant seed that remains viable and will allow for rapid re-establishment after the next fire. Other invasive nonnative species in burn areas are Scotch broom (Cytisus scoparius) and Spanish broom **(**Spartium junceum)**.** Gorse (Ulex europaeus), yellow and purple star thistle (Centaurea solstitialis, Centaurea calcitrapa) black mustard (Brassica nigra) and European grasses are invasive species that invade burned lands.

Conifer Forest
There are a number of conifer tree species that occur in various associations with other trees, with chaparral or in single species stands in the UVGBW (Figure 105).

Conifer species in the UVGBW include:
Douglas fir (Pseudotsuga menziesii) can withstand moderate fires but will die after a crown fire. Its seeds germinate best on mineral soils in full sun. Douglas fir has corky bark that has low heat conductivity to resist low and moderate severity fires

Grey pine (Pinus sabiniana) occurs with hardwoods and chaparral and can grow on serpentine soils. This species has pendent cones with wind dispersed seeds (Howard 1992e).

Knob cone pine (Pinus attenuata) grows on nutrient poor soils including serpentine and is often found in pure and even aged stands regrown after fires. The cones of this species are serotinous and dependent on fire to open and disperse seeds (Howard 1992b).

Ponderosa pine (Pinus ponderosa) grows on well drained, non-serpentine soil and will be killed by crown fires, but not moderate fires (Fryer 2018). This species has thick bark to resist moderate and low intensity fires.

Coastal redwoods (Sequoia sempervírens) only grow in the coastal fog belt along creeks and protected slopes. They require continuous moisture and will sprout following fire from epicormic buds underneath the bark (Griffith 1992).

Sargent cypress (Cupressus sargentii) is a fire dependent species that grows in widely scattered, isolated groves and as part of many vegetation types. Sargent cypress often grows on serpentine soils. Many trees die in larger fires. Fire opens cypress cones releasing seed resulting in the growth of dense thickets of new cypress (Esser 1994).

NATURAL FIRE REGIMES

In California's Mediterranean climate there is little to no rain from May/June to Oct./Nov. The long, dry hot summer leaves vegetation desiccated and easily burned. Several years of drought increases the dryness of vegetation and its flammability (Barrett et al. 2010).

Prior to human settlement lightning was the main ignition source for fires. Lightning in the coastal ranges comes from monsoons that move north out of the American Southwest bringing afternoon thunderstorms (Adams and Comrie 1997). These types of storms can occur for up to 10-20 days per summer season. The fires started by these lightning storms could have burned for months until put out by rainstorms.

Fire has been a major factor in landscapes in California for millions of years (Sugihara et al. 2006). The vegetation in the mountains in the UVGBW developed adaptations to these natural fire regimes. Table 2 lists the natural fire return intervals for the vegetation types in the UVGBW as modeled by the LANDFIRE Rapid Assessment Vegetation Model of the U.S. Forest Service.

Native American Indian tribes in California managed the landscape using fire to protect their villages, improve plant collection and hunting areas and to favor the growth of food plants (Heizer and Whipple 1972). Fires were set annually in certain areas (Anderson 2005).

Nineteenth century loggers burned cut over conifer forest land once logging was complete. This action cleared slash and logging debris and created grassland for livestock grazing (Sugihara et al. 2006).

In 1905 the US Forest Service began the practice of widespread fire suppression in national forests. State and local fire authorities adopted the same approach in 1924. Fires were put out quickly. Over time this practice resulted in the buildup of large fuel loads (Sugihara et al. 2006).

HISTORIC FIRES

Figure 106 depicts the extent and locations of fires larger than 1000 acres mapped by CalFire since 1960. The causes and sizes of the fires on the map are listed in Table 36 and also shown by size in Figure 107. The 1981 Cow Mountain fire was started by an arsonist and burned in 110^{o} F temperatures consuming over 25,000 acres in six days and destroying 20-30 structures (Ukiah Daily Journal 1981). Table 37 and Figure 108 depict the acres burned in wildfires since 1920. Table 37 shows six different fires between 1923-1995 that burned less than 15,000 acres.

More recent fires from 2017 and 2018 vary greatly in size from those of prior decades. The Redwood Valley fire burned over 54,300 acres, destroyed 543 structures and resulted in several deaths. This fire started on 10/8/17 and burned until containment was reached on 2/8/18 (CalFire 2018). The 2018 River fire burned over 48,900 acres in Mendocino, Lake and Colusa counties including 35 structures. The River fire burned from 7/27/18 until containment on 1/4/19 (CalFire 2019a). The 2018 Ranch fire was very large burning over 410,200 acres in Mendocino, Lake and Colusa counties including 246 structures. The Ranch fire started 7/27/18 and reached containment on 1/4/19 (CalFire 2019b).

Precipitation levels varied greatly from 2016-2018. Rainfall in the 2016-2017 water year (July 1 to June 30) in Ukiah was 51.6 inches, 138% of average. Rainfall in the 2017-2018 water year in Ukiah was only 23.6 inches total, 63% of average.

These recent, larger fires were spread by high erratic winds, high temperatures and low relative humidity. Relative humidity, or the moisture content in the atmosphere, and wind velocity affect fuel moisture. Low relative humidity changes moisture content in living plants and water diffusion in dead fuel increasing the amount of fuel available to burn and the intensity of the fire. In drier conditions the coarseness (larger particle size of fuel vs. fineness or smaller particle size) of the fuel that can burn increases. High wind speeds cause high fire spread rates and increase the intensity as well as the size of the fire.

Due to decades of fire suppression, fuel loads in these recent fires were large. Fuel loads are defined by a number of features including coarseness of the fuel, surface area to volume ratio of trees, fuel bed compaction or how tightly packed the fuel is and thus how easily ignited (Figure 109). The presence of ladder and understory fuels are also taken into account as these can lead to a crown fire in trees. In chaparral the height and density of shrubs and the litter fuels and downed wood fuels are used to determine the fuel load.

These recent fires are not only larger than fires in prior decades (Tables 36 and 37) they also burned for a long time and were spread by high wind events. Future fire conditions are likely to be similar to the past few years rather than the conditions of prior decades.

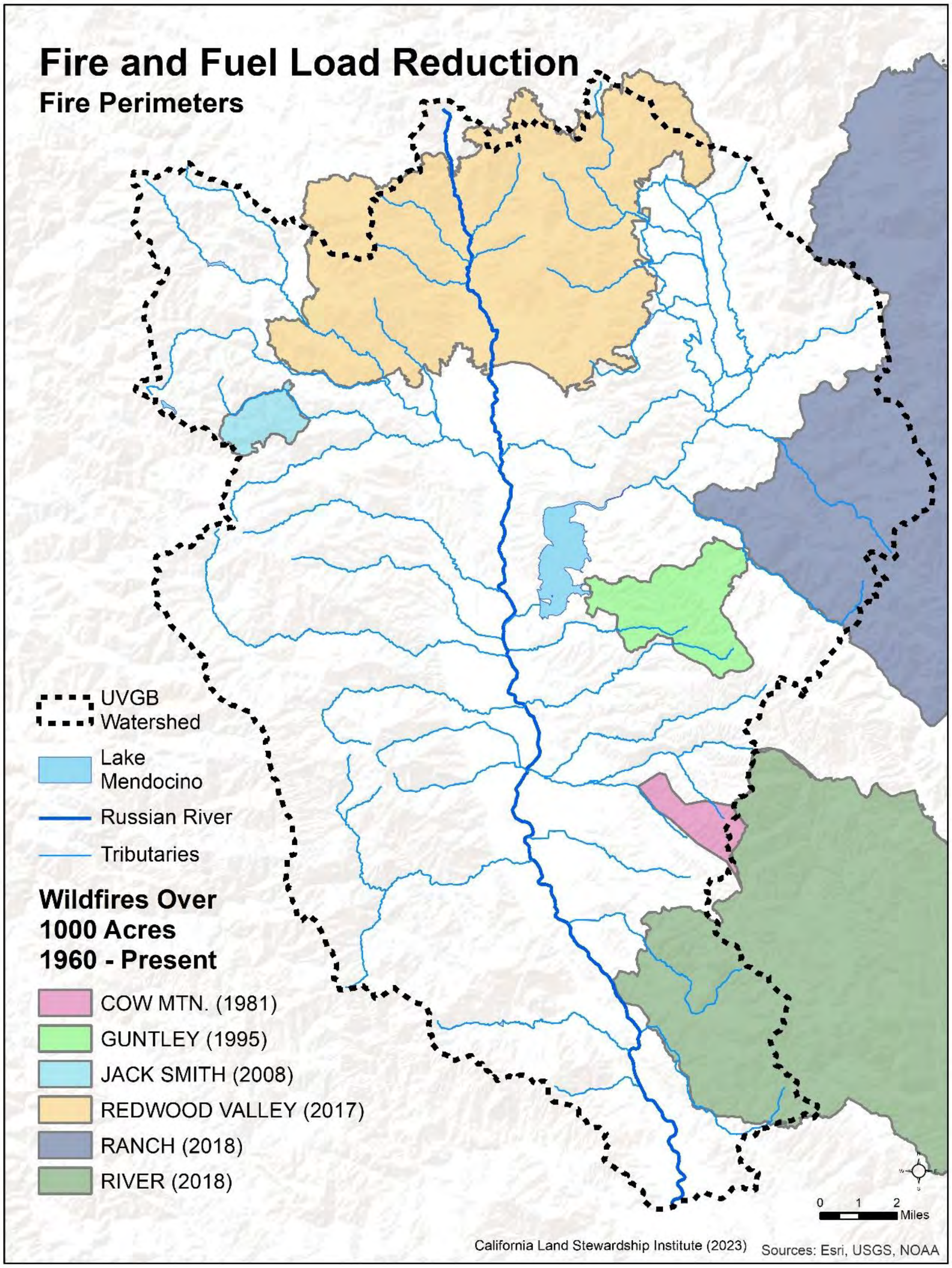


Figure 106. Fires since 1960 over 1000 acres in extent.

Table 36. Fires since 1960 larger than 1000 acres in the UVGBW

Name	Year	Cause	Acres in UVGB	Total Acres
RIVER	2018	Unknown/Unidentified	16,862.03	48,920.39
RANCH	2018	Miscellaneous	22,676.93	410,202.47
REDWOOD VALLEY	2017	Unknown/Unidentified	54,386.06	36,522.95
JACK SMITH	2008	Lightning	1,537.73	1,537.73
GUNTLEY	1995	Unknown/Unidentified	8,648.23	5,186.79
COW MTN.	1981	Arson	2,467.13	25,663.91

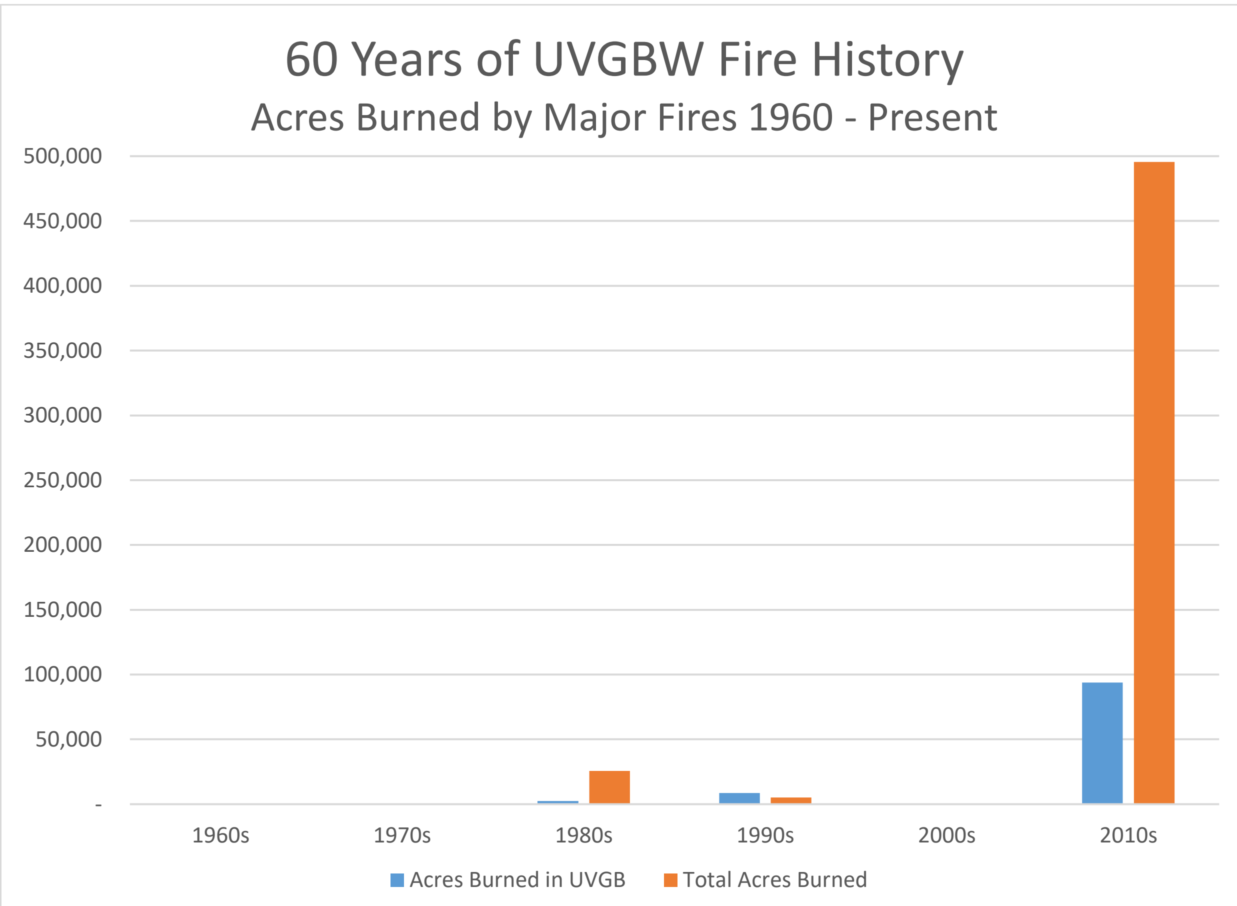


Figure 107. Acres of fires in the UVGBW since 1960.

Table 37. All fires over 1000 acres in size since 1920 in the UVGBW

Name	Year	Cause	Acres in UVGB	Total Acres
RIVER	2018	Unknown/Unidentified	16,862.03	48,920.39
RANCH	2018	Miscellaneous	22,676.93	410,202.47
REDWOOD VALLEY	2017	Unknown/Unidentified	54,386.06	36,522.95
GUNTLEY	1995	Unknown/Unidentified	8,648.23	5,186.79
COW MTN.	1981	Arson	2,467.13	25,663.91
ROADSIDE #26	1959	Unknown/Unidentified	7,519.99	11,150.27
Unnamed	1952	Unknown/Unidentified	7,720.60	8,644.68
N.W.P.RR #20A	1950	Unknown/Unidentified	8,673.41	5,185.08
IRENE PEAK	1950	Unknown/Unidentified	3,398.20	8,955.98
STREETER RIDGE	1923	Arson	12,674.73	14,996.30

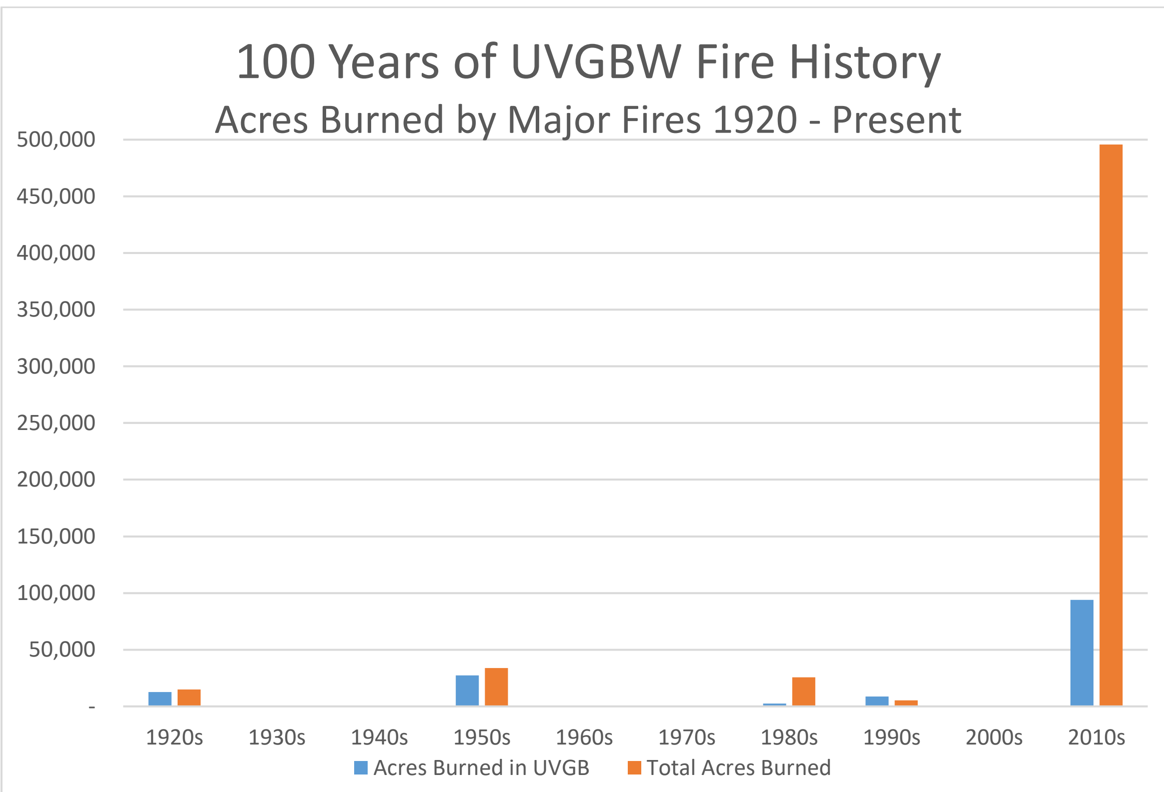
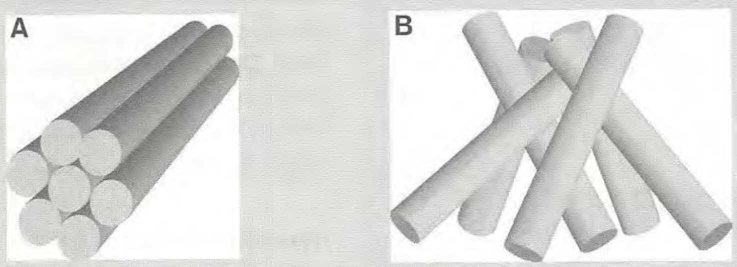


Figure 108. Acres burned in the UVGBW since 1920.



The packing ratio is the proportion of fuel in a unit volume of fuelbed. The same amount of fuel can be packed (A) tightly with only 10% air or (B) loosely with 90% air.

BOX 3.1. THE SURFACE AREA TO VOLUME RATIO

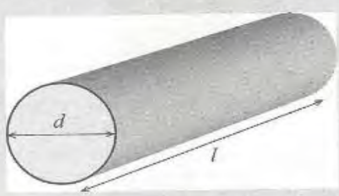
This ratio is calculated by dividing the surface area of a fuel particle by its volume:

$$SV = \frac{\pi d l}{\pi (d/2)^2 l}.$$

If you ignore the ends, the equation is simplified to dividing 4 by the diameter of the particle:

$$SV = \frac{4}{d}.$$

The ratio is increased if you split the fuels into smaller parts. For example, take a log with a diameter of 6:



if $d = 6$,
$SV = 0.67$.

When split into 7 pieces, the ratio increases from 0.67 to 14:

if $d = 2$,
$SV = 2$
and
$7 \times 2 = 14$.

Figure 109. Illustrations of packing ratio and surface area to volume ratio. From: Sugihara 2006.

EFFECTS OF FIRE ON HYDROLOGY, EROSION AND AIR QUALITY

Short-Term Effects

Wildfires increase erosion and the delivery of sediment to waterways as well as increase the rate and volume of runoff (MacDonald and Robichaud 2008; Sankey et al. 2017; Battany and Grismer 2000). Fires remove either all or a portion of the vegetative cover in a watershed changing hydrologic and erosional processes. Vegetation serves to intercept raindrops and break up their energy. Interception of rainfall by vegetation also slows the water from reaching the soil surface thus mediating the timing and volume of runoff. The root systems of trees and shrubs also reduce soil movement. Sheet and rill erosion can be considered as consisting of two related processes. First particles of soil are detached from the soil surface through rainsplash impact or the tractive forces exerted by flowing water. Second, sediment particles are transported from the point of erosion to a location downstream, usually a waterway. Runoff debris flows may also occur following fires, as these processes are driven by rainfall in excess of infiltration rates, lack of dense vegetative cover and change of dense forest to grassland/dead trees. Road density (miles of dirt road per square mile of watershed) and numbers of road-stream crossings are also directly related to erosion and sediment yield.

Fires also temporarily change the soil surface. For example, temperature in chaparral fires can reach 1,000^{o} F at the soil surface. All the litter and organic material as well as the above ground portion of the plants is burned producing a hydrophobic coating on the soil surface (Figure 110). This coating limits infiltration of stormwater resulting in larger volumes of runoff and a high potential for debris flows. The hydrophobic layer typically breaks down 2-3 years after the fire and rainfall will begin to infiltrate at higher rates (Sugihara et al. 2006).

Post fire surface erosion has been measured at 17 times greater in chaparral and up to 239 times greater in forests in the Sierra Nevada (Krammes 1960, Algren and Ahlgren 1960). Stormwater runoff volumes following fires can also increase greatly (Figure 111) and this increase can last for years (Hamilton et al. 1954, Glendening et al. 1961, Krammes and Rice 1963).

Following a fire, the seeds of forbs, grasses and annual plants germinate. Hardwood trees and chaparral shrubs stump sprout using reserves in their roots and root crown. Unfortunately, invasive plants such as French broom also germinate amongst the sprouting hardwoods (Figure 104). As these invasive nonnative plants grow, they begin to intercept rainfall, protect soil from erosion and reinvigorate their root systems to maintain structural stability to soils.

Following the 2018 River fire the Bureau of Land Management (BLM) completed an assessment of the Morrison Creek watershed that was burned. BLM staff completed field assessments including mapping the condition of surface litter, duff, ash color and depth (Figure 112), soil aggregate stability, amount and condition of fine and very fine roots remaining and water repellency of surface soil using the water drop penetration test. This information was used to determine soil burn severity and compared to a satellite-derived data layer termed Burned Areas Reflective Classification.

Table 38 lists the level of soil burn severity found in the Morrison Creek watershed (part of the UVGBW). The response of this watershed was modeled using the Automated Geospatial Watershed Assessment. a GIS -based hydrologic modeling tool that provides quantitative estimates of changes in runoff and erosion. The 2-hour, 25-year recurrence interval storm was chosen as the design storm for the model. This storm generates 1.45 inches of rain in the UVGBW.

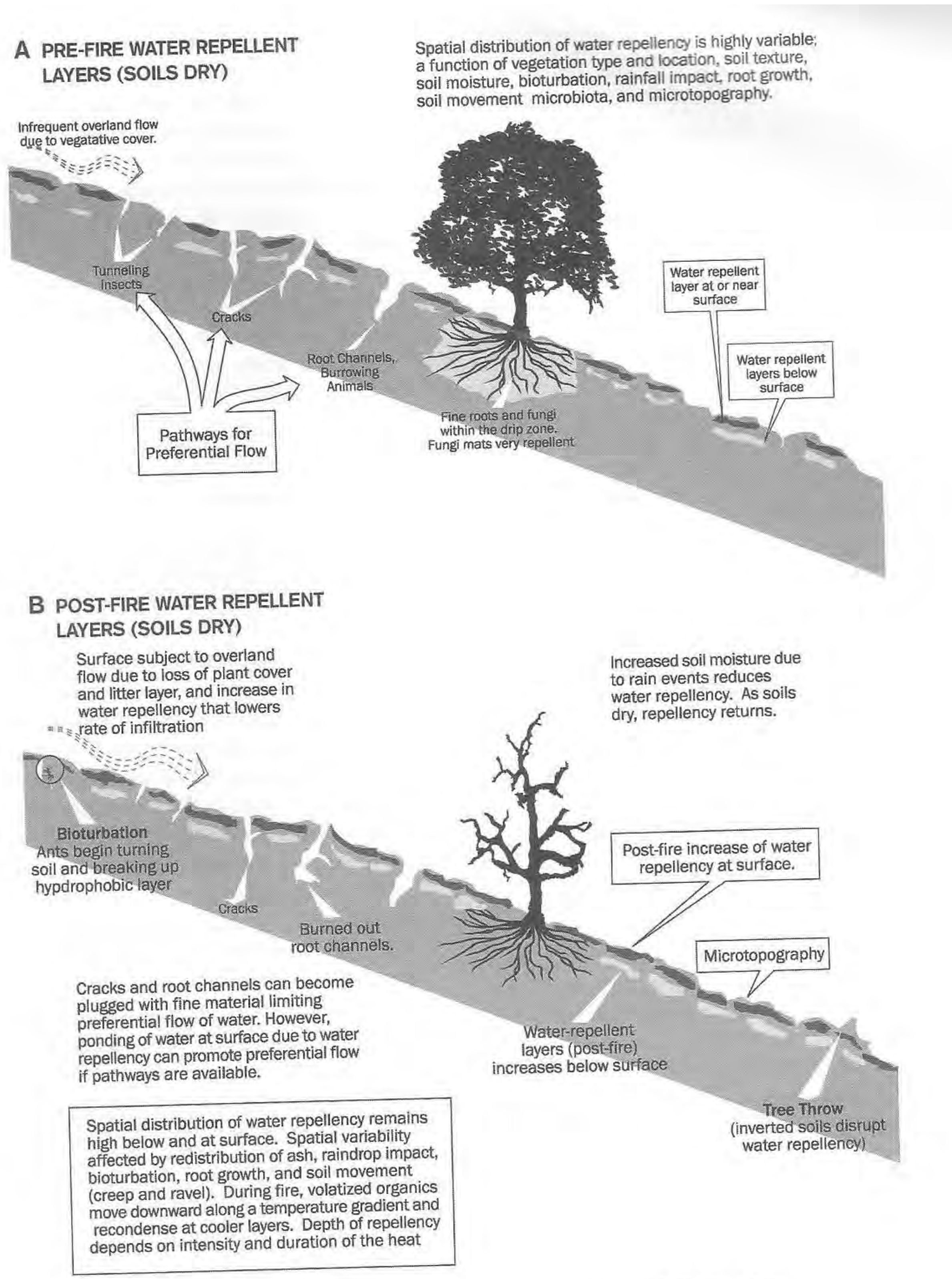


Figure 110. Soil water repellency and hydrologic processes before and after a fire. From Sugihara et al. 2006.

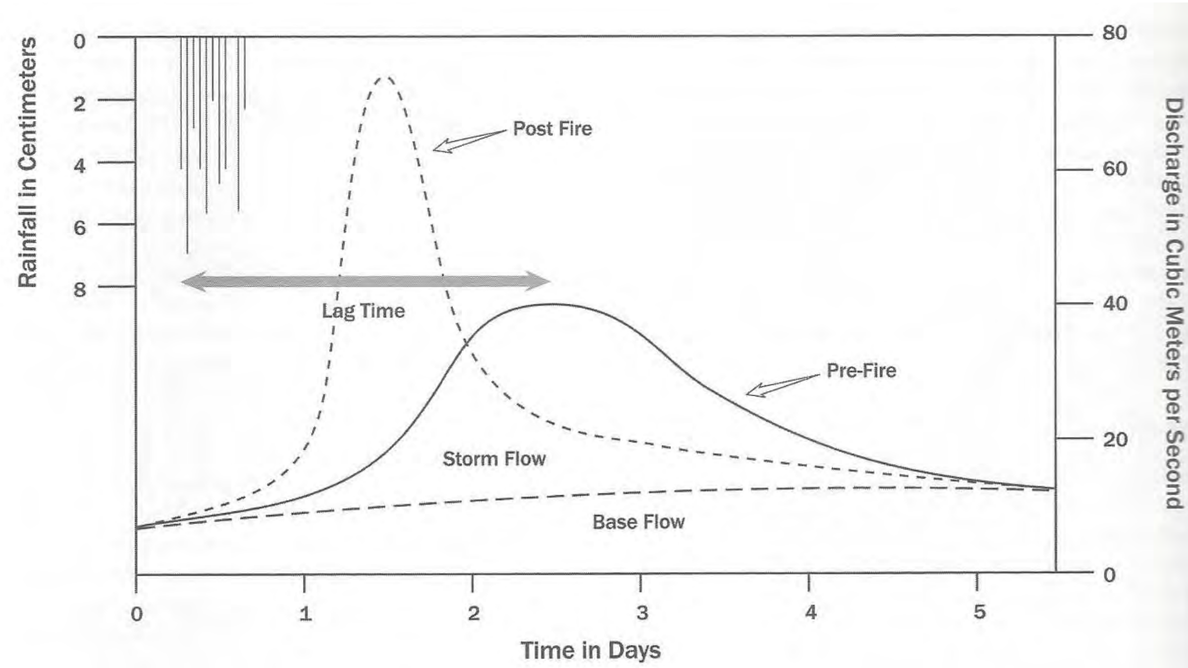


Figure 111. Streamflow hydrograph showing lag time and peak flow changes following a fire event

Figure 112. Different colors and depth of ash is part of determining the severity level of burning.

Table 38. Areas of soil burn severity class for Morrison Creek watershed.

Watershed	Watershed Acres	Soil Burn Severity	Acres	Percent of total watershed area
Morrison Creek	5,957	High	589	10%
		Moderate	3411	57%
		Low	620	11%
		Unburned	1337	22%

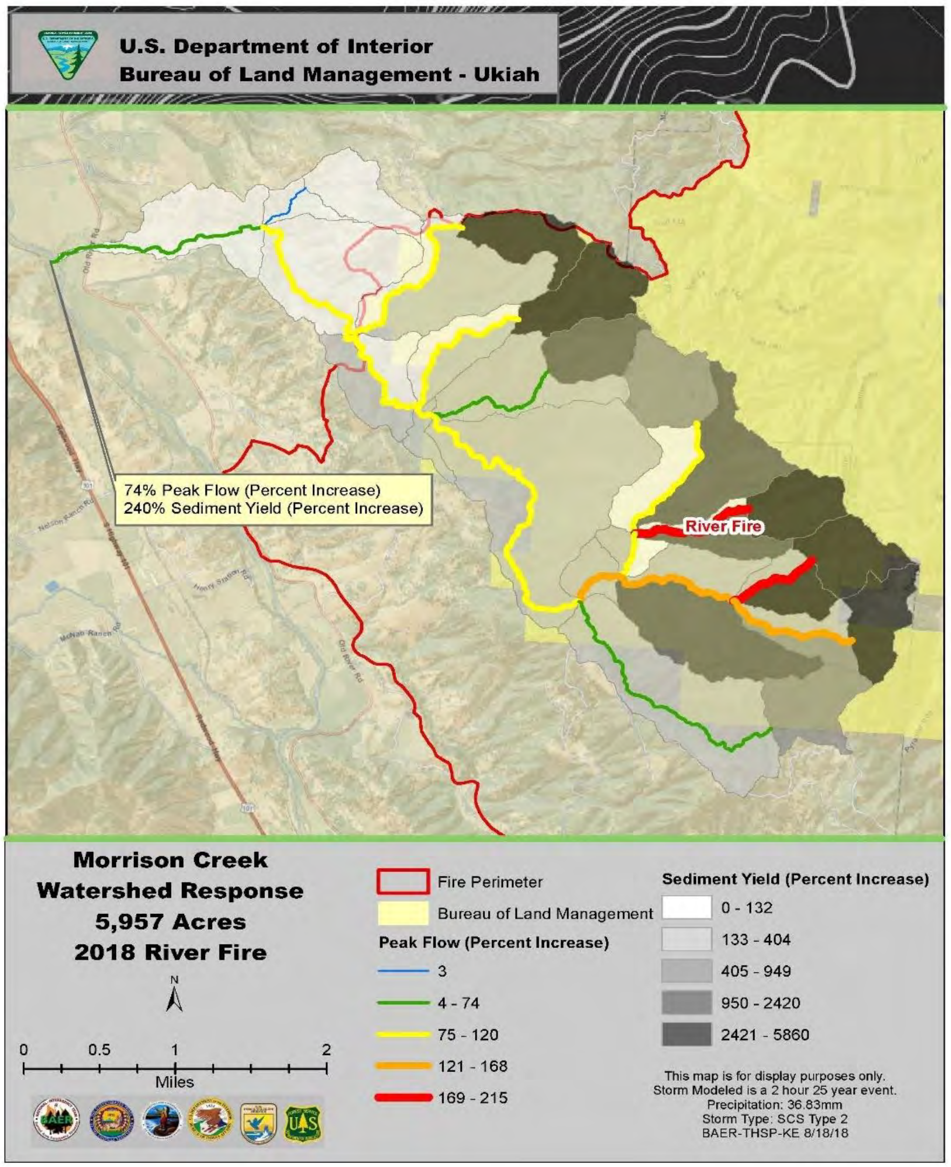


Figure 113. Results of Morrison Creek watershed assessment for effects of fire on erosion and runoff.

The model estimated that strong discharge and sediment generation are likely to occur in the upper reaches of the watershed with a 74% increase in peak flows and a 240% increase in background sediment generation due to the loss of vegetative cover. Figure 25 depicts the results of the model.

Long-Term Effects

Long-term effects of fire can occur in conifer forest for many years after the burn. High intensity fires are often crown fires. When most conifer trees, such as pines and Douglas fir, experience a crown fire it kills the tree. The exception is coastal redwood which often will resprout even after a crown fire. When the conifer forest dies the roots of the trees also die and begin to decay. Two years after the fire the rotted tree roots stop providing stability to hillsides. The hillsides become prone to debris flows and landslides. Replanting the hillside with native vegetation and restricting disturbance can reduce, but not stop the likelihood of major erosion.

Air Quality

Large wildfires produce smoke that can blanket nearby communities creating dangerous conditions for many people. The high levels of small particulates in wood smoke are unhealthy for anyone with existing respiratory problems. Staying indoors and wearing I-95 masks are recommended.

For grapegrowers wildfire smoke poses another risk. Chemicals in the smoke stick to the skin of the grapes and can result in smoke taint. Wines made from these grapes can taste like an ash tray and many growers are unable to sell their crops. In the 2017-2018 period many grapegrowers in the Ukiah, Redwood and Potter Valleys experienced significant economic harm as a result of smoke taint of their grapes.

CALFIRE MODELING AND MAPS

CalFire (Ca. Department of Fire and Forestry Protection) is the state's primary fire department and resource management agency. CalFire develops and provides a number of data sets on fire hazards. These analyses are described below.

Fire Hazard Severity Zones (FHSZ)

Fire hazard severity zones are based on a model that CalFire developed beginning in 1981 and improved through a 2007 iteration. The model quantifies natural fire hazards near homes and communities. The FHSZ reflect long-term hazards that remain constant for several decades. The zones are not updated following fuel reduction projects or recent fires.

The FHSZ model uses data on vegetation type, topography, climate, crown fire potential, potential ember production and movement and fire history in wildland areas. The zones delineate patches of land with similar physical features and hazard levels. The model assumes the worst possible fuel load and weather conditions. The probability of fire is based on burn frequency data over the last 30 years and then is interpolated to similar fuel and climate conditions. Potential flame length, another factor in the model, is based on long-term potential fuel loads and fire behavior on land with those fuel loads in hot, dry and windy weather that occurs in a locale. Typically, wildland areas with steep slopes, high fuel loads and hot, dry and windy weather receive the highest hazard ratings.

Figures 114 and 115 and Table 39 depict the results of the Fire Hazard Severity model for the UVGBW. High fire hazard zones make up 47% of the UVGBW for a total of 99,216 acres; very high fire hazard severity zones represent 19% of the UVGBW or a total of 40,697 acres. The model predicts that 66% of the UVGBW has a ranking of a very high to high hazard of wildfire.

Fire Threat

CalFire fire threat rankings reflect current fuel conditions and potential fire behavior. The rankings represent the relative likelihood of a damaging or difficult to control fire occurring in a specific location.

Figures 116 and 117 and Table 40 depict the fire threat ranking for the plan area. Very high fire threat areas total 26% (55,178 acres) of the UVGBW and high fire threat area total 54% (112,089 acres). High and very high fire threat areas make up 80% of the UVGBW.

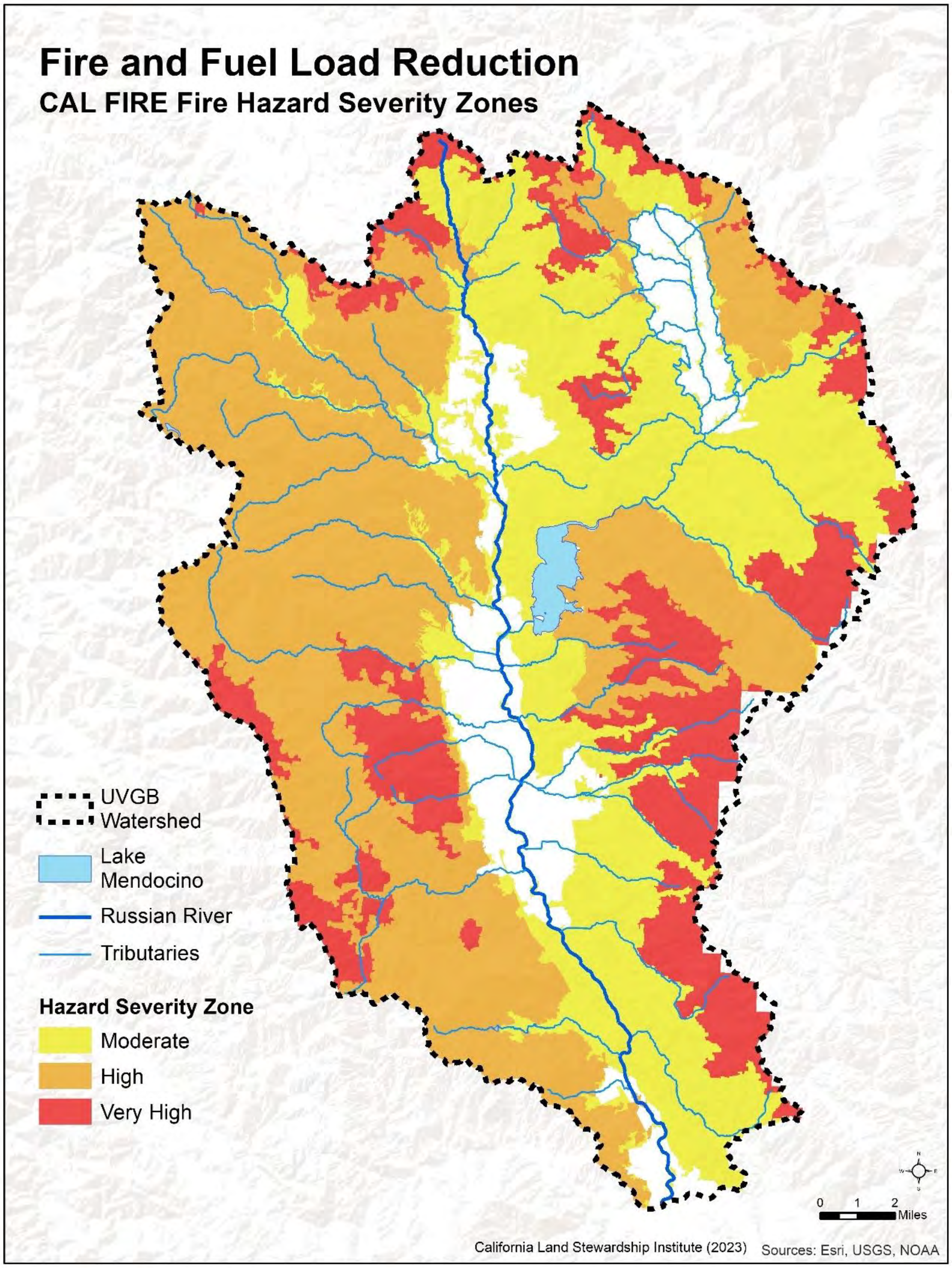


Figure 114. Fire hazard severity zones for the UVGBW.

Table 39. Acres by Fire Hazard Severity Zone

Fire Hazard Severity Zone	Acres
Moderate	72,033.18
High	99,215.84
Very High	40,696.50

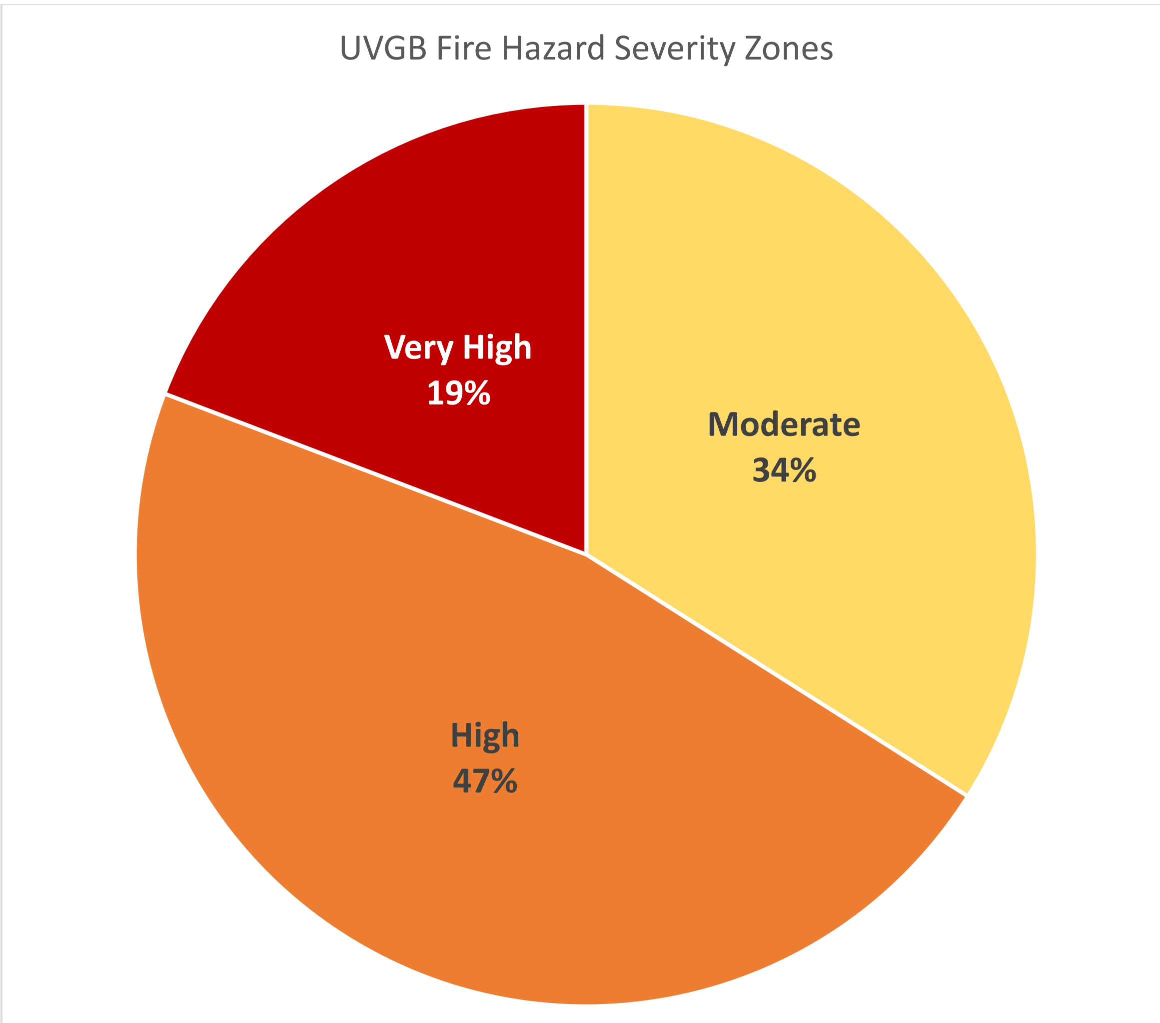


Figure 115. Graph of fire hazard severity zones in the UVGBW.

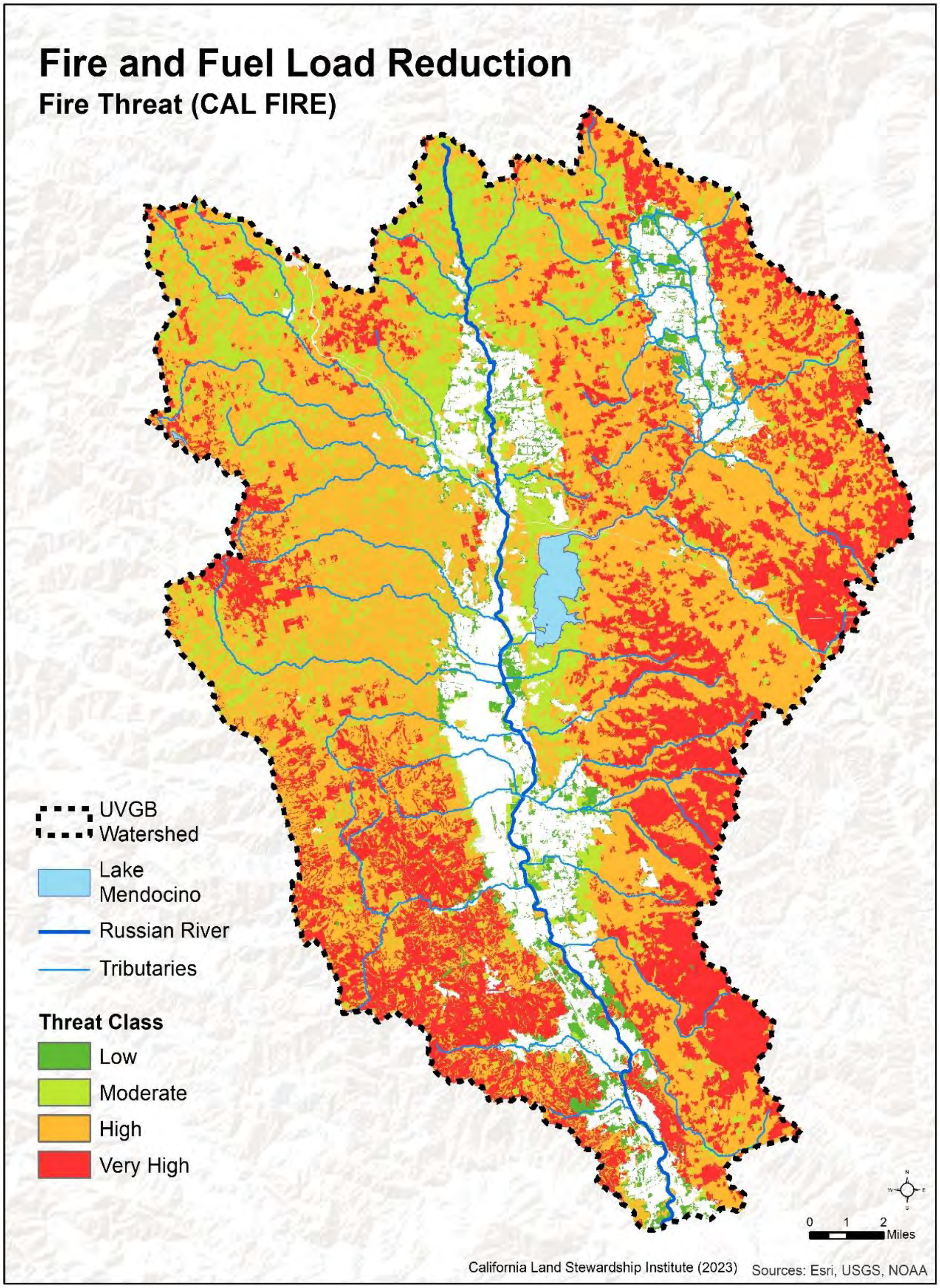


Figure 116. Fire threat by class for the UVGBW.

Table 40. Acres of each class of fire threat in the UVGBW.

Fire Threat	Acres
Low	7,818.61
Moderate	32,468.55
High	112,089.26
Very High	55,177.75

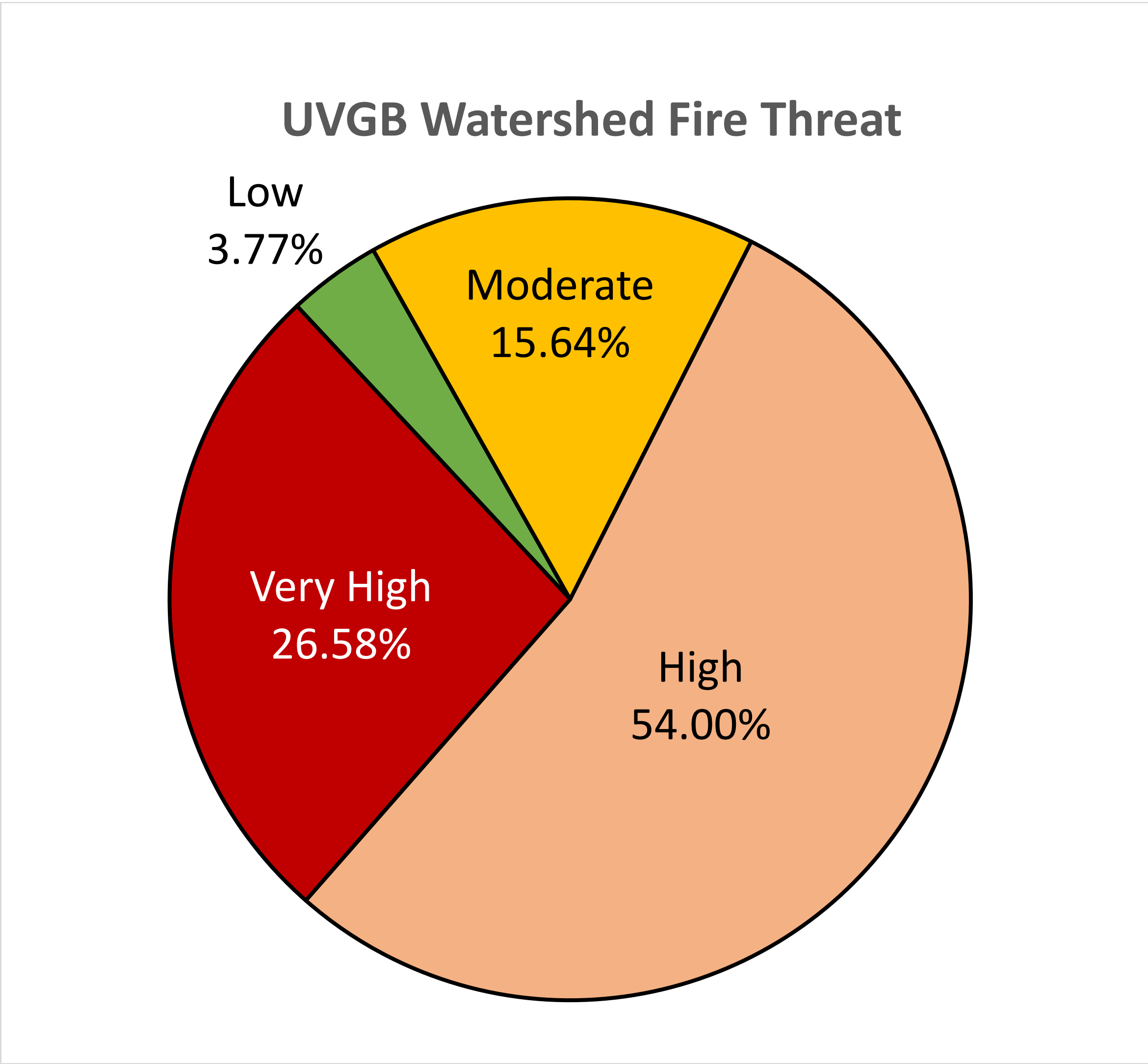


Figure 117. Graph of fire threat class for the UVGBW.

Risk to Communities

CalFire's Fire and Resource Assessment Program (FRAP) developed the Risk to Communities model in support of the 2018 California Assessment of Forest and Rangelands. The model builds upon the Fire Hazard Severity Zones (Figure 118) to produce new rankings that incorporate housing density within the Wildland Urban Interface (WUI). Lower density areas received lower values, and higher density areas received higher values, on a scale of 0 – 4. This density score was then combined with the Fire Hazard Severity scores to produce a final ranking of 1 (lowest risk to communities) – 5 (highest risk to communities). Figures 118 and 119 and Table 41 depict the areas of highest and lowest ranking.

Tree Mortality Hazard

California's record-breaking drought from 2012 – 2019 resulted in the death of millions of trees throughout the state. Dead trees increase wildfire fuel and fire hazard. The Tree Mortality Hazard model represents a combination of Tier One and Tier Two Tree Mortality Hazard Zones, as defined by the multi-agency Tree Mortality Task Force.

Tier One zones are not generalized to watershed boundaries, and represent areas of tree mortality that are in direct proximity to assets important to life and property (communications, transportation, recreation, residential communities, and utilities).

Tier Two zones are defined by tributary watershed boundaries. Watersheds are rated as high-hazard areas when they have both elevated tree mortality and significant, fire-susceptible community and natural resource assets.

Figures 120 and 121 and Table 42 depict high hazard zones in the UVGBW.

There is a federal program, LANDFIRE, that models similar features to the CalFire models. Appendix 1 includes maps and descriptions of the LANDFIRE modeling.

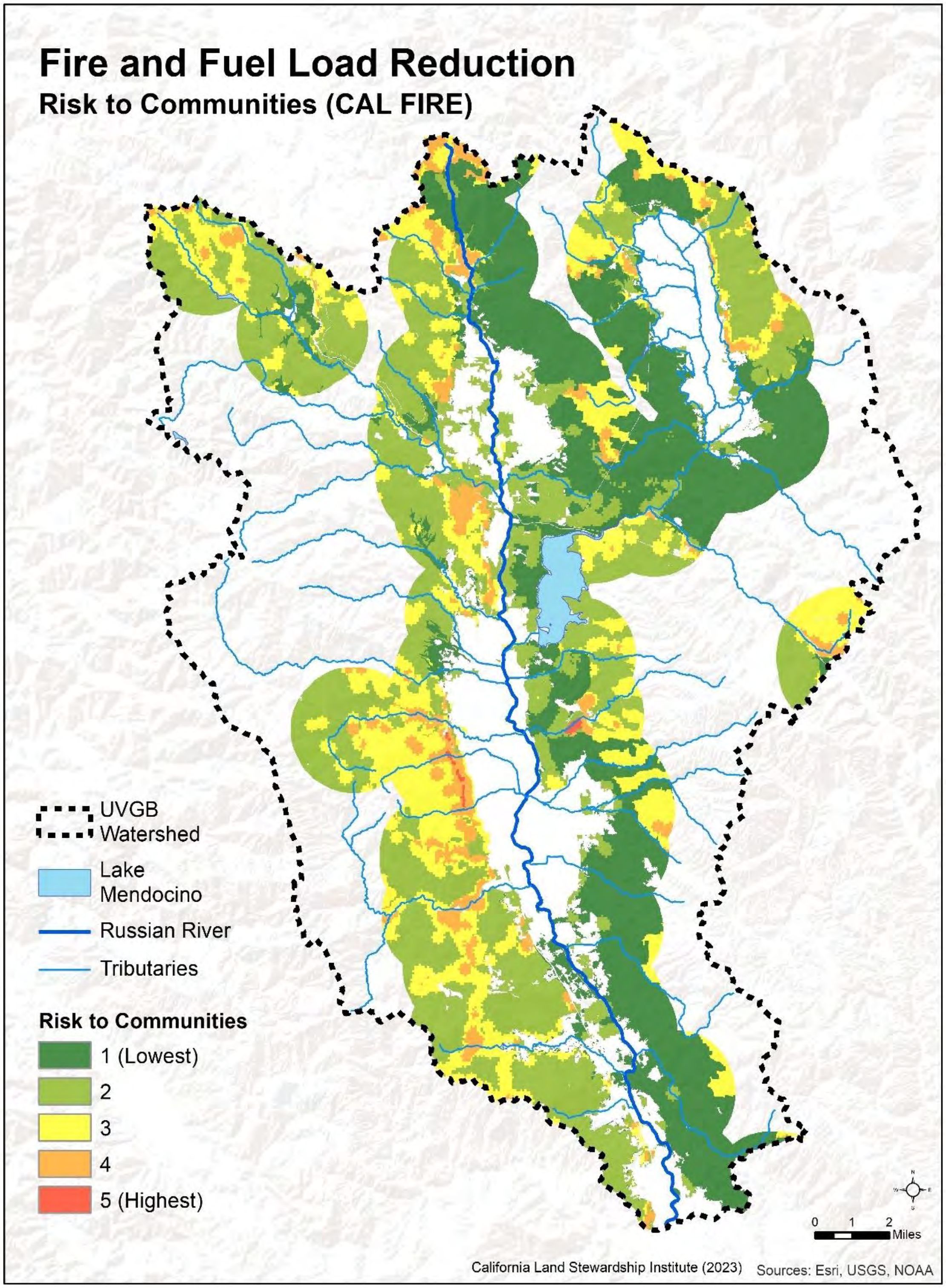


Figure 118. Ranking of risk of wildfire to communities in the UVGBW.

Table 41. Acres in each ranking of wildfire risk to communities

Risk to Communities	Acres
Low	41,790.27
Low-Moderate	49,076.18
Moderate	26,030.14
High-Moderate	7,237.10
High	161.76

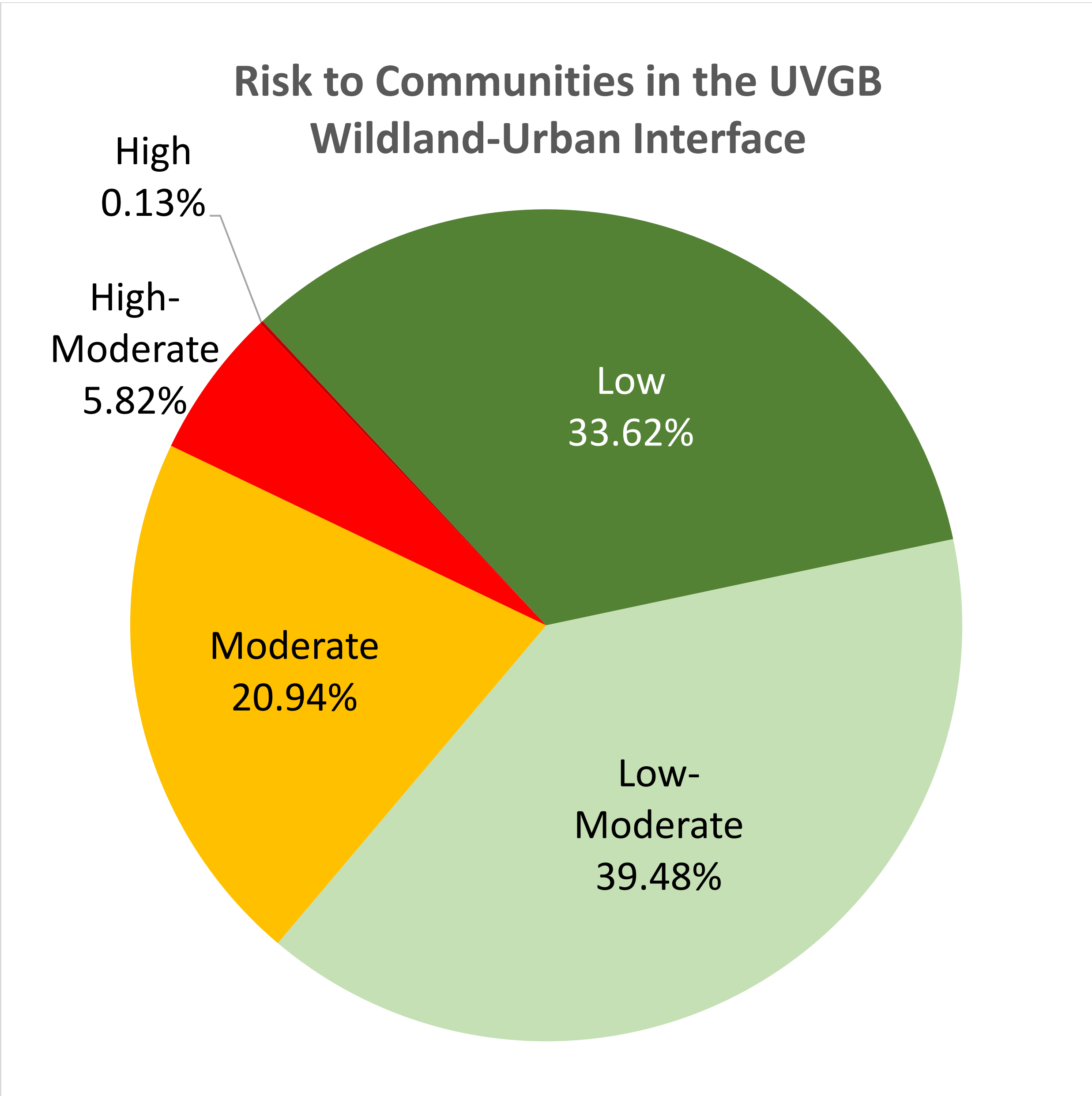


Figure 119. Graph of rankings of wildfire risk to communities in the UVGBW.

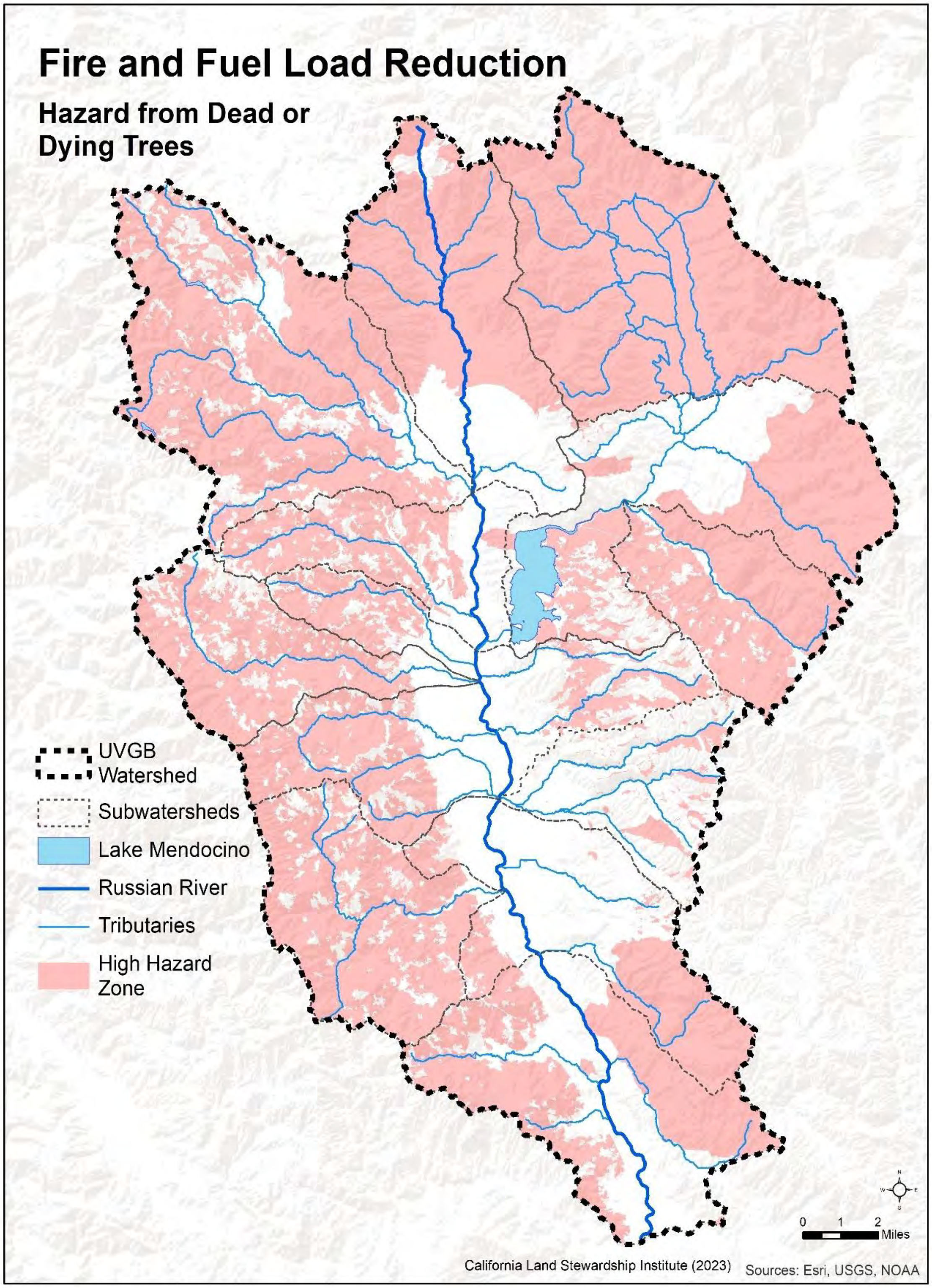


Figure 120. Area of high hazard from dead and dying trees in the UVGBW.

Table 42. Acres of high hazard from dead and dying trees by subwatershed of the UVGBW.

Subwatershed	Total Acres	Total Square Miles	Percent of Subwatershed Area in High Hazard Tier for Tree Mortality
Ackerman Creek	9,049.26	14.14	71.51%
Burright Creek-East Fork Russian River	29,753.98	46.49	100.00%
Cold Creek	10,305.48	16.10	88.40%
East Fork Russian River-Russian River	5,677.99	8.87	48.43%
Forsythe Creek	23,429.43	36.61	75.88%
Lake Mendocino-East Fork Russian River	12,487.68	19.51	48.68%
McNab Creek-Russian River	12,072.01	18.86	51.72%
Mill Creek	1,526.03	2.38	13.74%
Morrison Creek-Russian River	6,946.02	10.85	38.85%
Orrs Creek-Russian River	12,109.19	18.92	47.51%
Robinson Creek	13,324.16	20.82	80.37%
Salt Hollow Creek-Russian River	15,398.84	24.06	69.26%

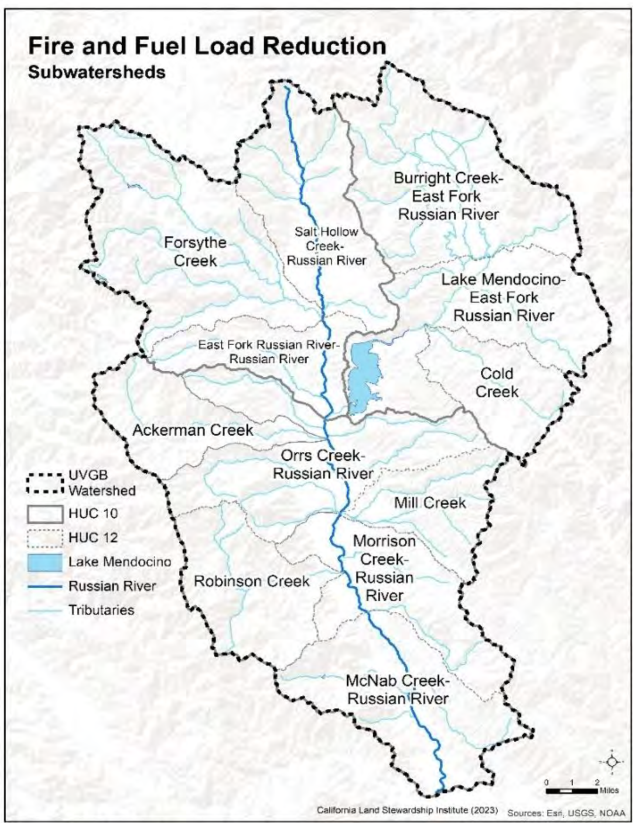


Figure 121. Subbasins used in Table 42 for evaluation of hazards from dead and dying trees.

EXISTING PLANS

There are a number of government agencies that have responsibility for fire prevention and management. Figure 122 shows the responsibility areas for federal, state and local fire agencies in the UVGBW. CalFire takes the lead for the state responsibility area. Cow Mountain Recreation Area is a federal responsibility area. Local responsibility areas are typically serviced by County and City fire departments. During a major fire all departments work together.

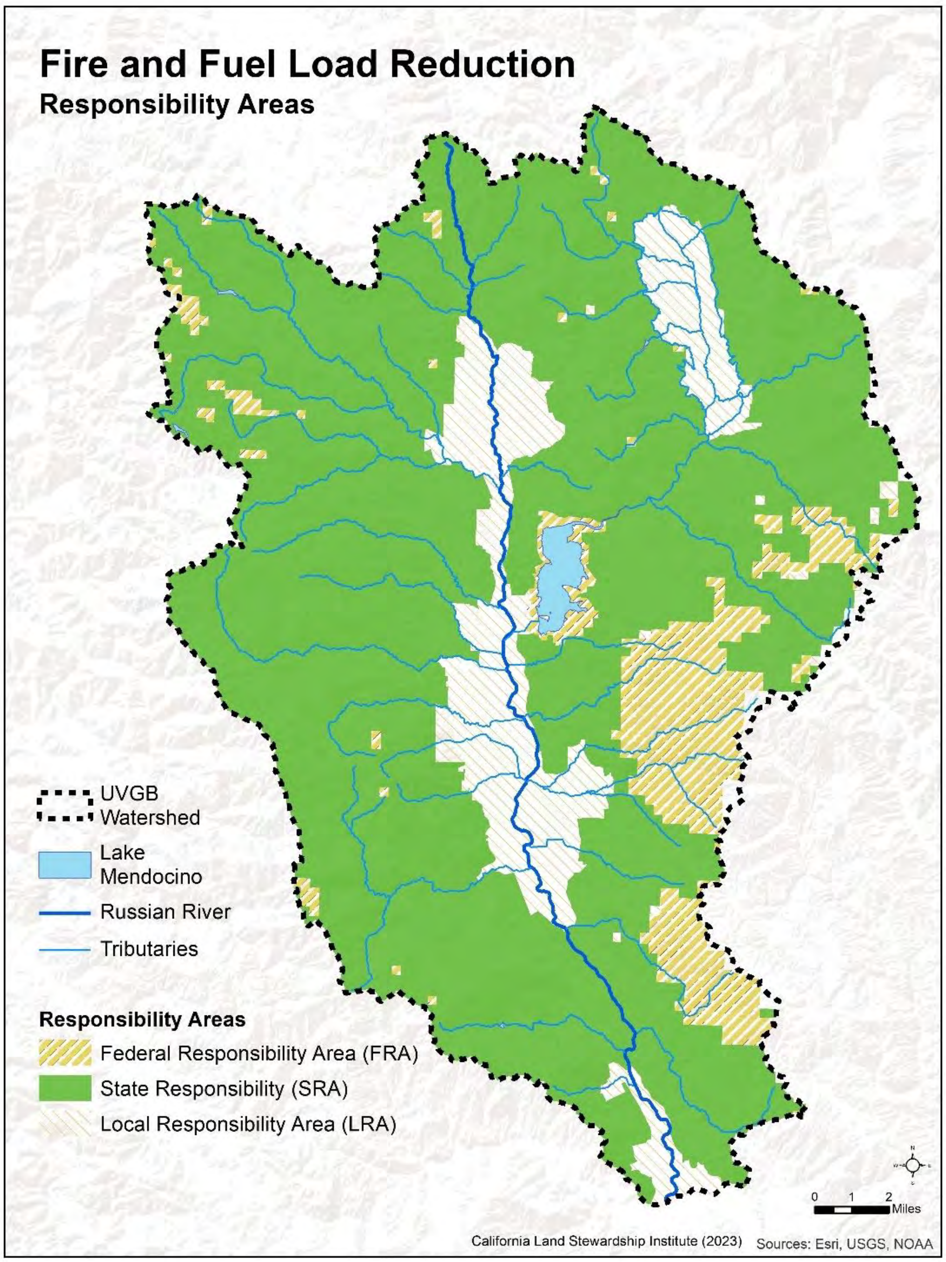


Figure 122. Responsibility areas for fire prevention and management.

Bureau of Land Management (BLM)

Ukiah Resource Management Plan (2006)

The Bureau of Land Management (BLM) Ukiah Field Office oversees management of approximately 300,000 acres of public lands across Marin, Solano, Sonoma, Mendocino, Lake, Napa, Yolo, Colusa, and Glenn Counties. Chapter 2.10 of the 2006 Ukiah Resource Management Plan emphasizes management of wildfire fuels in a way that mimics the natural role of fire, reduces risk to communities in the wildland urban interface, promotes plant biodiversity, and protects riparian and wetland areas. To meet these objectives, it proposes prescribed burning in conjunction with careful monitoring to document post-fire conditions as well as mechanical treatments, development of fuel breaks along the wildland urban interface, engagement of local fire safe councils, and implementation of public education programs. The plan also states a need for the development of a separate more detailed Fire Management Plan (FMP).

Cow Mountain Recreation Area Implementation Plan (2016)

The Cow Mountain Recreation Area straddling Lake and Mendocino Counties is one of 11 major management areas within the jurisdiction of the Ukiah Field Office of BLM.

The Cow Mountain Implementation Plan outlines vegetation management objectives such as increasing biodiversity and preventing the spread of noxious weeds. Past activities included mowing, prescribed burning, and planting of native species, especially in areas with invasive nonnative medusahead grass and yellow starthistle. Native species planted include California brome, blue wild rye, Lemmon's needlegrass, and willow. BLM outlines their planned continuation of these activities, and considers the use of bio-control agents and pesticides to aid in eradication of invasive species.
The Implementation Plan also address the increased wildfire risk associated with activities in the Recreation Areas. Listed potential ignition risks include maintenance projects, off road vehicle use, trash burning, construction projects, parties, vehicle fire, fireworks, exhaust/catalytic converters, shooting/hunting, illegal drug labs/cannabis cultivation, cooking/warming fires, smoking, use of transportation corridors and trails, cultural activities, use of chainsaws and dispersed recreation.
BLM recommends several prevention activities in response to these ignition risks. Activities include increased implementation of site evaluations for fire safety, informational signage, public engagement, patrols, campfire permits, and inspection of equipment such as power lines, spark arresters and mufflers. Fire safety evaluations will prioritize fuel reduction near campsites and parking areas, construction of perimeter firebreaks around potentially hazardous areas, and establishment of "safety islands" where park visitors can shelter in the event of a fire.

In 2021 the BLM Ukiah Field Office began the South Cow Mountain Watershed Assessment, and implementation is ongoing. Objectives include identification of recommended trail closures and potential rehabilitation activities.

CalFire Mendocino Unit 2022 Fire Plan

The CalFire Mendocino Unit completed their Fire Plan in April, 2022, in collaboration with federal, state, city, and county agencies. The Fire Plan has the following goals:

1. Identify and evaluate wildland fire hazards and recognize life, property and natural resource assets at risk, including watershed, habitat, social and other values of functioning ecosystems. Facilitate the collaborative development and sharing of all analyses and data collection across all ownerships for consistency in type and kind.

2. Promote and support local land use planning processes as they relate to: (a) protection of life, property, and natural resources from risks associated with wildland fire, and (b) individual landowner objectives and responsibilities.
3. Support and participate in the collaborative development and implementation of local, county, and regional plans that address fire protection and landowner objectives.
4. Support and enable the expansion of cultural practices to introduce beneficial fire across Mendocino County. Encourage and effectively leverage private landowner interest in prescribed fire as a land management tool.
5. Increase fire prevention awareness, knowledge and actions implemented by individuals and communities to reduce human loss, property damage and impacts to natural resources from wildland fires.
6. Integrate fire and fuels management practices with landowner/land manager priorities across jurisdictions.
7. Determine the level of resources necessary to effectively identify, plan and implement fire prevention using adaptive management strategies.
8. Determine the level of fire suppression resources necessary to protect the values and assets at risk identified during planning processes.
9. Implement post-fire assessments and programs for the protection of life, property, and natural resource recovery.

In 2018 and 2019, CalFire received funding to form ten Region Fuel Reduction Crews, whose primary objective was to implement prescribed burns for fuel reduction management. Three of these crews were assigned to the Northern Region, and in 2020 a crew was assigned to the Mendocino Unit, greatly increasing its capacity to address wildland fuel hazards. In 2022 CalFire contracted with the Mendocino Fire Safe Council for development of Vegetation Management Programs (VMPs) for West and East Hills Ukiah.

The Fire Plan describes plans to collaborate with the Mendocino County Fire Safe Council and its numerous Neighborhood Fire Safe Councils (Figure 123) on several road clearing and fuel break projects in areas where ingress and egress routes will be critical in the event of a wildfire. The plan also discusses participation in several post-fire programs such as Fire Suppression Repair (FSR), Emergency Watershed Protection (EWP), CalFire Archeology, and assessments in collaboration with the California Geological Survey.

Mendocino County Community Wildfire Protection Plan
In 2015 the Mendocino County Fire Safe Council (MCFSC) completed a wildfire protection plan in collaboration with local, state and federal agencies, PG&E, and the county's largest timber landowners. The MCFSC functions as an independent nonprofit, and encourages road associations, homeowner groups, towns, and housing clusters to create their own neighborhood fire safe councils, which can apply for grant funds. The goal of this organizational structure is for residents to identify and prioritize areas for hazardous fuel reduction that will make their communities safer. Figure 123 depicts these various groups.

The plan breaks the county into Planning Zones which follow the same boundaries as the CalFire Battalions. The zone that coincides with the UVGBW is Planning Zone 2, encompassing Ukiah, Redwood Valley, Hopland, and Potter Valley. The plan describes the CalFire wildfire protection resources, the Vegetation Management Program (VMP) and projects as previously discussed in the 2022 CalFire Mendocino Unit Fire Plan summary.

Mendocino FireSafe Council

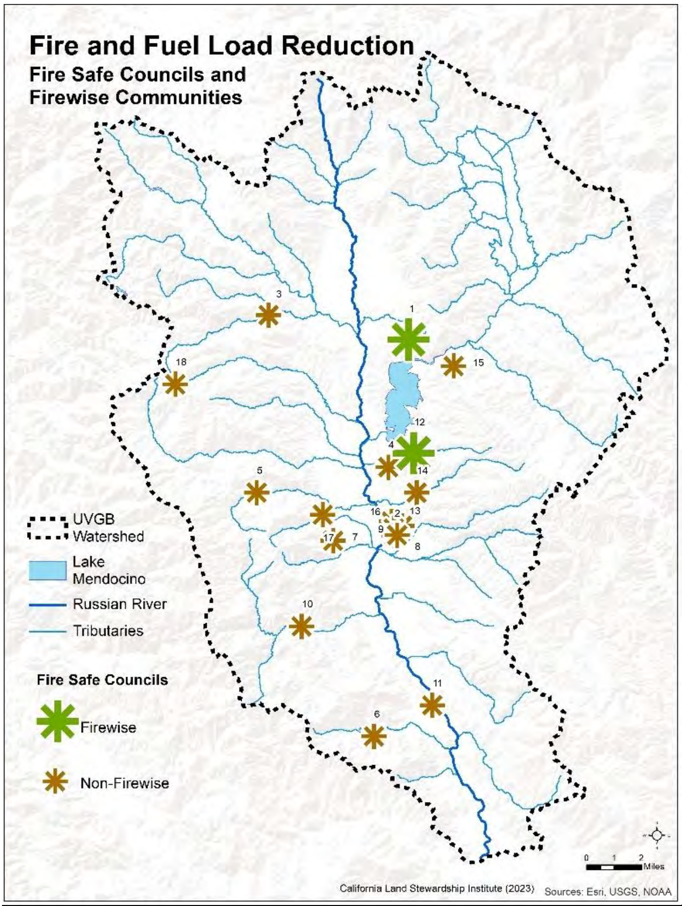
Mendocino FireSafe Council (firemendocino.org) operates a number of programs to assist home and landowners to manage vegetation, improve fire hardening of homes and reduce overall fire hazards. This organization has implemented the Ukiah Valley Fire Fuels Reduction Project. This project provided vegetation clearing on 21 miles of roads and 4.2 miles of shaded fuel breaks.

National Fire Protection Association (NFPA) Firewise USA Communities

Firewise USA is a national program that offers landowner organizations the educational and structural resources to assess their community's vulnerability to wildfire, identify threats, create an action plan, and execute it. Using annual review, the NFPA holds recognized Firewise Communities to rigorous standards, and community leaders are held accountable to the plans they have laid out. This contrasts with Fire Safe Councils, which, while often active in their communities, are largely independent, unstructured, and not held to any universal standards. Many FireSafe Councils to choose become recognized as a Firewise Community. Two of the 18 Fire Safe Councils in the upper Russian River have done so—Black Bart Trail FSC, and Upper Deerwood FSC (Figure 123).

2020 Mendocino County Fire Vulnerability Assessment

The Mendocino County Fire Vulnerability Assessment was developed in collaboration with Category Five Professional Consultants Inc. and a Technical Advisory Group consisting of key local stakeholders. The assessment was completed to prevent loss of life, minimize property damage, and therefore reduce recovery effort spending caused by wildfires. County areas and populations that are most vulnerable to fire were identified and recommendations were made on how to improve Mendocino County's current strategies and practices. The assessment broke the county into geographic planning areas that coincide with battalions referenced in the CalFire Unit Plan and the Mendocino County Community Wildfire Protection Plan and identified a series of projects in each area.



Map Key	Name	Firewise
1	Blackbart Trail FSC	Yes
2	Glennwood Drive FSC	No
3	Greenfield Ranch Association	No
4	Lower Deerwood FSC	No
5	Mariposa Neighborhood Fire Safe Council	No
6	McNab Fire Safe	No
7	Mendocino Drive/Mendocino Place	No
8	Regina Heights FSC	No
9	Ridge Road FSC	No
10	Robinson Creek FSC	No
11	Russian River Estates FSC	No
12	Upper Deerwood FSC	Yes
13	Vichy Hills Road	No
14	Vichy Springs Community Homeowners Association FSC	No
15	Vista Del Lago Fire Safe Council	No
16	Watson Road Fire Safe Council	No
17	Western Hills FSC	No
18	Westside Greenfield FSC	No

Figure 123. Firewise Communities and Neighborhood Fire Safe Councils.

FUTURE CONDITIONS: THE EFFECT OF CLIMATE CHANGE ON WILDFIRE

California's Fourth Climate Change Assessment uses global climate models to simulate the future climate of California using various assumptions regarding future emissions of greenhouse gases (GHG) generated by human activities and existing atmospheric and ocean conditions. The assessment predicts the following for the North Coast region in general and UVGBW in particular (Grantham et al. 2018). The assessment predicts:

• Average annual maximum temperatures are likely to increase by 5-9° F throughout the region through the end of the 21st century. Interior regions will experience the greatest degree of warming.
• Annual precipitation is not expected to change significantly, but will likely be delivered in more intense storms and within a shorter wet season. As a result, the region is expected to experience prolonged dry seasons and reduced soil moisture conditions, even if annual precipitation stays the same or moderately increases. Less precipitation will fall as snow and total snowpack will be a small fraction of its historical average.
• There is a higher likelihood of extreme wet years and extreme dry years (drought). An "average" rainfall year will become less common.
• A rise in extreme precipitation events will increase the frequency and extent of flooding in low-lying areas, particularly along the coast where flood risk will be enhanced with rising sea levels.
• Streamflows in the dry season are expected to decline and peak flows in the winter are likely to increase.
• Sea-level rise projections differ along the coast, but are greatest for the Humboldt Bay region and Eel River delta, threatening communities, prime agricultural land, critical infrastructure, and wildlife habitat.
• Wildfires will continue to be a major disturbance in the region. Future wildfire projections suggest a longer fire season, an increase in wildfire frequency, and an expansion of the area susceptible to fire.

These changes will have significant consequences for natural ecosystems, working landscapes, and the built environment. These include:
• Habitat loss for sensitive plant and wildlife species, including cold-water fish species such as salmon.
• Change in vegetation types, including forests.
• Reduced productivity of rangeland and pastureland.
• Increased food and landslide risks to critical infrastructure, including major transportation corridors, water supply systems, wastewater treatment plants, and energy and communication networks.
• Increased public health risks from wildfire, floods, heat waves, and disease vectors. These risks are greatest for vulnerable populations along the coast and in remote inland communities.

Figure 124 depicts average annual maximum temperatures for the 2011-2021 period as measured at the Ukiah Airport. There was a 1^{o} F increase over this period. Figure 125 shows the increase in the annual number of days with no rainfall from 270 to 279 days between 2011-2021.

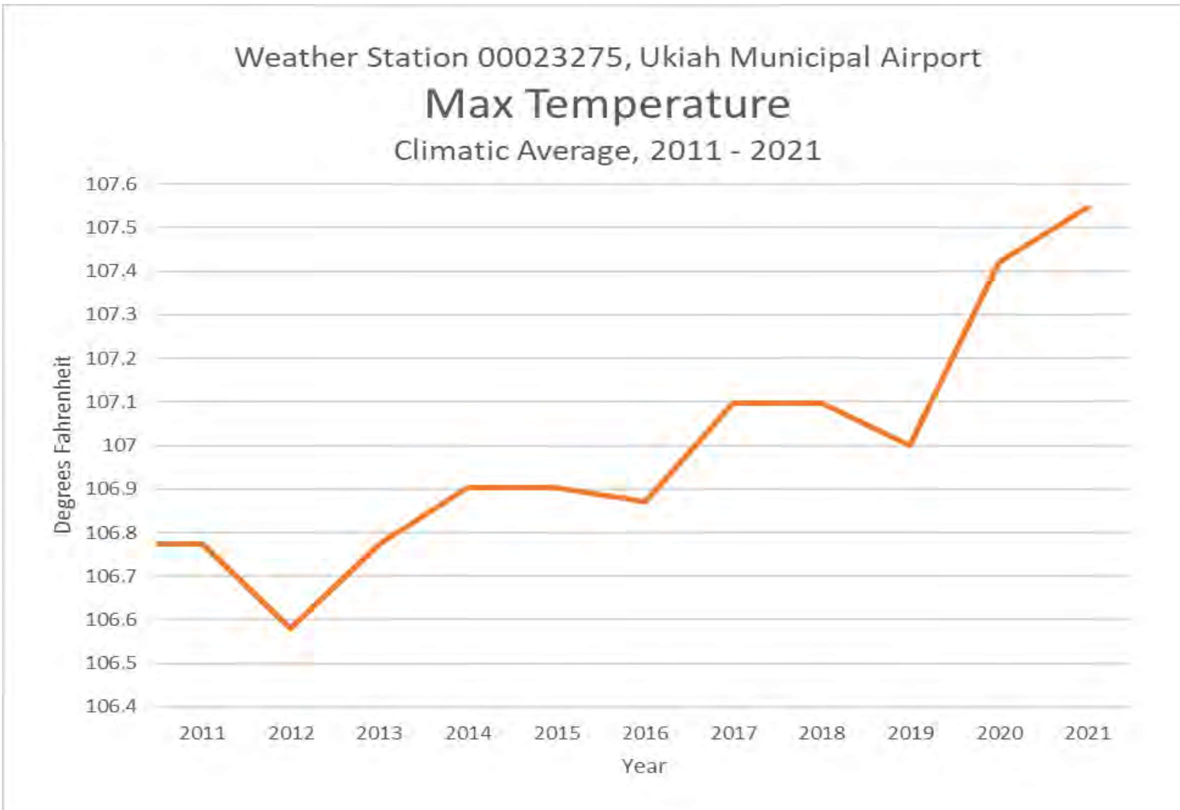


Figure 124. Increases in the maximum temperature as measured at the Ukiah Airport

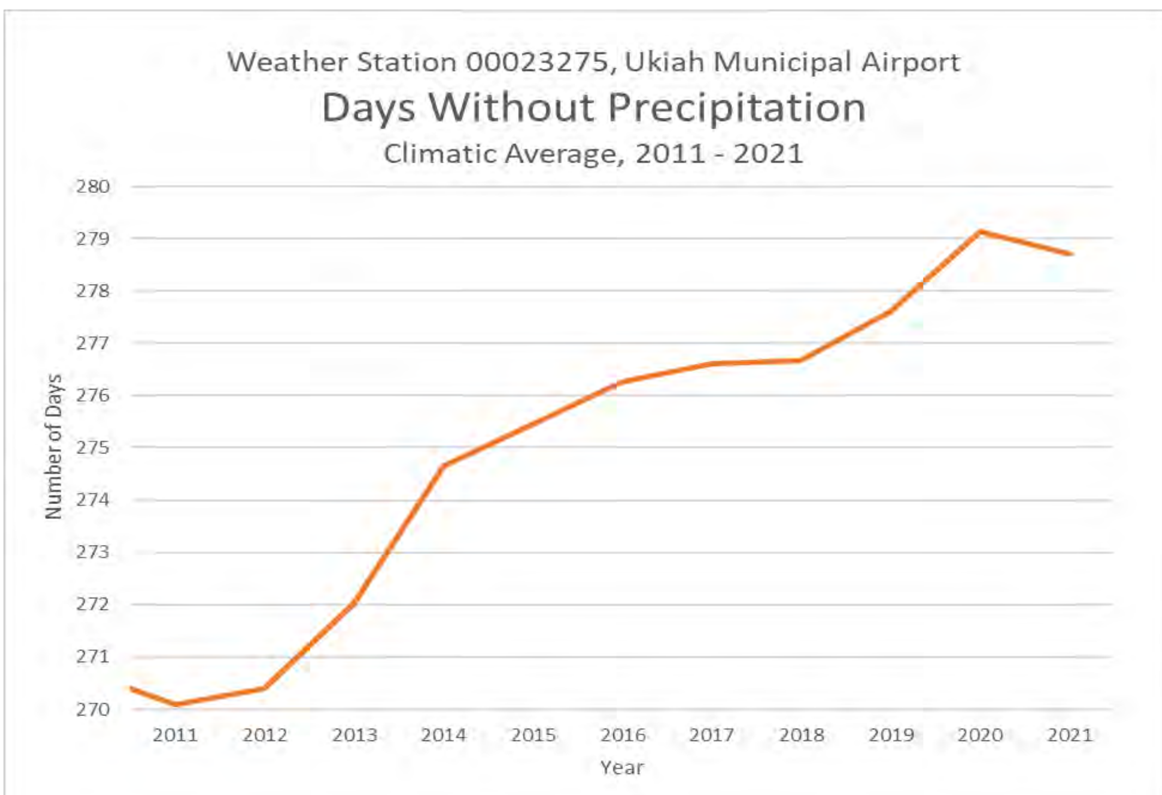


Figure 125. Increases in days without rainfall from 2011-2021 measured at the Ukiah Airport

Future Conditions
Using readily available tools (https://cal-adapt.org/) we developed graphs and maps of modeled changes that will increase the potential for wildfires in the UVGBW.

Summer Temperatures
Figure 126 shows the modeled increase in extreme heat days per year (temperatures exceeding 102.4^{o} F). These temperatures occurred an average of 4 days/year between 1961-1990. Between 2035-2064 11 days /year are predicted to have this extreme heat and between 2070-2099 17 days/year of extreme heat days are predicted to occur. Annual average maximum temperatures in 2035-2064 are expected to increase by 3.3-4.0^{o} F and between 2070-2099 temperatures are predicted to increase by 4.4-7.2^{o} F (Figure 127). These temperatures are based on year-round averages of daily high temperatures and therefore do not reflect the maximum high temperature.

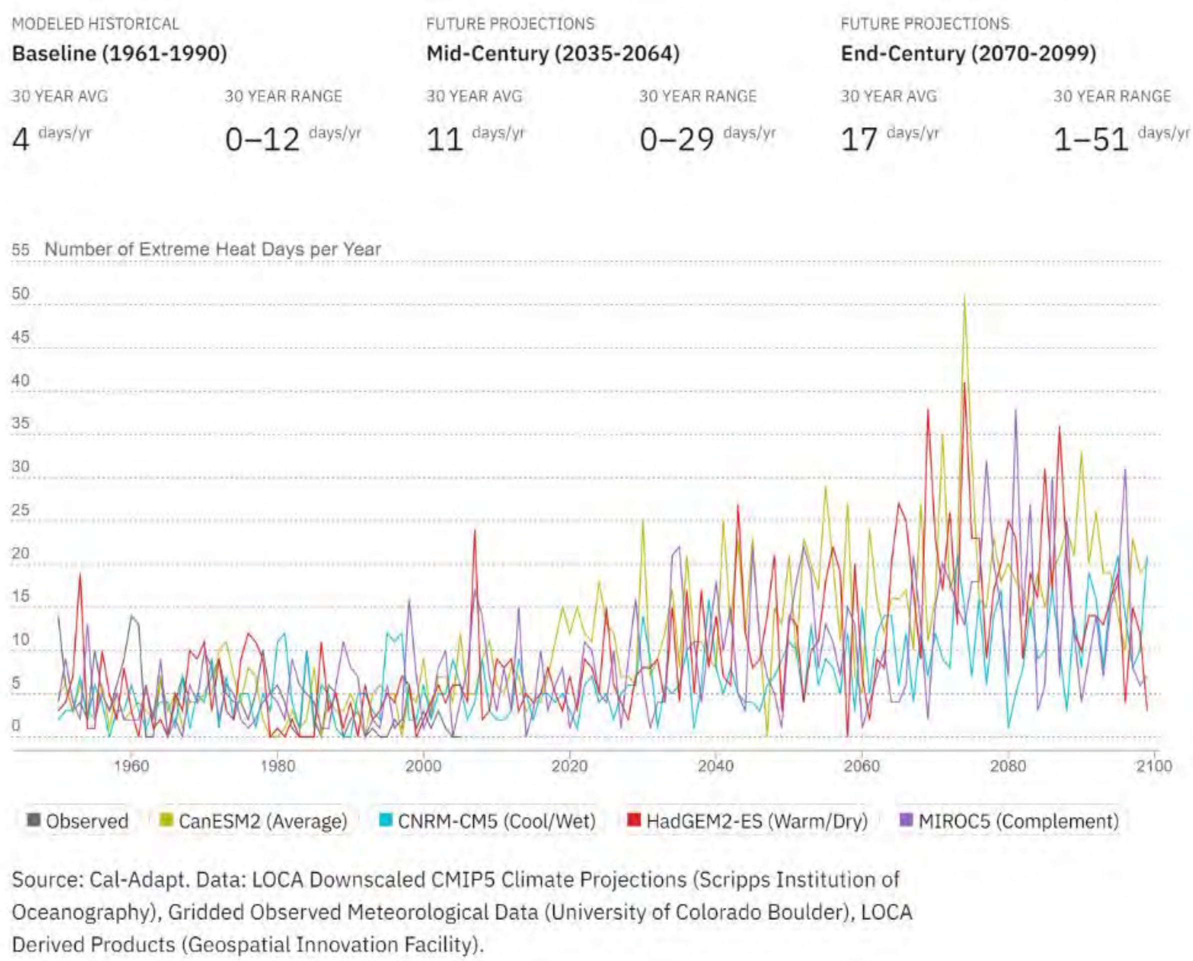


Figure 126. Modeled increase in extreme heat days per year in the UVGBW using the Cal-Adapts website. Each line reflects the outputs of a different climate model using slightly different assumptions about future changes in the climate and GHG emissions.

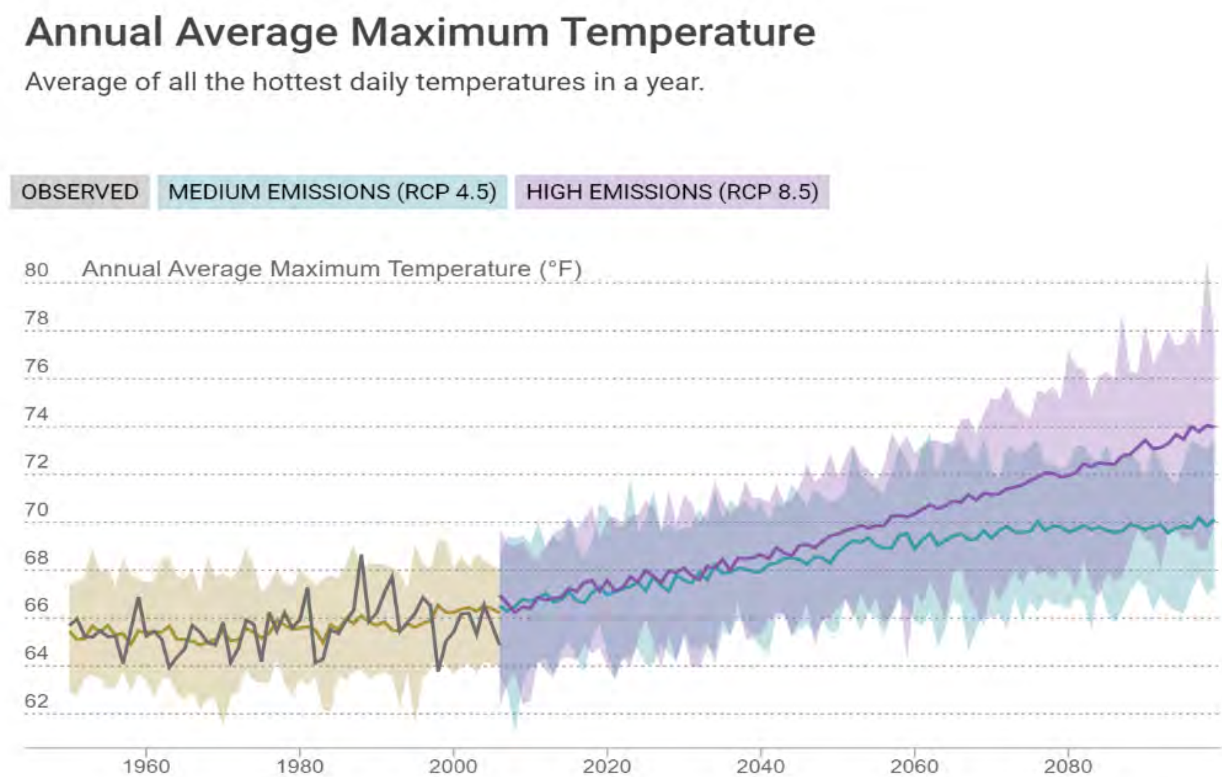


Figure 127. Modeled increases in annual average maximum temperatures in the UVGBW using the Cal-Adapts website and showing the results of two climate models.

Rainfall

Models show the total amount of annual precipitation for the UVGBW will increase from 45.9 inches/year (1961-1990 average) to 47.1 inches/year (2035-2064 average) and up to 48.8 inches/year (2070-2099 average). However, models show that this rainfall will occur in large intense rainfall events (atmospheric rivers) and likely generate floods, landslides and other problems.

Evapotranspiration

Climate models also show multiyear droughts becoming more common. Figure 128 shows modeled results of changes in evapotranspiration (ET) for a simulated 20-year long drought occurring between 2051-2070. ET would change from 23.8 inches of water (1961-1990 average) to an average of 24.2-29.1 inches in 2051-2070. A change of this magnitude would significantly affect vegetation and fires. When the ET demand of the plants increases, the ability of plant species to live in hot summer dry locations decreases. An increase in ET will especially affect conifer trees. As of 2023 the forests of the Sierra Nevada have thousands of dead conifers due to increased summer temperatures creating higher ET demand by the trees and lower rainfall amounts to fulfill the ET demand. Many of these conifers have died from insect infestation which increases when drought conditions weaken trees. Even hardwood and chaparral shrubs can become more insect and disease prone due to higher ET demand and drought conditions.

Upper Russian River Watershed, California

Projected changes in **Evapotranspiration** by **Water Year** under a **Late 21st Century Drought (2051–2070)***

*Scenario represents a late century dry spell from 2051–2070 identified from the HadGEM2-ES RCP 8.5 simulation. The extended drought scenario is based on the average annual precipitation over 20 years. This average value equates to 78% of historical median annual precipitation averaged over the North Coast and Sierra California Climate Tracker regions.

OBSERVED HISTORICAL

Baseline (1961-1990)

30 YEAR AVG

23.8 inch

FUTURE PROJECTIONS

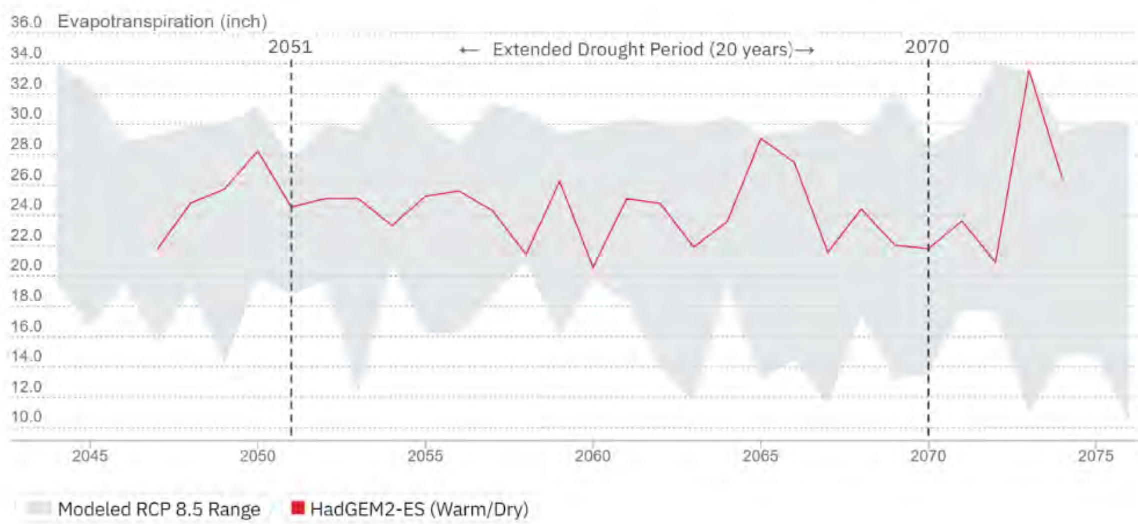
Late 21st Century Drought (2051–2070)

20 YEAR AVG

24.2 inch

20 YEAR RANGE

20.6–29.1 inch

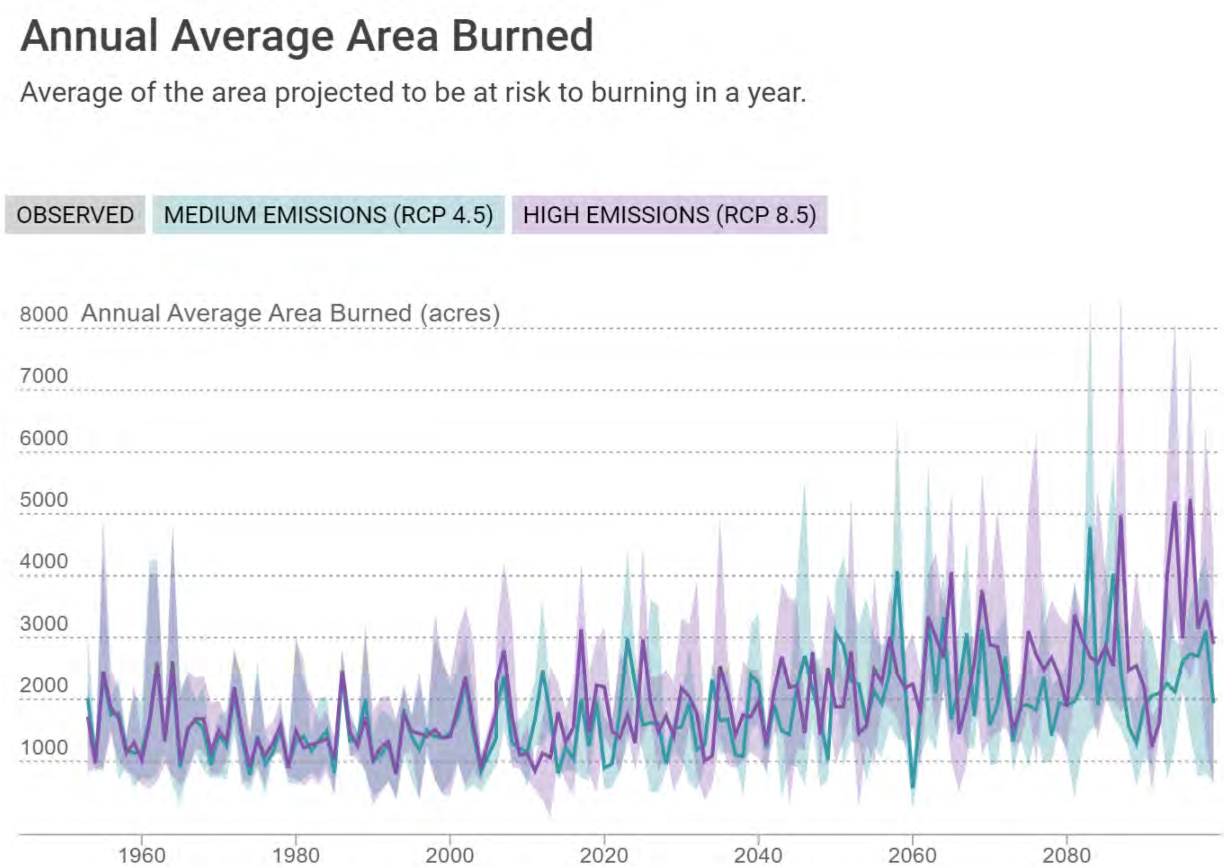


Source: Cal-Adapt. Data: Long Drought Scenarios (Scripps Institution of Oceanography), Gridded Observed Meteorological Data (University of Colorado Boulder), LOCA Derived Products (Geospatial Innovation Facility), LOCA VIC Runs Derived Products (Geospatial Innovation Facility).

Figure 128. Modeled changes in Evapotranspiration (ET) with a 20-year drought in the UVGBW.

As more trees die, fire hazards increase. Over many years of drought and fire forests may not regenerate in areas that have become too hot and dry for the conifer species that previously grew there. Additionally in areas where fire frequency increases due to changed climate conditions hardwood and chaparral species that are adapted to fire recurrence periods of 20-50 years may not be able to resprout and recover from one fire before another fire occurs. The increase in frequency of high severity fire can change vegetation types in the UVGBW from conifer forest to hardwoods or chaparral, and chaparral to grasslands.

Acres burned
Figure 129 depicts the increase in average annual area burned from 1960 to 2080 for the UVBGW. The 30-year average of burned acres between 1961-1990 was modeled at 1434-1479 acres/year. For the 2035-2064 period modeled acres burned increases to 2067-2170 acres/year. For the 2070-2099 period average burned acres were modeled at 2243-2857 acres/year, nearly double the average acres/year for the 1961-1990 period. It should be noted that while the model is predicting average burned acres/year and fires will occur as years with large fires interspersed with years with fewer fires.



1Data derived from 32 LOCA downscaled climate projections generated to support California's Fourth Climate Change Assessment. Details are described in Pierce et al., 2018.
2Observed historical data derived from Gridded Observed Meteorological Data. Details are described in Livneh et al., 2015.
3Data presented are aggregated over all LOCA grid cells that intersect Upper Russian River Watershed boundary.
4Upper Russian River Watershed boundary may contain locations outside the combined fire state and federal protection responsibility areas. These locations were excluded from wildfire simulations and have no climate projections.

Figure 129. Modeled increases of acres burned per year in the UVGBW.

Changes in range for selected species
We used the ForeCASTS model to evaluate how the ranges of Ca. live oak, Douglas fir, coast redwood and blue oak will change over time with climate change in the UVGBW. The ForeCASTS model estimates the future location of tree species in 2050 and 2100 under one of two climate models (Hadley Model and Parallel Climate Model (PCM)) under either high emissions (A1) or lower emissions (B1). We used the PCM model and lower emissions scenario (B1). The ForeCASTS model uses variables such as precipitation, heat, potential ET, temperature, water holding capacity of the soil and others to evaluate future distributions of specific plant species.

Figures 130 and 131 depict changes to the range of hardwood live oak (Quercus agrifolia), a common oak species in the UVGBW. By 2100 some areas in the UVGBW will no longer support live oak.

Figures 132 and 133 show changes in the distribution of conifer Douglas fir (Pseudotsuga douglasii). This species will be unable to grow along the east side of the Ukiah Valley by 2050.

Figures 134 and 135 show where coastal redwood will continue to grow in 2050 and 2100. This species requires coastal fog to survive and its range will retreat to the west.

Figures 136 and 137 show the future range of blue oak (Quercus douglasii) in 2050 and 2100. This drought tolerant species will primarily occur on the east side of the Ukiah Valley.

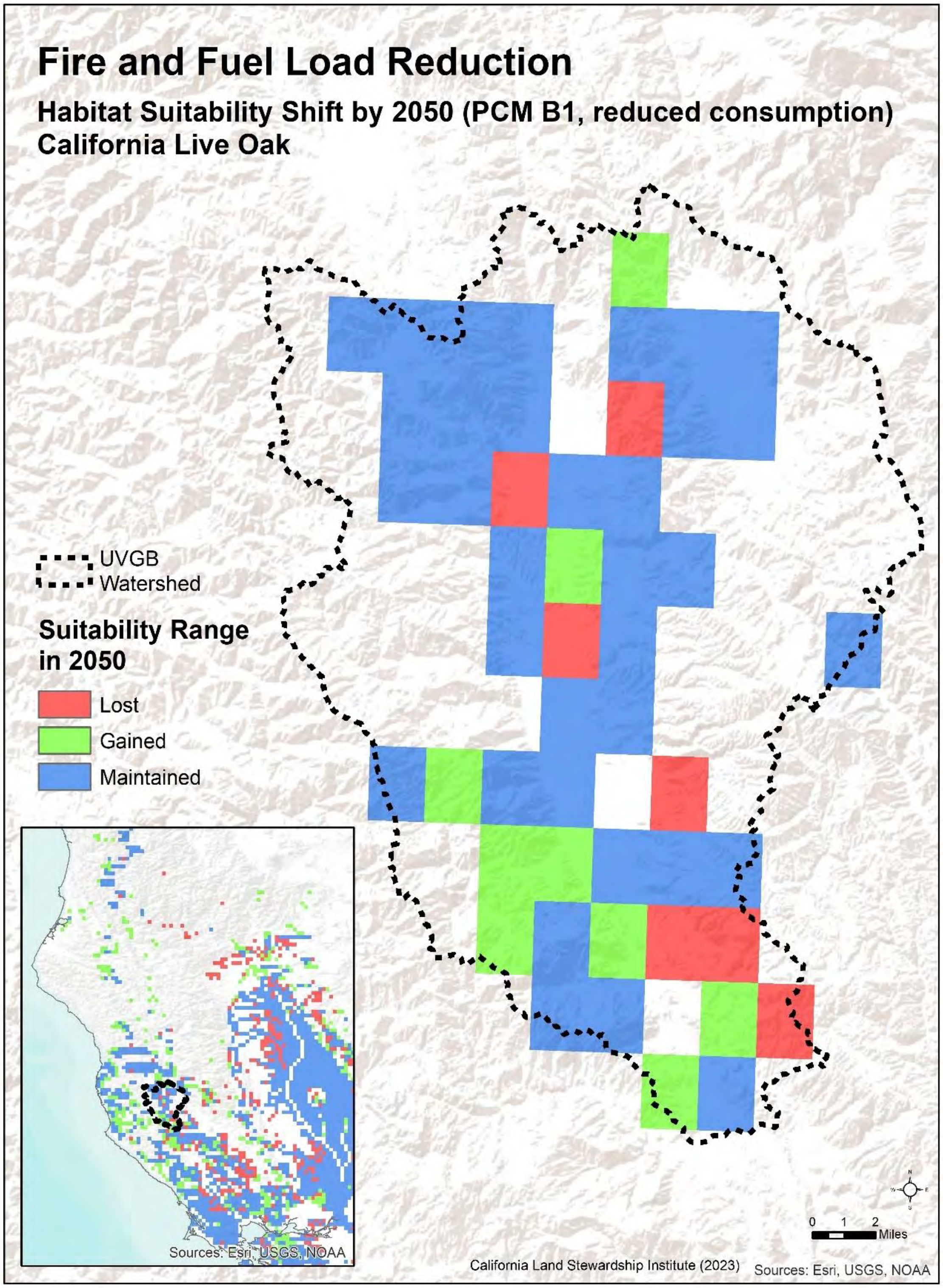


Figure 130. Modeled changes to the range of live oak (Quercus agrifolia) in the UVGBW in 2050.

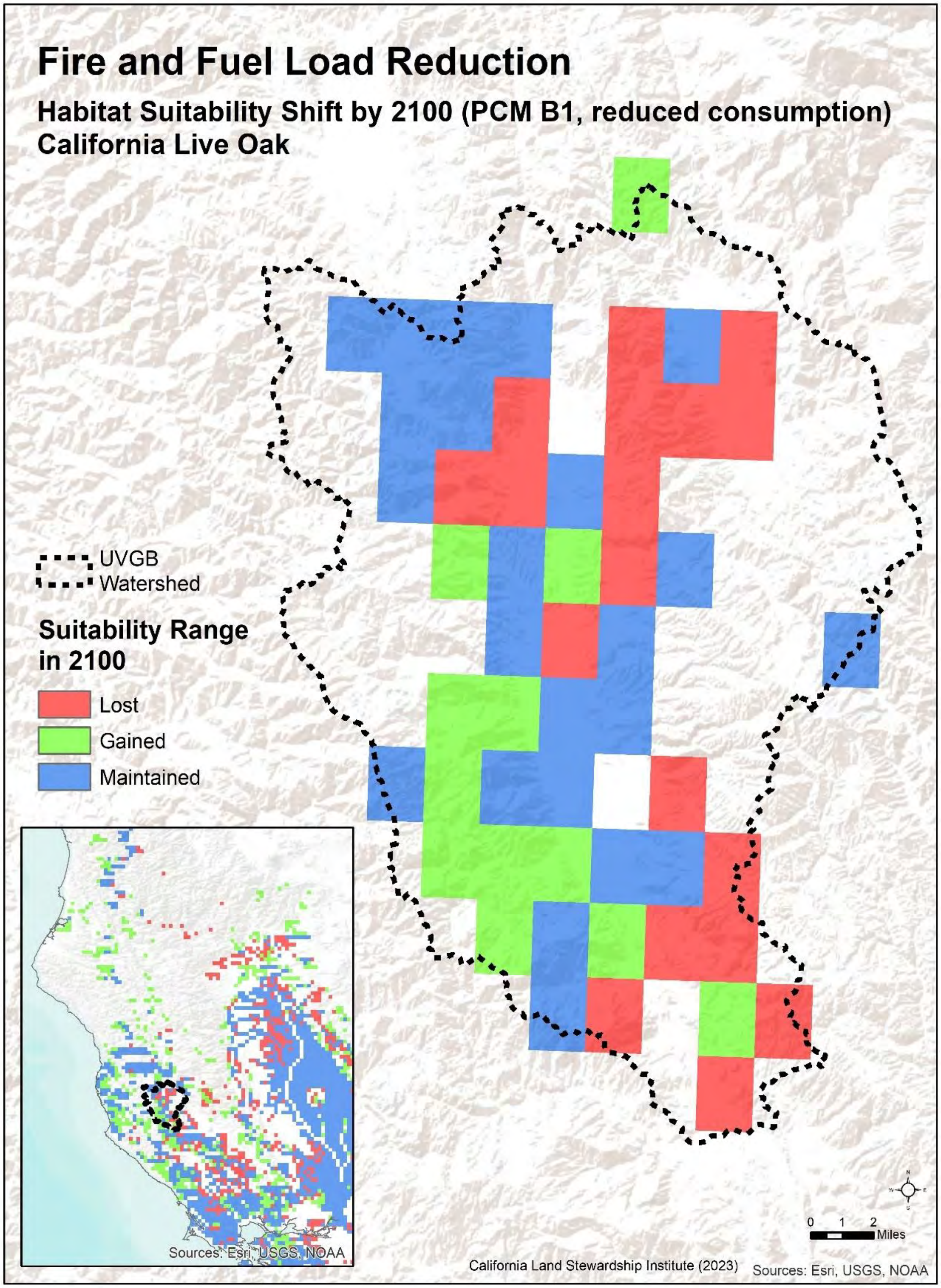


Figure 131. Modeled changes to the range of live oak (Quercus agrifolia) in the UVGBW in 2100.

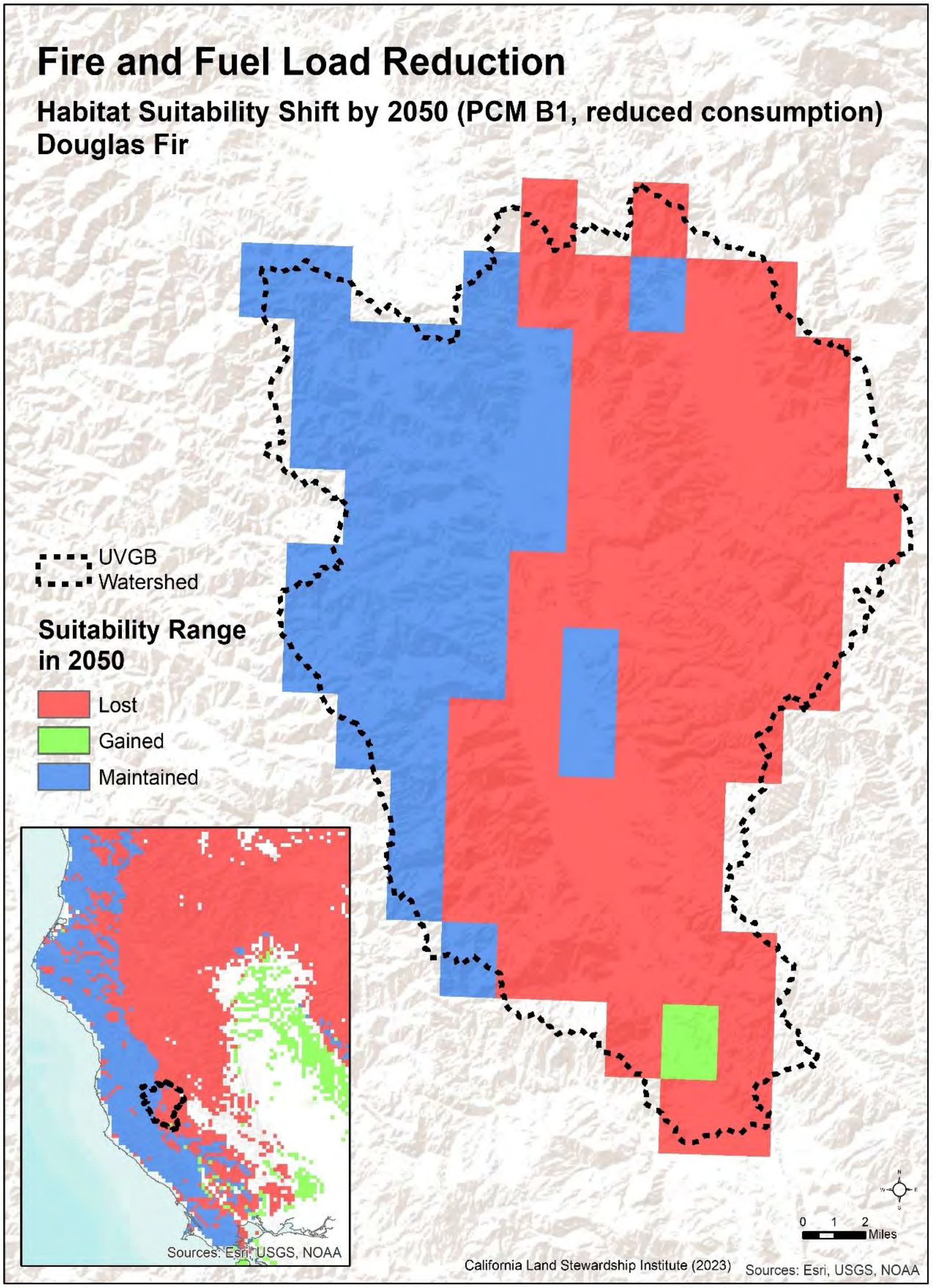


Figure 132. Modeled changes to the range of Douglas fir (Pseudotsuga douglasii) in the UVGBW in 2050.

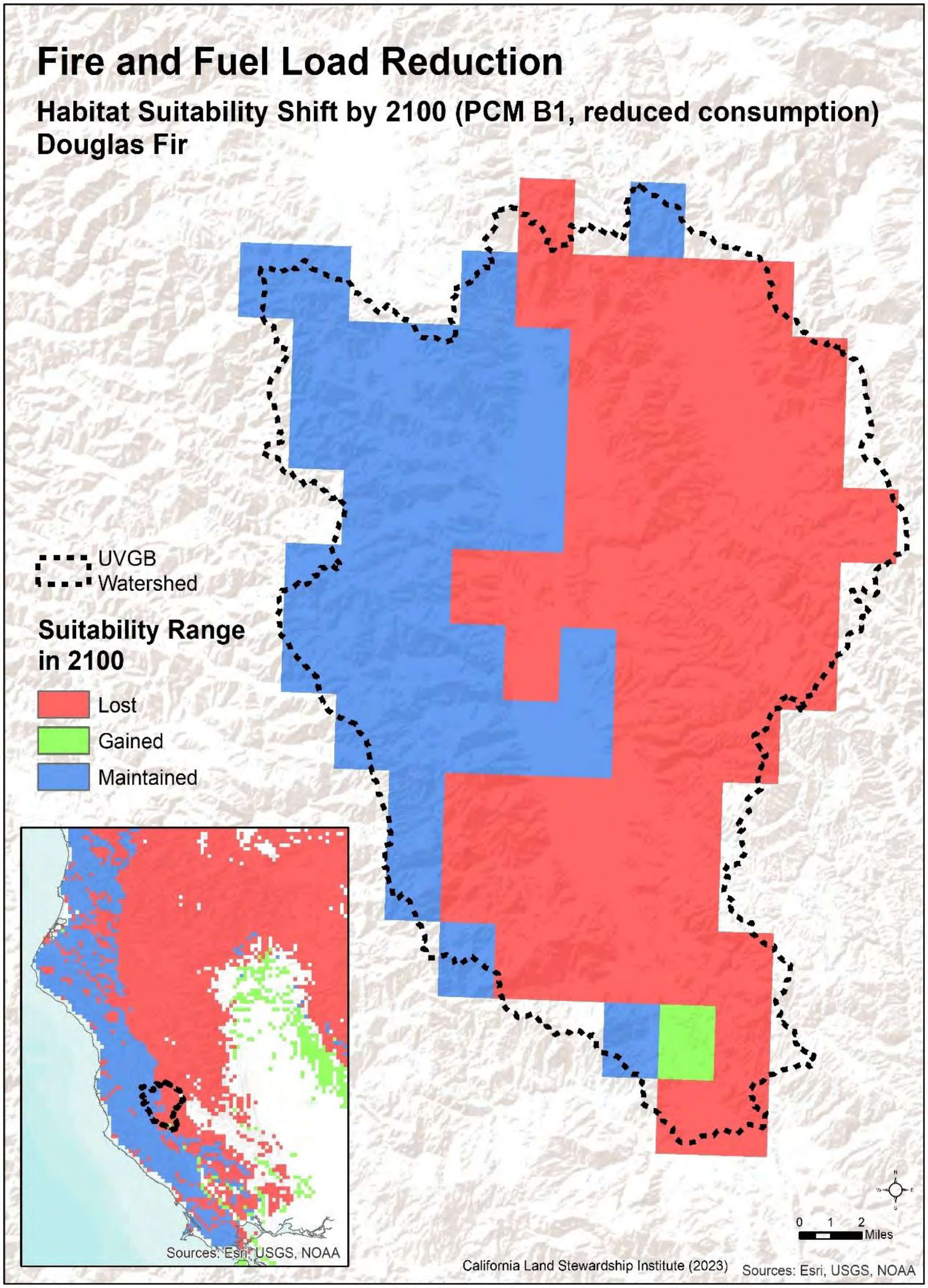


Figure 133. Modeled changes to the range of Douglas fir (Pseudotsuga douglasii) in the UVGBW in 2100.

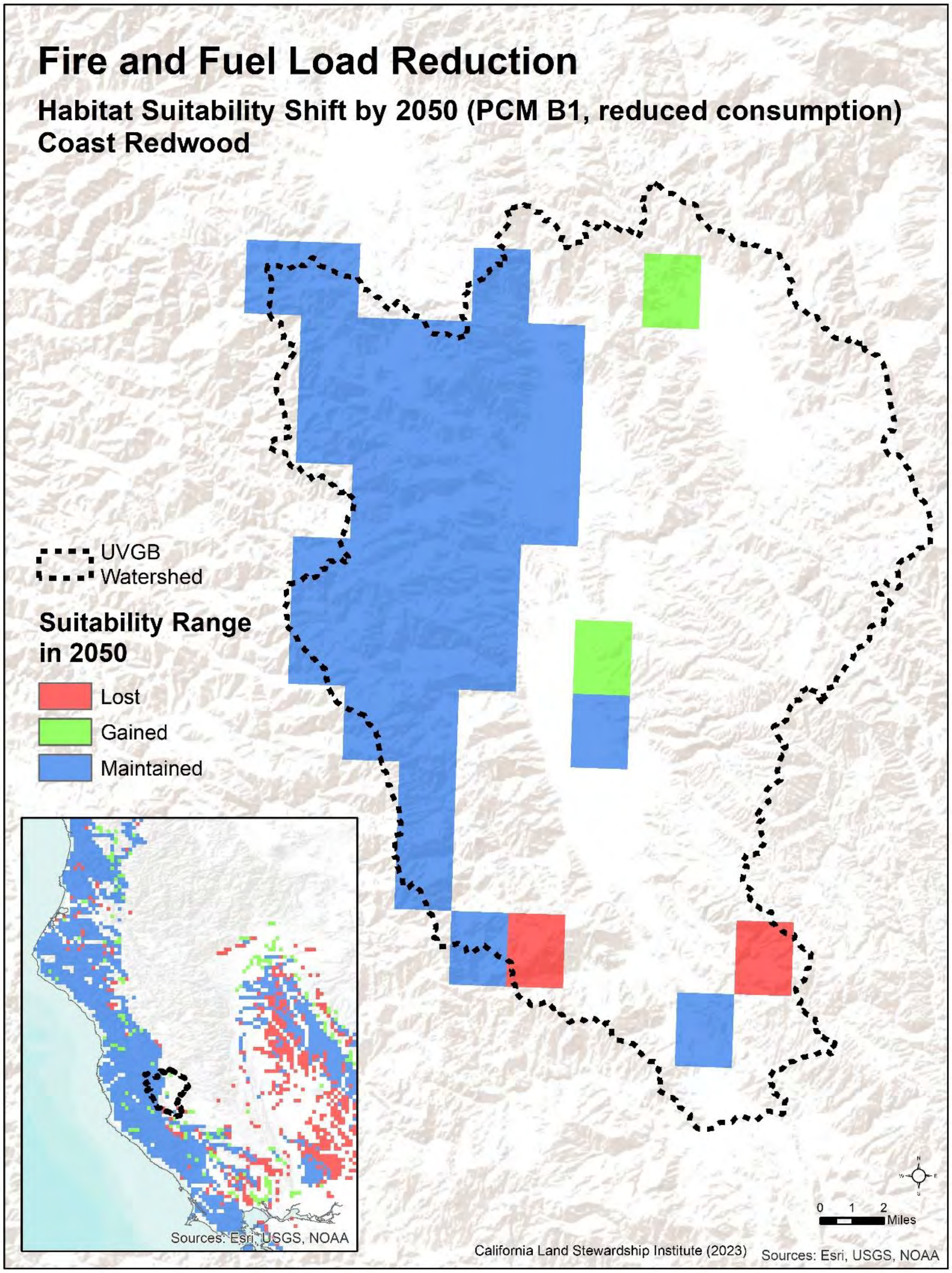


Figure 134. Modeled changes to the range of coast redwood (Sequoia sempervirens) in the UVGBW in 2050.

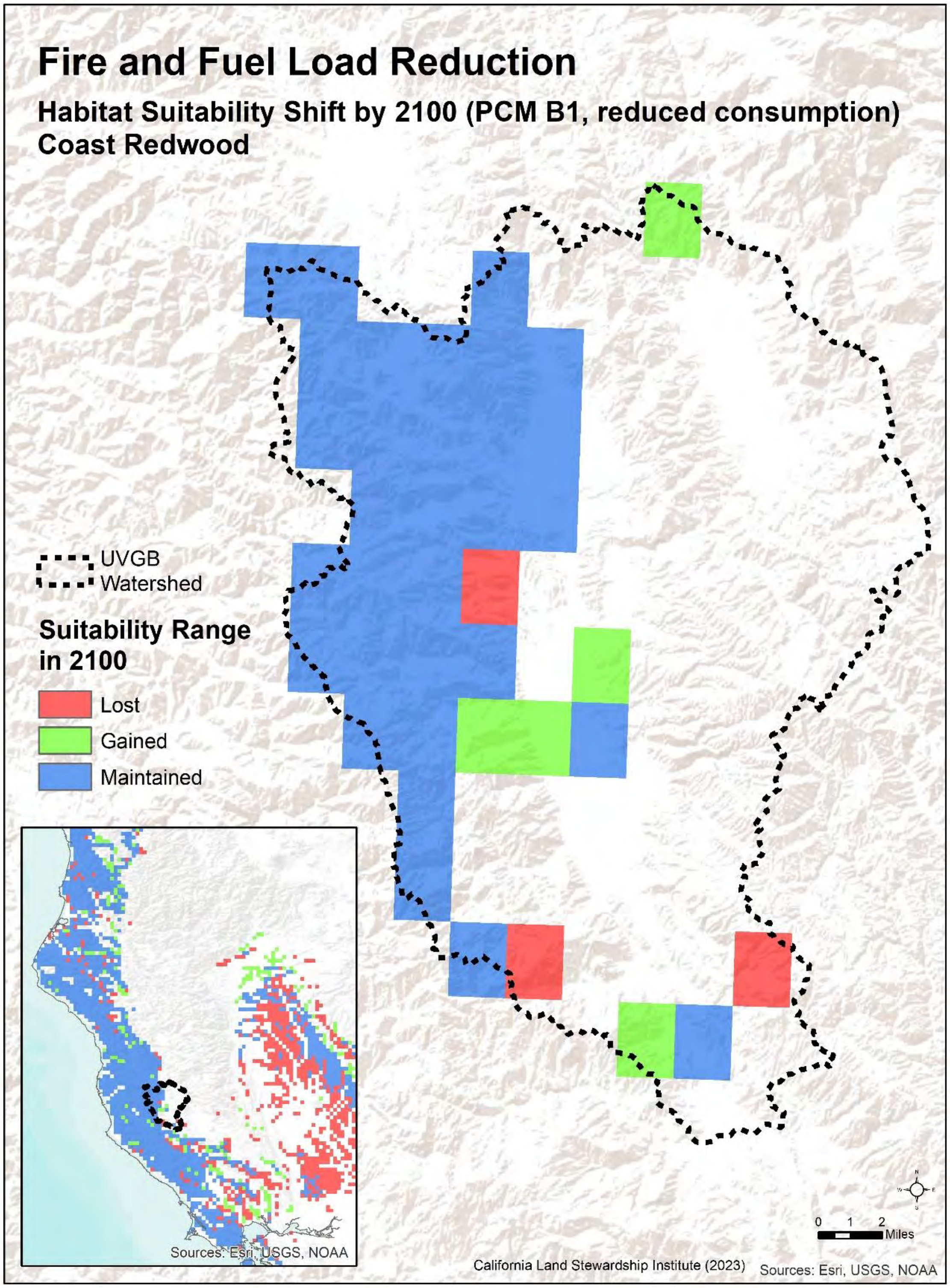


Figure 135. Modeled changes to the range of coast redwood (Sequoia sempervirens) in the UVGBW in 2100.

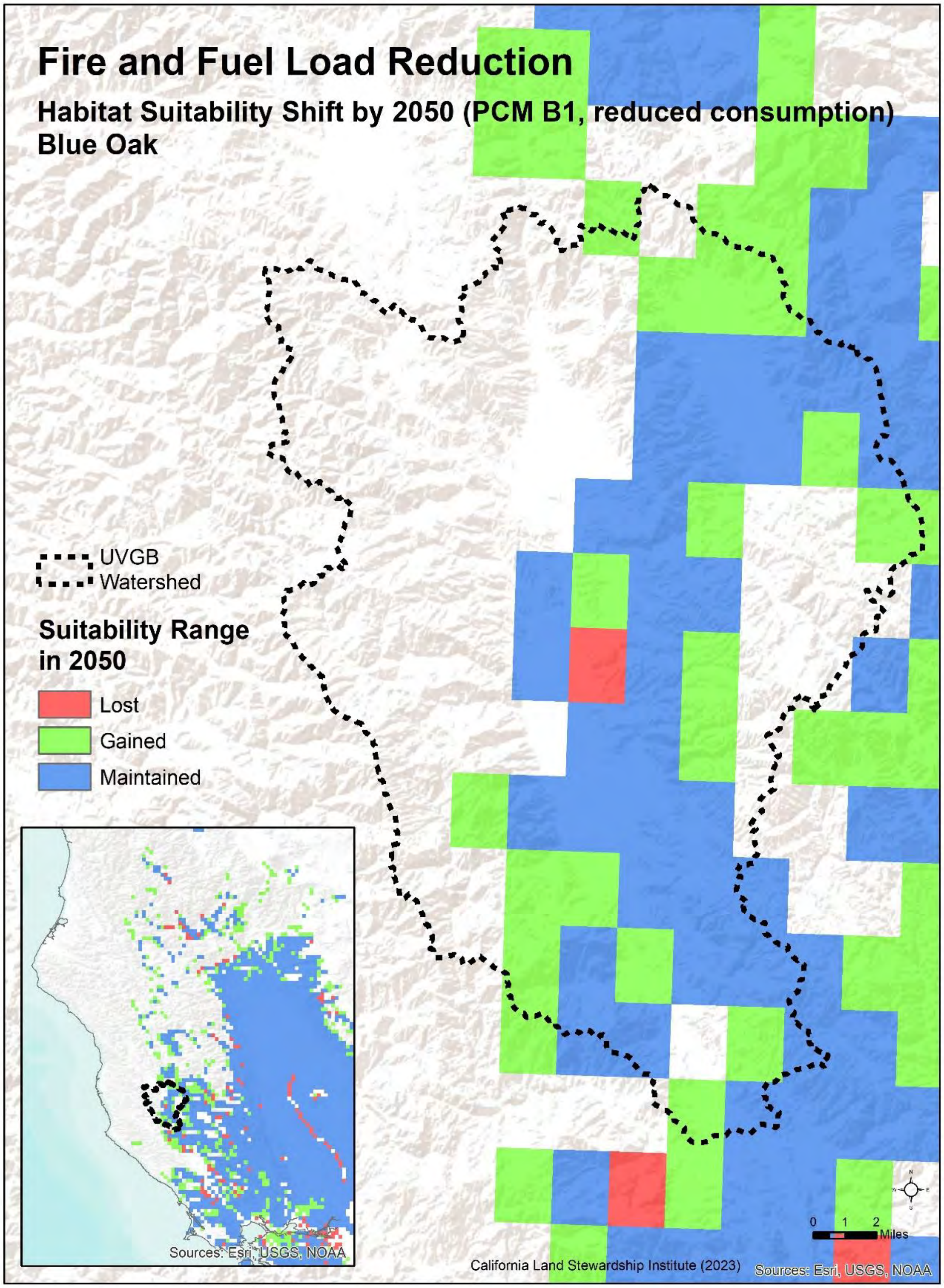


Figure 136. Modeled changes to the range of blue oak (Quercus douglasii) in the UVGBW in 2050.

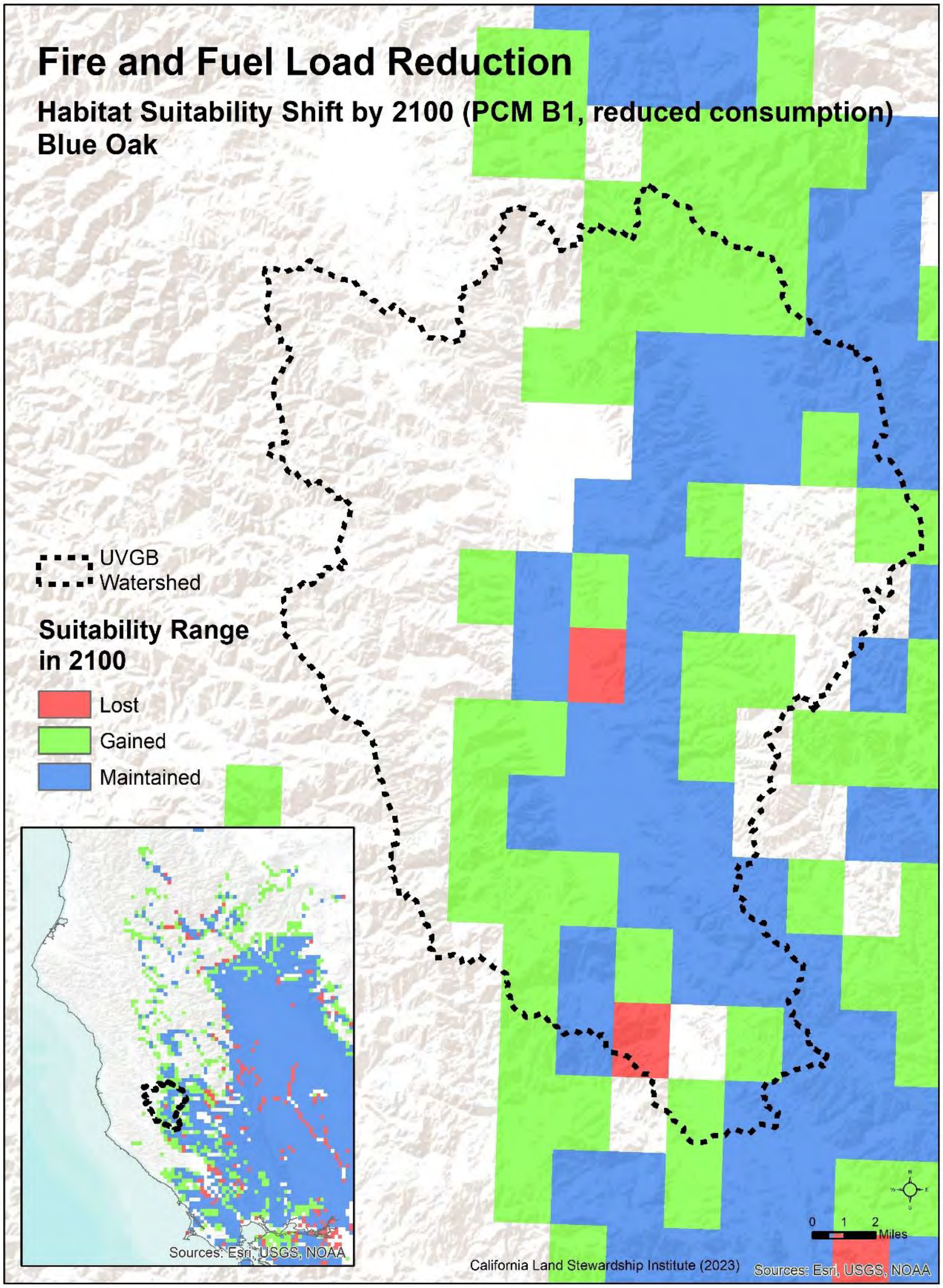


Figure 137. Modeled changes to the range of blue oak (Quercus douglasii) in the UVGBW in 2100.

FIRE MANAGEMENT AND FUEL LOAD REDUCTION PROJECTS

Summary of Watershed Conditions

- Steep mountains border the Ukiah Valley Groundwater Basin Watershed (UVGBW) on its east, north and west perimeters. The mountains of the eastern watershed are drier than those to the west and north. This difference in annual rainfall gives the eastern mountains a vegetative cover primarily of chaparral, oak woodland, hardwood forest and grassland with little conifer forest. The wetter western slope also has oak woodland, hardwood forest and grassland, but also significant areas of coastal redwood, ponderosa pine and Douglas fir.
- Chaparral shrubs, hardwood forest and oak woodlands are all adapted to fire and quickly recover through seed germination and resprouting from the root crown. Conifers, with the exception of redwoods, are able to withstand low to moderate intensity fire, but will die after high intensity crown fires.
- Native California Indians understood the role of fire in their environment and used it to burn areas to supply their needs and steward their lands. Europeans stopped Indian burning and Americans began the policy of fire suppression. Since then, vegetation has become dense and fuel loads greater resulting in larger, more intense fires. In the past 6 years there have been three very large wildfires in the UVGBW that burned for months.
- Fire is a major feature of the California landscape. For each vegetation type there are time intervals between fires, called return intervals, that are typical of the ecosystem. The fires described by these intervals historically burned all the above ground vegetation in chaparral, but only the understory in conifers. Hardwood forests would have gone through a complete loss of above ground vegetation occasionally, but more typically would lose undergrowth and dead material. Post burn the plants recover through their various adaptations. If the natural interval becomes more frequent, vegetation may change from one type to another. For example, hardwood forest will transition to chaparral or grassland or large infestations of nonnative invasive species.
- Following a fire the lack of vegetative cover increases sheet and rill erosion in the short term and possibly debris flows and landslides in the long term. Burn areas will also experience greater volumes of storm runoff for years.
- CalFire is California's primary fire department and resource management agency. CalFire has developed a number of data sets that show fire hazards. Fire hazard severity zones reflect long term fire hazards that remain constant for decades. Over 66% of the UVGBW is in the very high to high fire hazard severity zones. Another CalFire model that ranks the likelihood of a damaging or difficult to control fire found 80% of the UVGBW is in a high to very high fire threat ranking.
- These CalFire models make clear that the likelihood of fires in the UVGBW is high. Climate change is expected to increase fire hazard severity. Annual average maximum temperatures are predicted to increase by 3.3-4.0^{o} F by 2035-2064 and 4.4-7.2^{o} F by 2070. The number of extreme heat days where temperatures exceed 102.4^{o} F will increase from 4 days/year (the average from 1960-1991) to 11 days/year in 2035-2064 and up to 17 days/year by 2070.
- Future climate also will include droughts where evapotranspiration (ET) requirements of plants will increase from 23.8 (1960-1991 average) to 24.2 -29.1 inches in 2051. These increases in average and maximum temperature as well as drought and increased ET will kill plant species that are not able to withstand the change. The more dead trees the higher the fire hazard. The average annual area burned is predicted to more than double by 2070; however, fires are likely to occur over large areas every few years rather than an average amount of burning each year. The ranges of various species will change significantly; Douglas fir will become a coastal species in this area and live oak distribution will shrink.

Human Safety Projects

When large wind driven fires start it is essential that rural residents in the path of the fire quickly evacuate (Figure 138). Rural roads are typically 2 lanes and, if lands adjacent are overgrown, the road can become impassable due to burning vegetation. Clearing along major roads is a primary need in the UVGBW. Figure 139 shows all the parcels with structures in the UVGBW. Figure 140 shows the number of structures per square mile along with the CalFire high and very high fire hazard severity zones. This map demonstrates the high number of rural residential areas that need improved roads that can accommodate evacuations during major fires. Figure 141 depicts several roads identified in the Mendocino County Fire Vulnerability Assessment that could become chokepoints in an evacuation. We added a few more based on the number of residences with limited access. Table 43 provides the miles of road clearing proposed and the number of structures each road serves

Additional roads that need to be cleared include roads in the Russian River Estates, Redwood Valley Rancheria, and many communities in Potter Valley as well as Nakomas Rd. on the Hopland Rancheria, and small roads on the east side of Ukiah that were not included in Mendocino Fire Safe Council's Ukiah Valley Fire Fuel Reduction Project (Category Five 2020).

Table 43. Projects planned or recommended on roads in the UVGBW

Road	Miles of road	Structures served
Black Bart Drive	8.36	145
Highway 253	6.91	233
McNab Ranch Road	3.53	159
Orrs Spring Road	8.43	209
Potter Valley Road and Highway 20	4.02	1553
Tomki Road	3.2	166

Table 44 lists the proposed and completed road clearing projects listed in the CalFire Fire Plan for the UVGBW and the status of each project. Orr Springs Road, Highway 253 and the numerous other rural roads are not on the Calfire project list and all will require treatment for public safety.

The Mendocino County Fire Safe Council works with rural residents to assist them in clearing vegetation around houses and with hardening structures to increase safety and reduce loss of property.

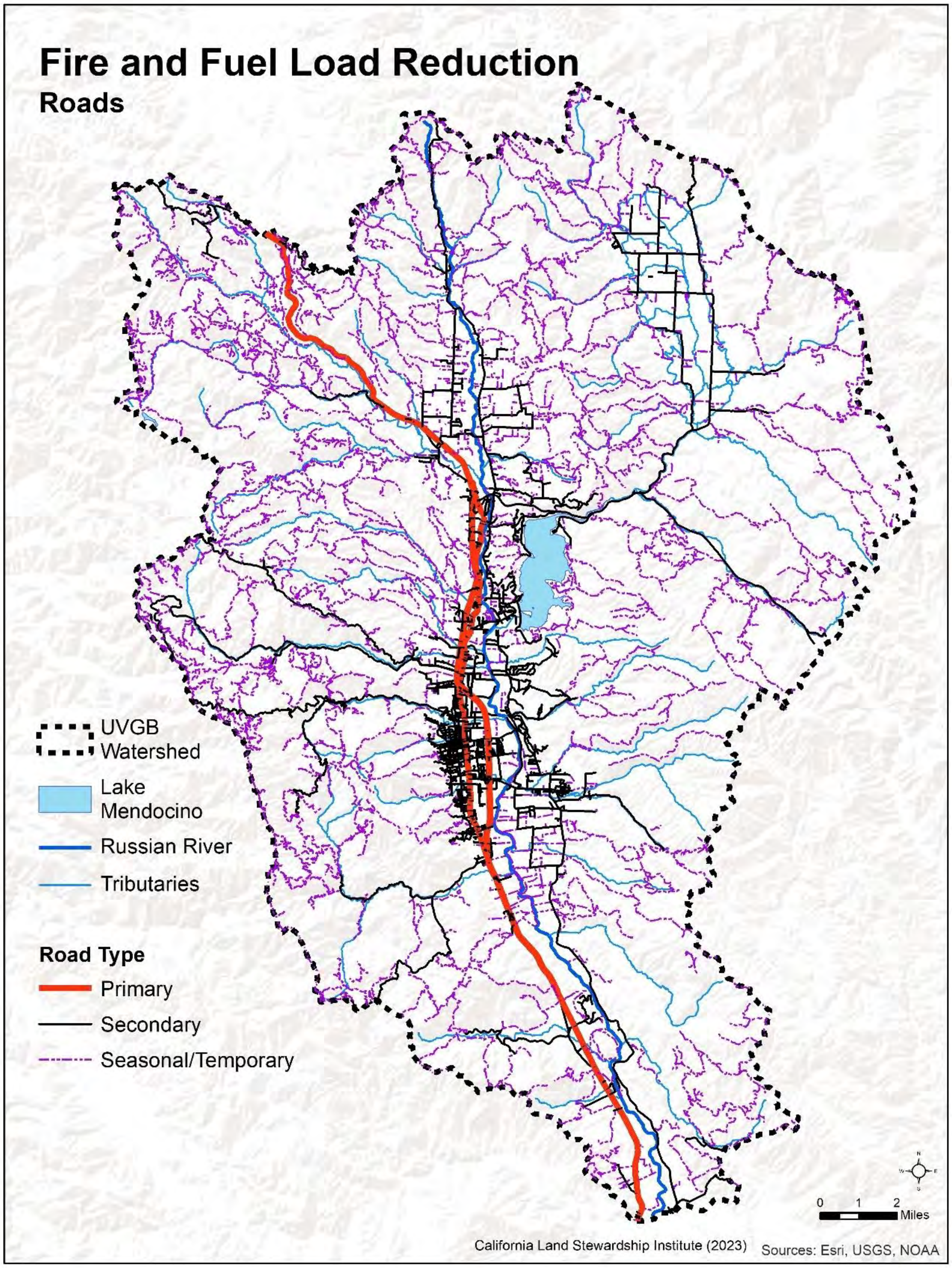


Figure 138. Primary and secondary roads and the numerous seasonal roads in the UVGBW.

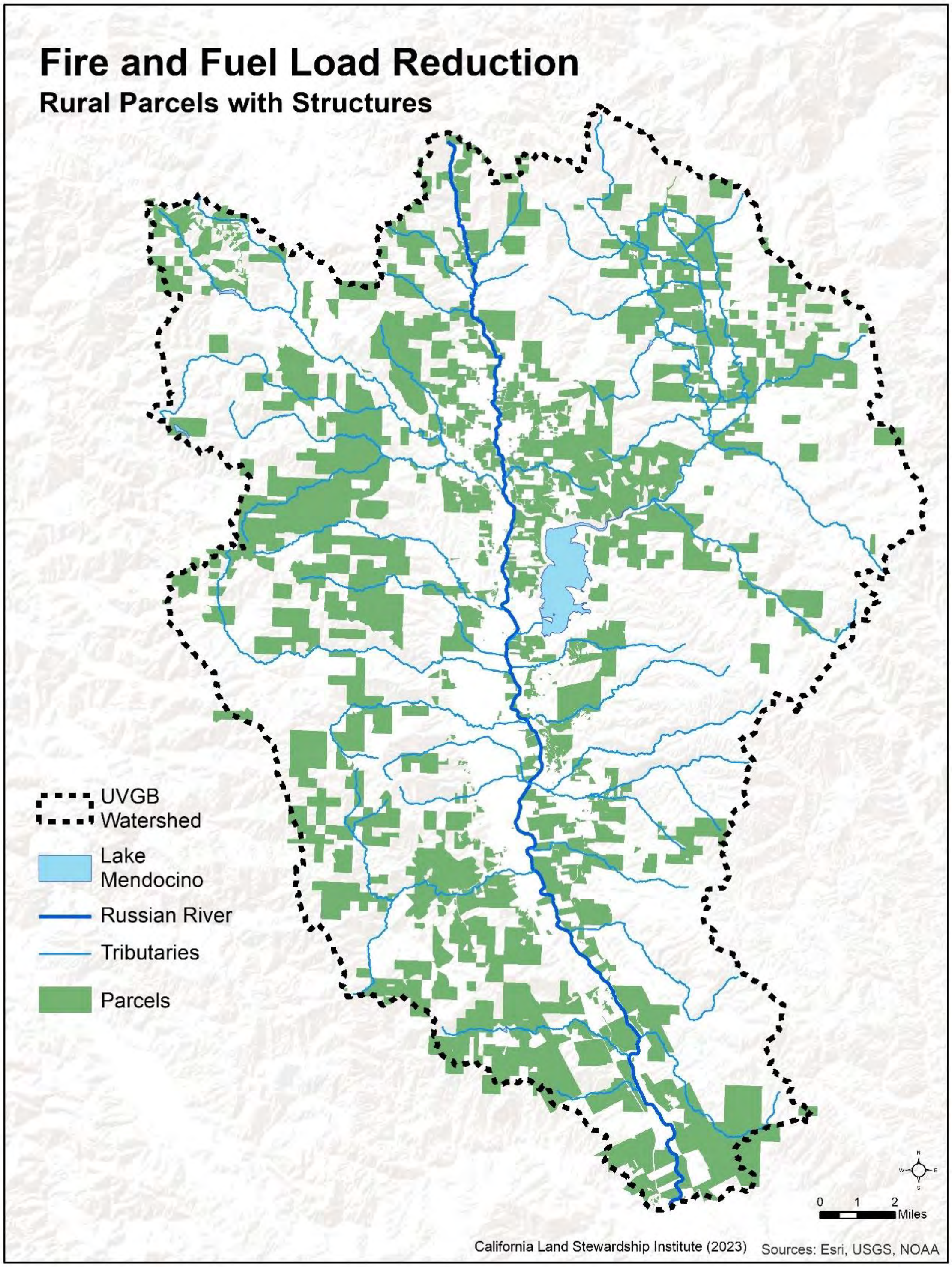


Figure 139. Parcels with structures in the UVGBW.

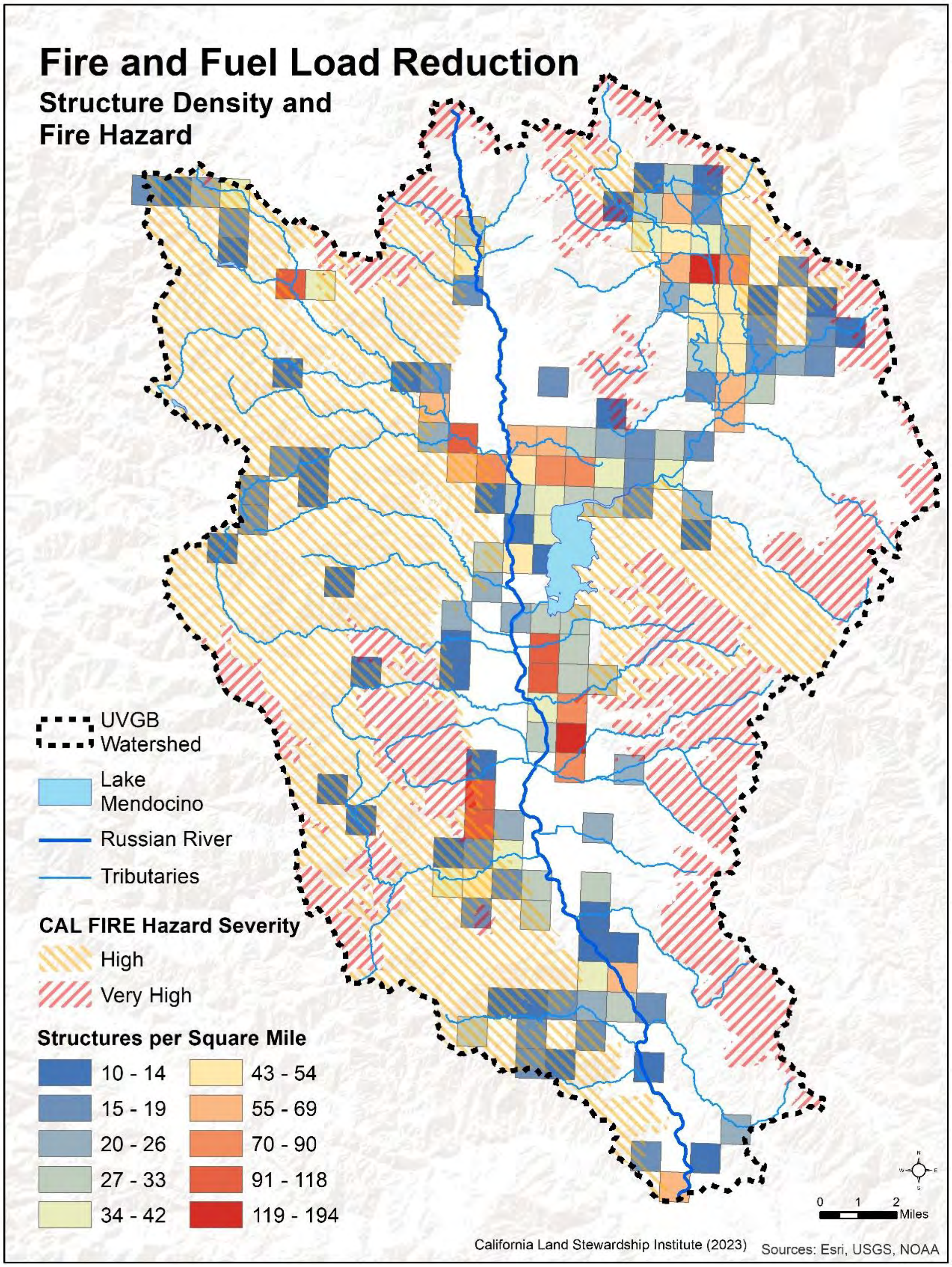


Figure 140. The density of structures in the high and very high fire hazard severity zones in the UVGBW.

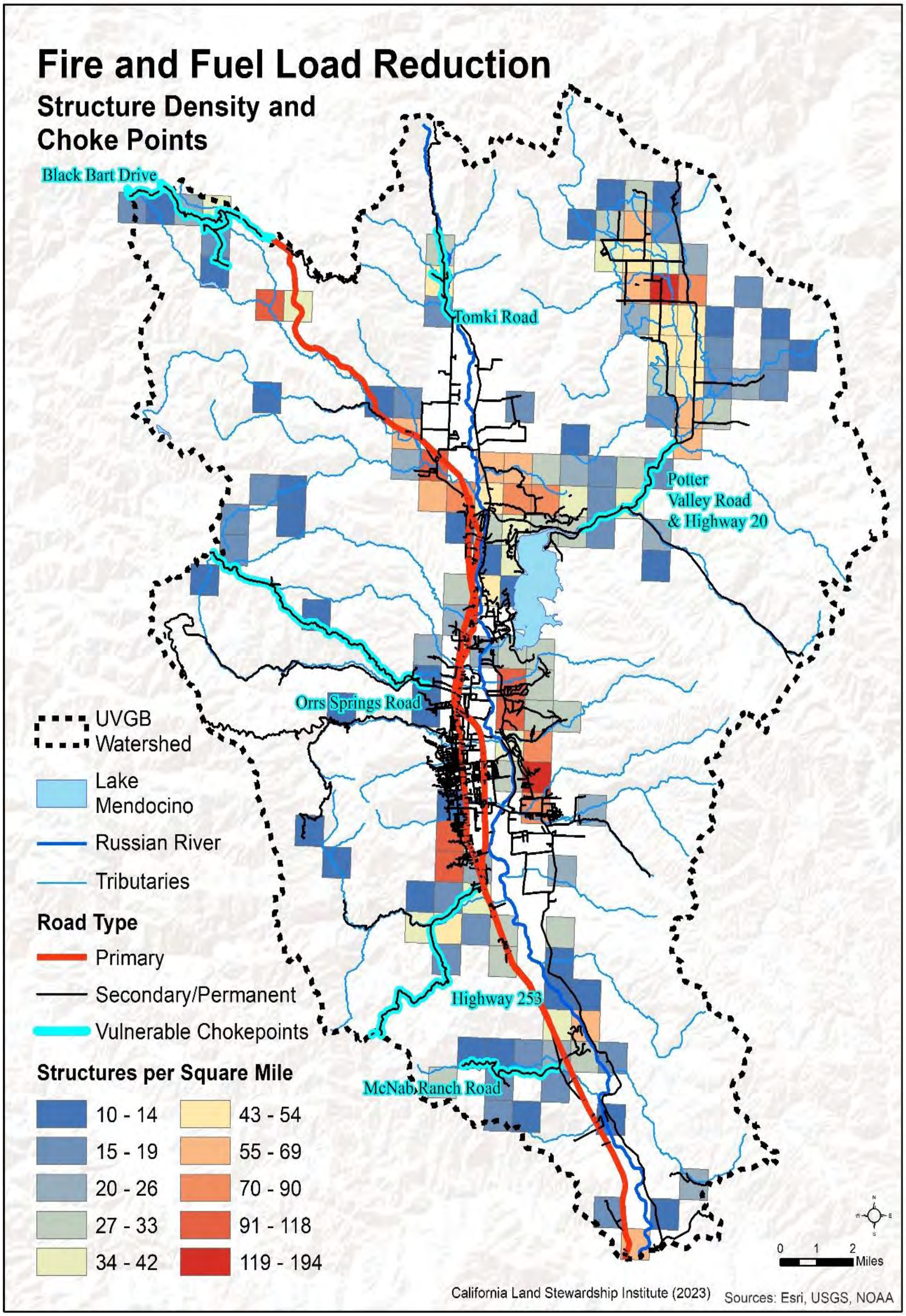


Figure 141. Major choke points for resident evacuation in fires.

Table 44. Planned or In-Progress CalFire Road Clearing projects in the UVGBW

Name	Description	Status
Mill Creek Fuels Reduction	This project reduced fuel loads and improved wildlife habitat on chamise and mixed-chaparral slopes. Mechanical clearing was carried out on both sides of Mill Creek Road.	Stage I complete. Maintenance underway
El Dorado Fuels Reduction	This project created and maintains a shaded fuel break from Redemeyer Road to Fawnwood Drive along the south side of El Dorado Estates east of Ukiah.	Stage I complete. Maintenance underway
Highway 101 Fuels Reduction	This project will reduce fuels immediately adjacent to Highway 101 (within a 40-ft. buffer) between North State St. and Ridgewood Grade.	Planning
Vista Del Lago Fuels Reduction	This project will create and maintain shaded fuel breaks along the Vista Del Lago and the King Ranch Road system.	Planning
Greenfield Ranch Fuels Reduction	This project will create and maintain a shaded fuel break along the Greenfield Ranch Road system.	Planning
Burke Hill	This is a fire hazard reduction project along Highway 101 from Nelson Ranch Road to Burke Hill Road. The fire hazard reduction will be accomplished by creating a shaded fuel break. The shaded fuel break will include vegetation thinning, understory reduction and removal of ladder fuels. The area consists of steep terrain with a mix of grasslands, conifer and mature brush.	Planning
Potter Valley Fuels Reduction Projects	This project will identify fuel reduction projects in and around Potter Valley focusing on removal of understory fuels, brush, and small trees along both sides of various roads, creating and maintaining fire breaks on ridgetops, and conducting prescribed burns at strategic locations.	Not yet implemented

In 2020 CalFire passed State Minimum Fire Safe Regulations for the State Responsibility Area (Figure 34). These regulations define requirements for new construction including clearing along roads and around structures, 20 ft. width requirement for two-way roads, 12 ft. width requirement for one-way roads and requirements for one-way roads to connect to a two-way road over a specified distance, percent road grades, vehicle load requirements and vertical clearance.

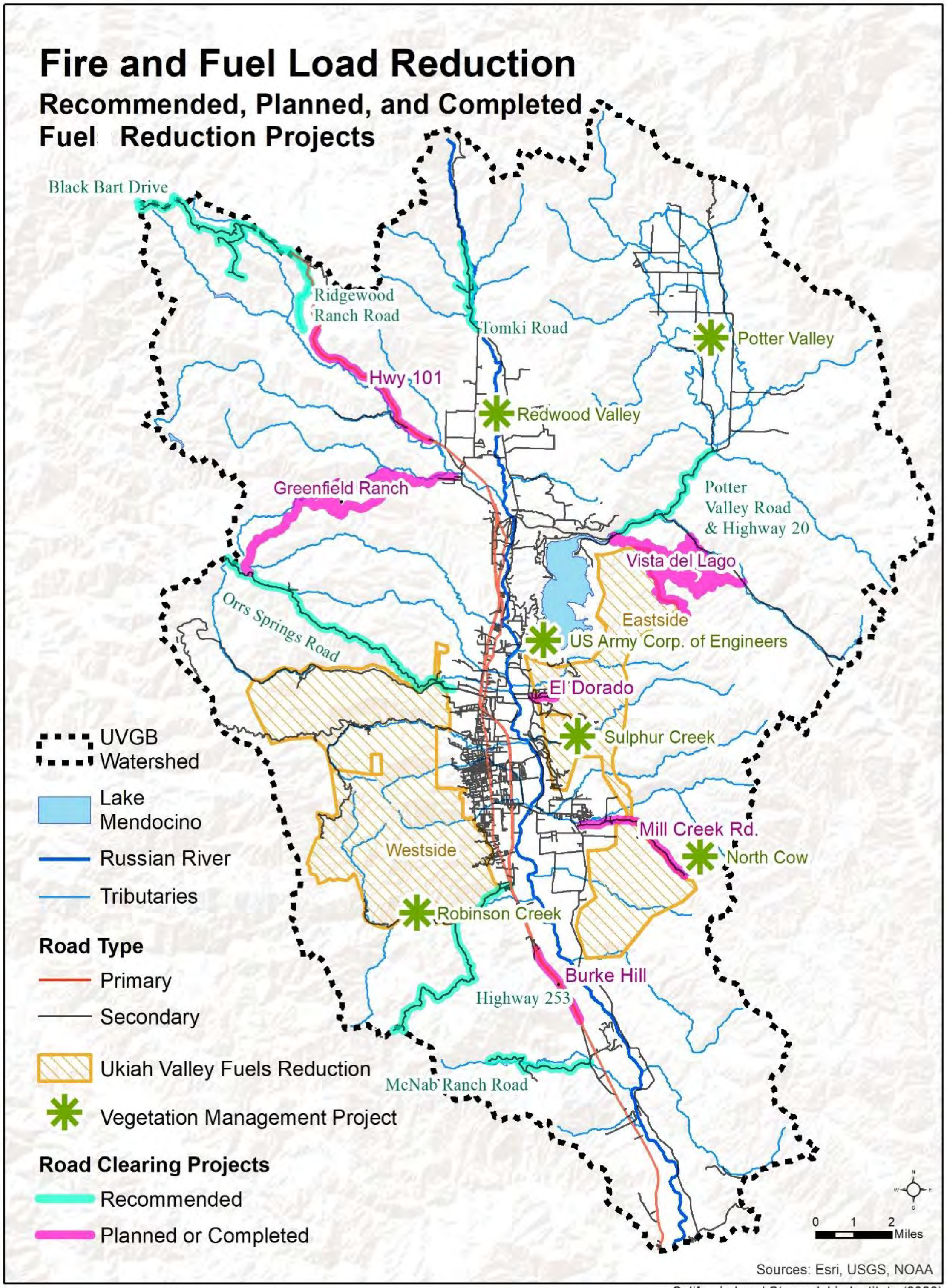
Vegetation Management Projects

This category of project typically involves using hand crews or machinery to remove understory vegetation and thin out dense small trees in forests. The machinery cuts and clears the vegetation in areas accessible by roads. Masticators chew up small trees and brush and distribute the shreds over the forest floor. These mechanical projects are completed in conifer and hardwood forests. Hand cut vegetation is piled to be burned, put through a chipper or loaded into a portable burner. All these methods are fairly expensive over large areas of land, but are essential to clear evacuation routes, fire breaks and areas surrounding communities. CalFire and Mendocino County Fire Safe Council have completed a number of vegetation management projects along the east and west side of the City of Ukiah (Table 45). There are also many similar projects in the planning stage for the UVGBW. Figure 142 depicts the locations of many of these projects.

Table 45. CalFire Vegetation Management/Fuel Load Reduction Projects in the UVGBW.

Name	Description	Status
Ukiah Valley Eastside Fuels Reduction	This project removed understory fuels, brush, and small trees along both sides of selected roads, installed ridgetop fire breaks, and reduced fuel load hazards with prescribed burns. Fuel breaks were installed at the base of Cow Mountain.	Stage I complete Maintenance underway
Ukiah Valley Westside Fuel Reduction	This project created and maintains shaded fuel breaks along selected roads, improved ingress for firefighters and egress for evacuation, developed a vegetation management program, and reduced fuel load hazards with prescribed burns in the urban-wildland interface west of Ukiah. Ridgelines as well as south and west facing slopes will be prioritized.	Stage I complete Maintenance underway
US Army Corps. of Engineers Coyote Dam Vegetation Management	This project will burn all vegetative material from the face of Coyote Dam and re-establish fire lines on the east and south side of USACOE property along roads and on the east side of the lake in strategic locations.	Planning
Sulphur Creek	This fire hazard reduction project consists of fuel reduction along Sulphur Creek in the community of Vichy Springs east of Ukiah. It will remove the dead and dying debris adjacent to structures. This project is in cooperation with the local homeowner's association.	Planning
Black Bart	The Mendocino County FireSafe Council is in the planning stages of a fire reduction project in the area of Black Bart Trail. This will be accomplished by creating shaded fuel breaks, and fuel reduction areas. The Council is also in the planning process to mitigate damage from the recent Black Fire.	Planning
North Cow	This project will use prescribed fire on private and public lands east of the Ukiah Valley. The goals of the project are hazard reduction and range improvement. Treatment would reduce the rapid expansion of an uncontrolled fire burning west towards the urban interface areas on the east side of the Ukiah Valley and to prevent a fire that starts in the eastern hills and burns uncontrolled to the east towards Lake County and the community of Blue Lakes. Range improvement goal is to remove undesirable woody vegetation and increase forage production for domestic stock and wildlife. The project area is predominantly chaparral brush with a mix of oak woodlands and patches of conifer forests. A majority of the lands are west and southwestern aspects with a north aspect along Highway 20 on the north side. Access is limited to unmaintained, seasonal roads which make fire extinguishment difficult. The project will be a cooperative effort working in conjunction with the private landowners and the US Bureau of Land Management. The prescribed burns will be in concert with a focused inspection and public education program in the affected urban-interface communities.	Planning
Robinson Creek	The Mendocino County FireSafe Council is in the planning stages of a fire reduction project in the area of Robinson Creek. This area is prone to vegetation fires. This will be accomplished by creating shaded fuel breaks and fuel reduction areas, and installing water tanks for fire suppression activities.	Planning

Name	Description	Status
Redwood Valley Fuels Reduction Projects	Identify fuel reduction projects in and around Redwood Valley focusing on removal of understory fuels, brush, and small trees along both sides of various roads, creating and maintaining fire breaks on ridgetops, and conducting prescribed burns at strategic locations.	Not yet implemented
Pine Mountain – located outside the UVGBW	The prescribed burning conducted under this project will be conducted under specific climatic conditions to ensure control and minimize air quality and biological impacts. These conditions will mimic air, soil, and vegetation moisture, and other conditions under which natural wildfires occur so as to maximize the positive effects of fire on vegetation. The primary goal of this prescribed burn is to reintroduce fire as a natural element of the ecosystem. A second goal is to improve wildlife habitat by inducing new shoots from sprouting species to increase forage production, with islands of unburned fuel left within burn units to provide shelter for small mammals. The Mendocino Fire Safe Council will also be working to develop a Community Wildfire Protection Plan. Fuel mitigation via shaded fuel breaks and fuel reduction will also be performed. A third goal is to reduce overall fuel loading to decrease the chance of catastrophic wildfires in the future.	Planning
Pieta – located outside the UVGBW	Prescribed burning conducted under this project has been done to meet specific objectives under specific climatic conditions to ensure control and minimize air quality and biological impacts. The burning in this project has been completed. This project is in the maintenance phase.	Stage I complete Maintenance underway
Hopland Fuel Reduction Projects – located outside the UVGBW	Identify fuel reduction projects in and around Hopland focusing on removal of understory fuels, brush, and small trees along both sides of various roads, creating and maintaining fire breaks on ridgetops, and conducting prescribed burns at strategic locations.	Not yet implemented



California Land Stewardship Institute (2023)

Figure 142. Implemented and planned vegetation management/fuel load reduction and road clearing projects in the UVGBW.

Livestock Grazing
Livestock – cattle, sheep and goats can be used to reduce fire fuels in grassland areas. Adequate developed water sources and fencing as well as access roads to bring and remove livestock from the site are all needed. Livestock can be managed to remove grass and herbaceous cover without impacting creek areas through limitations to the number of animals and the season of grazing.

Expansion and Normalization of Prescribed Burning.
While several large fuel reduction projects have been done there is a great need to complete many more in the UVGBW. Climate change will greatly increase the need for increased vegetation management and continual maintenance of fuel reduction areas. Prescribed burning offers a relatively low-cost method to reduce and maintain low fuel loads in the UVGBW.

Prescribed or controlled burning is a cost-efficient method to control and maintain fuel loads in conifer and hardwood (oak woodland) forest as well as grasslands. Prescribed burning requires a detailed plan for each unit of land. These units can be defined in the UVGBW using ownership, topography and vegetation types. Then within this large unit a number of smaller or project burns can be defined. Burn plans both for large land units and smaller project burns should always be prepared by personnel with experience directing controlled burns. The unit plan should include the following sections:

1. Objectives of the burn plan
Objectives for using controlled burns can include reducing fuel and fire hazards, restoring fire to the landscape and ecosystem, preparing the seedbed for forest tree planting, reducing understory brush and others. For a dense forest the objective may also include mechanical or hand removal of small trees and brush prior to burning.

2. Description of the vegetation
This section describes the types of vegetation, species present, density and size classes for a variety of locations.

3. Fuel conditions
This section describes the understory conditions, kinds of fuels, amount of fuels, size classes and proportion of dead to living plants for each vegetation type. For example, for a conifer or hardwood forest type the number and size class of living trees, depth of litter or duff, and the density of underbrush and small trees and the size class of each would be described. For grassland or chaparral all the plant material is considered fuel and would be described.

4. Topography
This section describes the steepness and direction of slopes as these features determine and the direction the fire will burn. A topographic map can be used for this analysis. Surprisingly, flat areas of forest can be the most difficult to manage whereas burning on slopes offer greater control of the fire.

5. Wind patterns
Wind information is needed for all seasons and on a daily basis to understand how the fire will behave. A nearby weather station should have basic information that can be bolstered with local knowledge.

6. Size and shape of burn

This evaluation uses the information from items 1-5 and defines the smaller project areas within the unit that will burn in a reasonable time. Creeks, recent burns and roads may serve as boundaries to burn areas.

7. Prescriptions for burning

The fire needs to effectively implement the project objectives and be managed without an escape. The season for the burn will vary (spring/fall/winter) depending on weather patterns for the site and fuel conditions. For example, deep duff/litter will burn for many months and require monitoring. If burned in the fall winter rains will put the fire out and reduce the time and expense of the fire.

The size of project burns will depend on the initial fuel load. Large fuel loads may require a more complex initial burn and easier follow-up burns.

The prescription will not only define the season and size of the project burn but also the constraints needed should be well defined. All prescriptions should be done by qualified experience personnel.

8. Burn techniques

There are different techniques for fires on various types of terrain:

- Level area fires need to burn against a steady breeze to move at a reasonable rate and not scorch trees.
- Backing fires are typically set to burn downslopes or on level site and move slowly. This type of fire is best in heavy fuel loads.
- Head fires burn upslope or on level ground with the wind and can move fast.
- Flanking fires spread at right angles to the slope or wind. These can be used next to a backing fire for increased control.
- Circular, center and spot burning are additional techniques used.

9. Preparations for the burn

A great deal of public education will be needed so the community understands what will be done, where and for how long. The precautions included in the burn should be emphasized. Education of the public should be done by all the agencies involved and include many different media outlets and in both English and Spanish to reach the entire community.

Burn permits have to be acquired from CalFire and possibly the local air quality board and local fire districts.

All equipment should be avaible and in working order. An experienced burn boss should oversee all aspects of the burn. The number of crew members is determined by the size and complexity of the burn and be adequate to manage all aspects of the fire.

10. Patrolling the fire

Careful patrolling of burns is a requirement and may involve overnight patrols.

11. Recording burning conditions

Keeping records of the conditions before and during a burn can help to document the process should anything go wrong. Fuel moisture should be measured and weather conditions recorded at least once in the early afternoon but more favorably every 2 hours from 9 am to 6 pm.

12. Inspections
Following a burn, the area should be thoroughly inspected and any unexpected conditions recorded.

13. Monitoring
Following the burn, the site should at least be monitored and conditions noted for several years to 10 years following the burn. Quantitative monitoring may also be designed to answer specific ecological questions.

Controlled burns have a number of benefits beyond the reduction of fuel loads and reduction of wildfire risk. Controlled burns do not result in large erosion risks as wildfires do. The burning of understory and small trees provides for the release of nitrogen for use by the larger conifer and hardwood trees.

Table 46 lists the natural fire return intervals for different types of vegetation. Replacement fire severity is a crown fire that kills 75% of the trees. In the case of chaparral and grassland all fires are replacement fires. Surface or low fire severity affect the understory of the forest and would be the objective for prescribed burns in hardwood, redwood and conifer forests.

Chaparral is the most difficult vegetation type to burn as it is highly flammable and, like a grassland, the vegetation will burn completely. Given the large acreages of chaparral on the east side of the UVGBW prescribed burning of chaparral will be needed for reducing wildfire hazards and maintaining this ecosystem.

Table 46 shows a mean fire return interval in mixed chaparral of 50 years with a minimum interval of 30 years and a maximum interval of 125 years. These intervals allow the completely burned chaparral to adequately recover and withstand another replacement intensity fire in these time intervals. Montane chaparral which occurs in the UCGBW in smaller acreages than mixed chaparral has a fire return interval of 95 years. Using prescribed burns over these return periods will create a more biodiverse habitat and reduce fuel loading.

Figure 143 shows the surface or low fire intensity intervals from Table 46 for the forest types in the UVGBW and the replacement fire severity return intervals for mixed chaparral and grassland. Recently (since 2017) burned areas were removed from the map coverage.

Figure 144 shows the same fire return intervals but only for the high and very high fire hazard severity zones defined by CalFire. These areas should be considered the highest priority for a prescribed burn program. Areas with houses and structures (Figures 139 and 140), creeks and roads and topographic variability can be used to define burn units. For each unit a detailed prescribed burn plan should be completed with an implementation program. The best organizations to carry our such a program are the Mendocino County Fire Safe Council in collaboration with Mendocino County, BLM, private landowners and CalFire.

Limiting development in high and very high fire hazard severity zones
Much of the east and west sides of the Ukiah Valley are undeveloped. Limiting housing, winery, resort and other nonagricultural development in these areas will greatly reduce future damage and potential loss of life. Mendocino County should evaluate the zoning of these areas and develop options to reduce development over the long term

Table 46. Fire frequency intervals for various vegetation types in the UVGBW.

Vegetation type	Fire severity	Fire regime characteristic			
		Percent of fires	**Mean interval in years**	**Minimum interval in years**	**Maximum interval in years**
Annual grassland	replacement	100%	2	1	3
Mixed chaparral	replacement	100%	50	30	125
Montane chaparral	replacement mixed	34% 66%	95 50		
Oak woodland	replacement mixed surface or low	8% 2% 91%	120 500 10		
Ponderosa pine	replacement mixed surface or low	5% 17% 78%	200 60 13		
Ca mixed evergreen	replacement mixed surface or low	10% 58% 32%	140 25 45	65 10 7	700 33
Coast redwood	replacement Surface or low	2% 98%	>1,000 20		
Mixed conifer north slopes	replacement mixed surface or low	5% 7% 88%	250 200 15	 10	 40
Mixed conifer south slopes	replacement mixed surface or low	4% 16% 80%	200 50 10		

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

From: US Forest Service Fire Effect Information System. 2023 LANDFIRE Rapid Assessment Vegetation Models. Fire regimes of the conterminous United States.
https://www.fs.usda.gov/database/feis/fire_regime_table/fire_regime_table.html#California

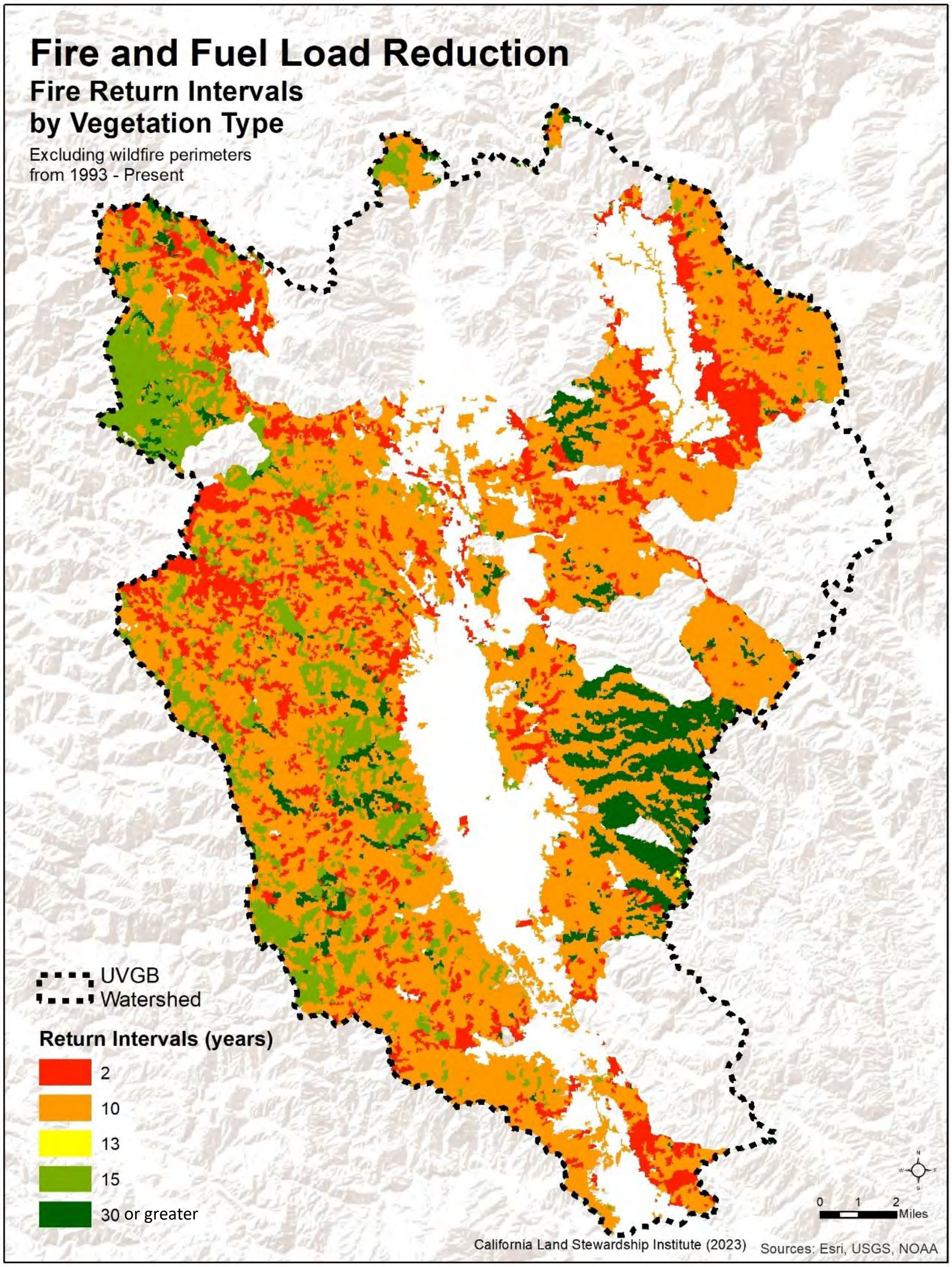


Figure 143. Natural fire return intervals for areas that have not burned since 1993.

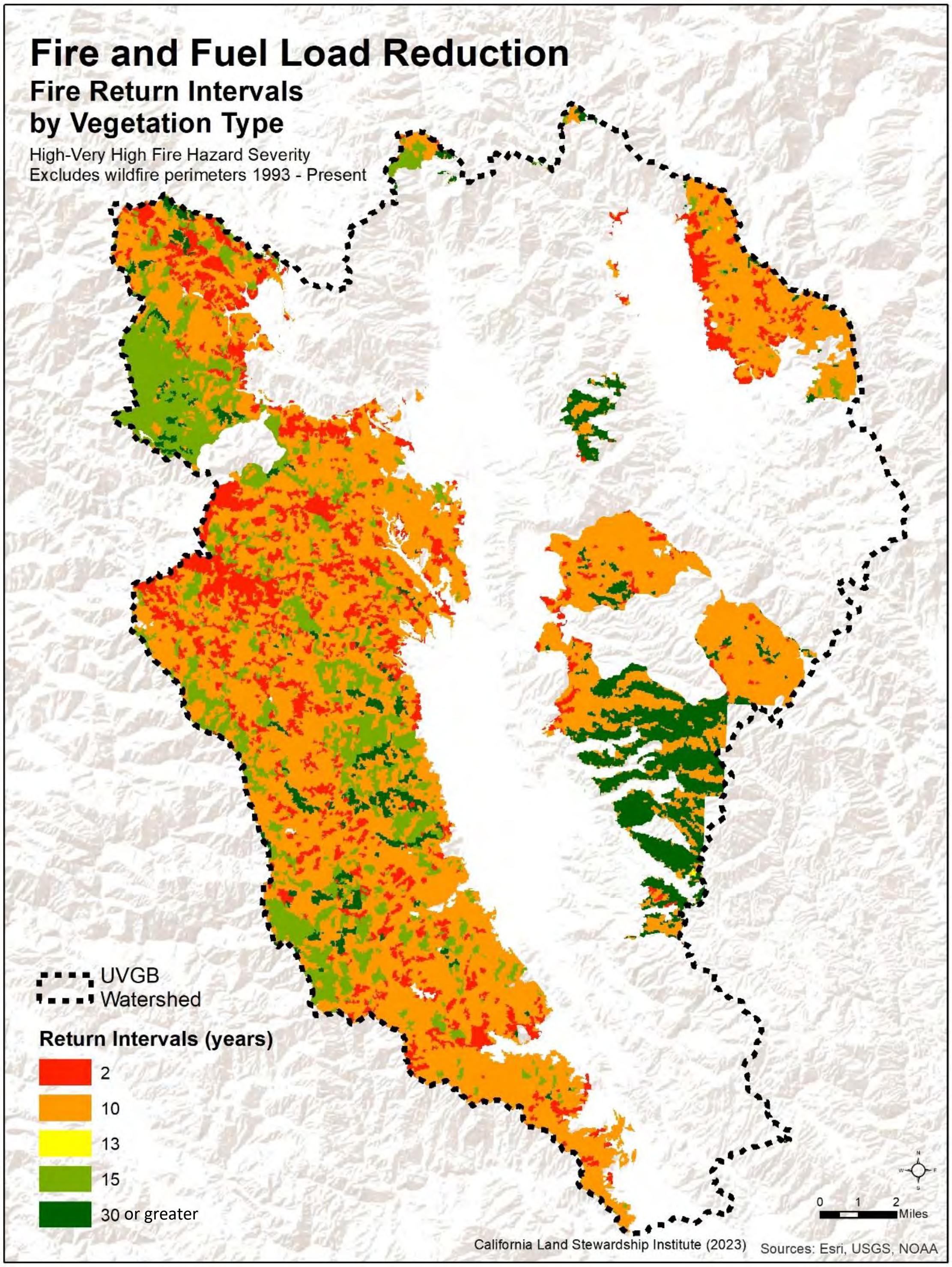


Figure 144. Natural fire return intervals for areas that have not burned since 1993 and are located in CalFire very high and high fire hazard severity zones.

IV. AGRICULTURAL WATER SUPPLY

INTRODUCTION

CLSI met with farmers and ranchers as described in subtask 4e of the grant work plan to determine the types of projects that were most needed by these groups. The issue identified was the future of water supply both surface and groundwater in the Ukiah Valley especially with proposed changes to the Potter Valley Project (PVP). Growers were concerned with how restrictions on surface water supply on the mainstem Russian River could be addressed and how these restrictions would affect the groundwater supply and new regulations under the Groundwater Sustainability Plan (GSP). CLSI completed an analysis of water use reporting data from the State Water Resources Control Board (SWRCB), water rights, possible scenarios for changes in the PVP to devise projects to increase reliability of agricultural water supplies.

HISTORIC WATER SUPPLY DEVELOPMENT

To account for the seasonal and inter-annual variability of precipitation, water demands in the Russian River basin are met with both large centralized water projects and smaller diversions.

Large Water Projects

Private companies and the U. S. Army Corps of Engineers (USACE) constructed several large water projects in the Russian and Eel River watersheds for hydroelectricity, water supply, and flood control.

The Snow Mountain Water and Power Company constructed the first major project in 1908, with the Cape Horn Dam that impounded and diverted the upper main stem Eel River through a transbasin tunnel to Potter Valley, the headwaters of the East Fork of the Russian River. The primary goal of the project was generating electricity for Ukiah, but the diversion also augmented flow in the main stem Russian River during the winter. During the summer dry season little flow came through the tunnel. In 1922 operators of the tunnel (Potter Valley Project) constructed the larger Scott Dam 12 miles upstream of the Cape Horn Dam to provide year-round hydroelectric power. Scott Dam created Lake Pillsbury which has a storage capacity of 74,993 acre-feet. The average annual runoff at this point in the Eel River is 400,000 acre-feet (AF). Water stored in Lake Pillsbury is released to the Cape Horn Dam and then flows into the power tunnel and the Russian River. Between 1930 and 1940 157 cfs flowed through the tunnel between April and October (Shapovalov 1944). In 1930 ownership of the project was transferred to the Pacific Gas and Electric Company (PG&E). The release of Eel River water into the Russian River has spurred crop irrigation and urbanization in the Russian River over the past 100 years (Figure 145).

The Federal Energy Regulatory Commission (FERC) relicensed the Potter Valley Project in 1983. Part of the new license was Article 39, which required a 10-year study to determine the impact of new project flows on salmon and steelhead and to adjust flows if needed.

A Fisheries Review Group (FRG) was formed to evaluate Eel River fisheries. The FRG consisted of scientists from PG&E, U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Wildlife (CDFW), and National Marine Fisheries Service (NMFS). In March of 1998, following 10 years of study, the FRG completed its findings, and a report was provided to FERC recommending flow modifications. FERC then began its National Environmental Policy Act (NEPA) process. A draft EIS was completed by FERC in February 1999. After further public meetings, many comments, additional proposed alternatives, and new modeling inputs, FERC issued its final EIS in May 2000.

The FERC recommendation was based predominately on the recommendations of the FRG. The resulting complex flow regimes were calculated in such a way as to make the project nearly invisible to the environment by releasing flows below Cape Horn Dam to mimic natural flows in the Eel River as closely as possible. NMFS produced a Biological Opinion (BO), a requirement of the Endangered Species Act. The Reasonable and Prudent Alternative (RPA) of the BO was submitted to FERC in November 2002. FERC issued a Final Order Amending the License for the Project on January 28, 2004 which expires in 2022.

Between 1922 and 1983, Potter Valley Project (PVP) diversions averaged 154,000 AF/yr. From 1983 and 2006, diversions averaged approximately 131,000 AF/yr. In 2006, PG&E concluded that its amended FERC license did not authorize that level of diversions and between 2007 and 2013 diversions have averaged 72,000 AF/yr. (SCWA 2012).

A series of floods in the 1930s and 40s, a growing demand for urban and agricultural water supply and the need for stream flows for recreational uses in the lower river prompted the construction of the Coyote Dam on the East Fork Russian River in 1959 creating Lake Mendocino. The Coyote Dam was to be constructed in two phases. To date only the first phase has been completed. The maximum storage capacity of Lake Mendocino is 122,000 AF. Lake Mendocino has lost approximately 7000 AF of storage area due to sedimentation (SCWA 2015). Dam operations reduce peak flood flows and prolong high flows in the winter as well as augment summer baseflows (Steiner 1996). Six large collector wells are operated by SCWA near the Wohler Narrows on the Russian River to provide water supply for Santa Rosa and other nearby municipalities, including some out of basin transfers to Marin and southern Sonoma Counties.

Management of Coyote Dam operations is split between two agencies – the US Army Corps of Engineers (USACE) and the Sonoma Water. The USACE manages the lake when water levels are in the flood pool (111,000 to 122,500 AF). Sonoma Water manages the lake when the water level is in the water supply pool (68,500 to 111,000 AF). In recent years operation of Lake Mendocino has changed to allow more water to remain in the water supply pool while maintaining adequate storage for flood inflows. This change uses updated forecasting and monitoring systems (Forecast Informed Reservoir Operations or FIRO). Lake Mendocino was the first UCACE reservoir to use the FIRO system.

The PVP augments Russian River flows when water is released from Coyote Dam during dry periods and accounts for an average of 10% of the annual discharge at Healdsburg, but are up to 50% of summer and fall flows (Grantham et al. 2008). The PVP significantly changes summer flows in the Russian River (Figure 145). Warmer water and elevated summer flow velocities have significantly degraded the habitat quality of the main stem for salmonid species (Steiner 1996). This additional water has allowed for issuance of numerous water rights along the river and from Lake Mendocino.

Sonoma Water (2015) released a report analyzing the reliability of Lake Mendocino as a water supply. An Excel spreadsheet model was used in conjunction with USGS current and future hydrology inputs to evaluate flows into Lake Mendocino and river flows at seven locations on a monthly time step. Eight model scenarios were developed including current conditions, the current system without the PVP, current hydrology inputs with 2045 estimated municipal and agricultural demands, and future hydrology inputs with climate change and 2045 estimated municipal and agricultural demands. The study concluded that without the PVP, Lake Mendocino would be dry 60% of the time.

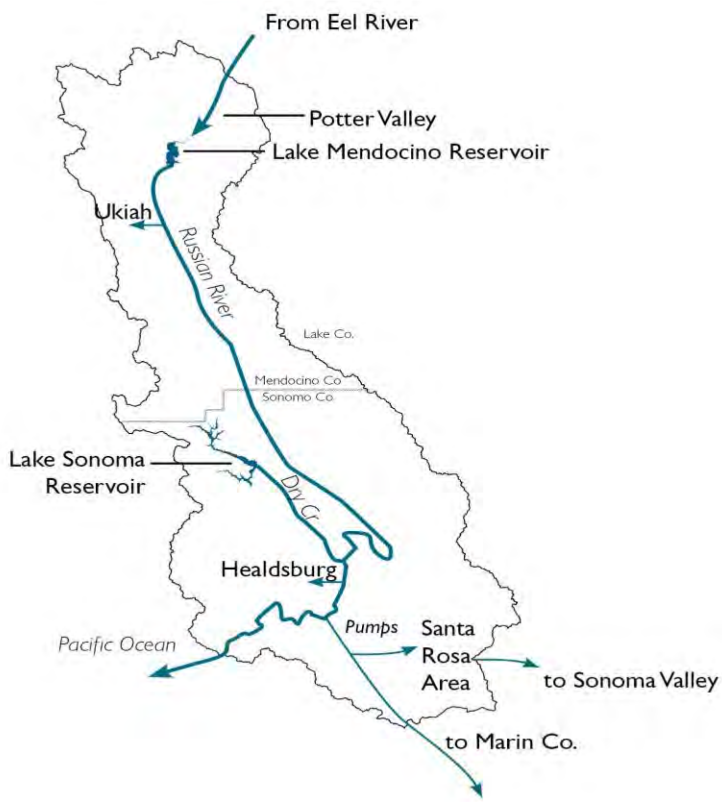


Figure 145. Large water supply facilities and transmission system in the Russian River watershed. From: Walls 2013

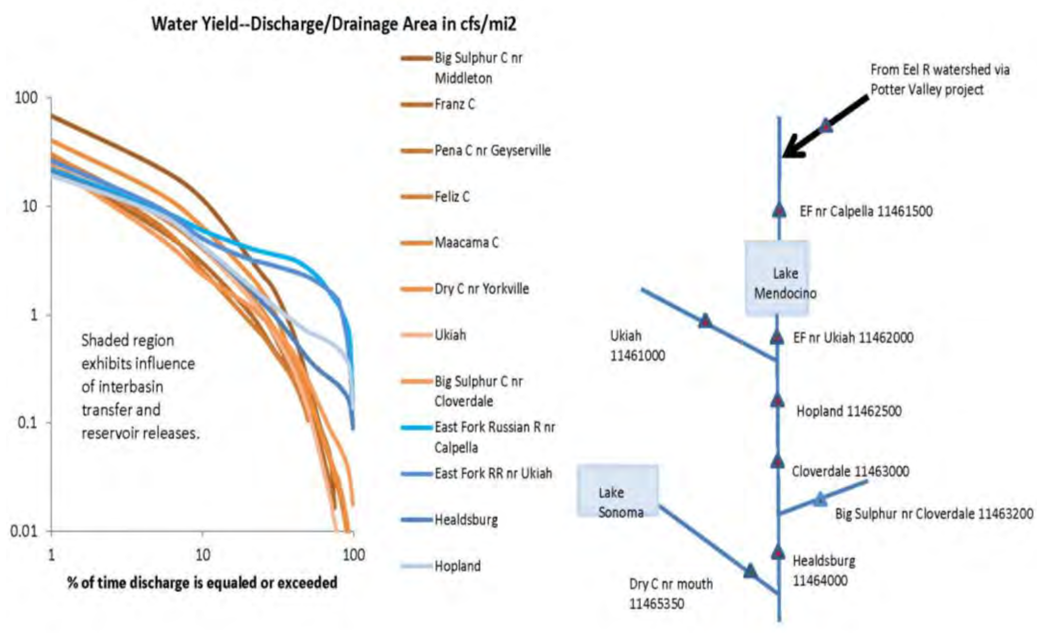


Figure 146. This plot shows the influence of the Potter Valley Project and releases from Lake Mendocino on dry season flows in the Russian River. Duration curves for four gages along the Russian River main stem (blue curves) show that these sites have dry season water yields that are an order of magnitude greater that the other gages on tributary streams. Schematic on right shows relative locations and station numbers of stream flow gages. From: Shields 2012.

Elimination of the PVP has long been a campaign by several local environmental groups and several statewide salmonid organizations. Lake Pillsbury created by Scott Dam restricts access by salmonids to approximately 349 sq. miles of the upper main stem Eel River or about 8% of the Eel River watershed. Two federally-listed threatened species – Chinook salmon and steelhead trout and one federally listed endangered species- Coho salmon have experienced loss of rearing and spawning habitat due to large scale disturbance in the Eel River watershed. These disturbances include: large scale destructive logging and road building in the 1950-70s, a flood of record in 1964 with massive sediment inputs into many areas of the river and its tributaries, loss of summer water flows to illegal cannabis growing, introduction of invasive predatory fish, and installation of dams and diversion of water out of the basin. Populations of steelhead trout and Chinook salmon plummeted affecting commercial and sportfishing. It is possible to construct a fish ladder around Scott Dam, but this has not been a popular alternative to dam removal in the environmental community. Removal of Scott Dam will affect at least 600,000 people in the Russian River watershed and Marin County who will lose a portion of their water supply.

WATER USES IN THE WATERSHED OF THE UKIAH VALLEY GROUNDWATER BASIN

Water is used by agriculture for frost control and irrigation for crops and water for livestock. Each grower has separate water rights. There is one water retailer the Mendocino County Russian River Flood Control and Water Conservation District (RRFC) that supplies water to both agricultural and municipal users. The primary crop in the watershed is primarily winegrapes with smaller acres of pears, alfalfa, irrigated pasture and legal cannabis. Table 47 lists the typical water demand for each crop.

The majority of agricultural crops in the Ukiah Valley use irrigation methods that are adapted to the Mediterranean climate of the region The dry summer months have high temperatures; the irrigation methods used limit evaporation to conserve water. Winegrapes use drip irrigation, a technology developed to grow crops in the Middle East. Winegrape growers also practice deficit irrigation where less water is applied than needed by the vine in order to stress the plant to produce unique flavors in the fruit and ultimately in the wine. Pears use low flow sprinklers. These methods supply water needed by the plants with no runoff and little infiltration beyond the root zone of the crop plants. Alfalfa is typically flood or furrow irrigated. This method can be used to evenly apply water across a field with a minimum of return flows and some infiltration into groundwater. Cannabis may use drip irrigation, sprinklers or other types of irrigation.

The City of Ukiah is the largest urban water supplier in the basin. There are several other water districts that also provide primarily municipal water supply – Willow County Water District, Millview County Water District, Calpella County Water District, Redwood Valley County Water District, Regina Water and Russian River Estates. The Mendocino County Russian River Flood Control and Water Conservation District (RRFC) sells water to several of these districts as well as supplying water directly to agricultural diverters.

Table 47. Agricultural Crops in Ukiah Valley

Crop	Estimated Acres	Annual Irrigation Water Use	Other Water Use
Winegrapes	14,212	0.5-0.8 AF/acre/year	Frost control varies greatly each year
Pears	1867	2.5-3.0 AF/acre/year	
Alfalfa Hay	3144	3-3.5 AF/acre/year	
Legal Cannabis	290*	4-6 AF/acre/year	

*County wide acreage; From McGourty et al 2020, Drotleff, Laura 2021

WATER CONSERVATION IN AGRICULTURE

Most growers in Ukiah Valley regularly conserve water in their irrigation practices. Water conservation practices apply to the type of irrigation used, how decisions to irrigate are made, how efficient the irrigation system is in applying the water and soil and plant management practices.

Certification of Water Conservation Practices

Most of the farms in the Ukiah Valley are in the Fish Friendly Farming Certification Program (FFF). This certification requires that water conservation and efficiency management measures are implemented by growers. Table 48 lists the FFF required water conservation and efficiency management measures. The management measures in Table 48 address the choice of irrigation system, how irrigation decisions are made, how the system is maintained and upgraded and how soil is managed to retain moisture (Marcus 1999).

Additionally, FFF documents all sources of water used for both frost control and irrigation including surface water, groundwater, municipal recycled water, winery wastewater and purchased water as well as all conservation and efficiency measures. For each surface water source, FFF documents the acres irrigated, storage facilities, water rights, season, source and amount of each diversion, measurement devices used for each water source (SB 88 compliant) and measurement devices used for bypass flows. All stream and river diversions are required to be metered and be in compliance with State water rights. Fish screens are also required to protect endangered salmonids. For wells FFF maps the location of active, domestic and abandoned wells on every site and document the well production in gallons/minute, total depth, depth of first screen, proximity to streams, protection from polluted runoff (backflow protection, proximity to chemical storage and mixing sites), acres irrigated from each well, if well fills a storage feature, if there are water rights as for an underflow well.

Soil Moisture Monitoring Systems

An important feature of determining when to irrigate is to evaluate the level of moisture already present in the soil. There are a number of ways soil moisture can be monitored.

Soil Texture

For a simple test of soil moisture conditions dig a hole for each soil type and pick up a handful of soil at the depth of the root zone (Table 48).

Table 48. Soil moisture characteristics indicating irrigation is needed

Soil Texture	A handful of soil will
Coarse	Tend to stick together slightly but will not form a ball
Medium	Be crumbly but will form a ball
Fine	Be pliable and will form a ball

Soil Moisture Monitoring

Soil moisture monitoring includes continuous monitoring and instantaneous monitoring. There are a number of different types of devices.

Tensiometers indirectly measure soil tension. They measure continuously and indicate the soil tension in the root zone. As wet soil dries soil-water tension or suction increases. This change is measured by the tensiometer. Typically, several tensiometers are installed at different depths and each must be maintained frequently.

Electrical Resistance Blocks (gypsum blocks) are installed permanently at various depths in the root zone. They have wires attached and measure electrical resistance in the block. The readings are transmitted to a datalogger. The data shows when soil is dry and will show if irrigation water reaches the various depths of the blocks. Sets of 3-6 blocks and a datalogger are installed in the soil in an area representative of soil conditions in the field. Two stations per 40 acres are recommended although additional stations can be installed in unusual soil conditions.

Dielectric Soil Moisture Sensors measure the dielectric constant of the soil, a soil property highly dependent on moisture content. Change in soil moisture content causes a significant change in the dielectric constant. Dielectric soil moisture sensors include capacitance instruments and TDR sensors. These sensors record soil moisture from 1-4 inches from the instrument and record continuously.

Neutron Moisture Meters (neutron probes) use radioactive material to measure soil moisture. The neutron probe has a pellet of Americium 241/Beryllium that emits high energy neutrons and measures hydrogen atoms in the soil. Moisture is the primary source of hydrogen atoms in the soil. Permanent tubes are installed down to the root depth in the field and the neutron probe is placed in the tube to take a reading. A minimum of two sites per 40 acres is recommended. More sites may be needed in sites with variable soil types. This type of measurement is not continuous, but instead instantaneous and requires a certified technician.

Plant-based Measurements

Plant-based measurements of leaf water potential are done using a pressure chamber. A leaf or petiole is placed inside the chamber and pressurized gas is added to the chamber. When the pressure increases enough to force liquid out of the xylem this pressure reading can be used to measure the water potential of the sample. Samples are taken at pre-dawn when the plant is not transpiring. There are also sap flow sensors and porometers that measure transpiration processes in plants and can be used to inform irrigation needs.

Use of ET calculations, soil and plant moisture measurements assist the grower in deciding the timing for irrigation and the approximate quantity of water needed.

<u>Irrigation System Efficiency</u>

Irrigation efficiency is defined as the ratio of the amount of water beneficially used to the amount of water applied. There are irrigation efficiency/water conservation practices that are applicable to all types of irrigation and practices specific to certain types of irrigation.

Determining Applied Water Amounts

It is important to know if the irrigation system is applying the amount of water required by the crop and therefore has a high level of efficiency. McGourty et al (2020) reviewed water use in Ukiah Valley and found the efficiency of irrigation systems at 88% in most locations. This is an excellent level of efficiency. The methods listed below are often used by growers.

Flow Meters. The easiest method to evaluate the efficiency of the irrigation system is to install a flow meter in the irrigation pipeline. This approach can be used for drip and sprinkler irrigation systems as well as flood irrigation systems that use a pipeline to bring the water to the field/orchard/vineyard. Using a recording flow meter will also fulfill SB88 water use reporting requirements. There are several types of flow meters.

Propeller meters consist of a propeller in the pipe that is moved by water flow. These meters are installed in a section of pipe that is straight and unobstructed for 8-10 times the pipe diameter upstream and 4-6 times the pipe diameter downstream from the meter. This type of meter can entangle debris in irrigation water.

Magnetic meters do not create an obstruction in the pipe and require a section of pipe that is straight and unobstructed for 3-5 times the pipe diameter up and downstream of the meter. These meters require a power source.

Ultrasonic meters use ultrasonic pulses that bounce off particles in the water. The meter is installed in a section of pipe that is straight and unobstructed for 8-10 times the pipe diameter upstream and 4-6 times the pipe diameter downstream of the meter. This meter requires particles in the water to work and may not be appropriate for high quality groundwater.

Turbine meters use a rotor blade in the pipe and are installed in a section of pipe that is straight and unobstructed for 10 times the pipe diameter upstream and 6 times the pipe diameter downstream of the meter.

Table 48. Water Conservation Measures Required in FFF

Drip irrigation practices are used and the system is checked regularly for leaks and water efficiency to reduce losses.
Irrigation system has a uniformity test done every other year and repairs are made to improve uniformity
Soil moisture/plant condition is monitored to determine irrigation needs.
Frost water conservation measures are installed.
Use non-water or waste/recycled water for frost control.
Water diversions are measured or metered
Fish screens are installed on all direct diversions (if applicable).
Winery wastewater/recycled water is used for irrigation (if applicable).
Water is purchased from irrigation district or other entity (if applicable).
Water right permit/license has been issued (if applicable).
Season of diversion/impoundment is Dec 15-March 31.
Winter diversion (December 15-March 31) into off-channel reservoir.
Winter cover crop use over entire vineyard floor and terraces by Oct. 15, use of a perennial cover crop, or if harvest is later than Oct. 15, install erosion control practices by Oct. 15, then seed cover crop post harvest.
No tilling in the vineyard until after end of rainy season and no sooner than April 1. Mowing to reduce frost damage is okay.

TYPES OF WATER SUPPLY

Several different types of water rights are used for agricultural and municipal supply. The State Water Resources Control Board oversees and regulates all water rights in California.

Riparian Water Rights

Riparian water rights are the right to divert water from creeks and rivers where the property is adjacent to the channel and the water is used only on the adjacent property. Water obtained through riparian diversion can be stored in a regulatory pond for no more than 30 days. Riparian diverters are required to file notices of their water use with the State Water Resources Control Board (SWRCB) annually.

Appropriative Water Rights

Appropriative water rights are issued by the State Water Resources Control Board, in accordance with the California Water Code and other state laws, through a permit and license process. Appropriative rights provide for longer-term (greater that 30 days) storage of a certain amount of water diverted at a defined location and used for certain beneficial purposes. Diversion periods and volumes are typically defined as part of the water right. Appropriative water rights usually take several steps –completion of an application, issuance of a permit to install the storage facility and divert water into it and issuance of the water right, or license, after it is demonstrated that all the stored water is being put to beneficial use in the irrigation of crops. When a grower applies to appropriate water, the application must specify where the water will be used, period of diversion, purpose for which the water will be used, and point and type of diversion. The date of first appropriation and the estimated size of the completed project are also critical to establishing an appropriator’s seniority on the stream and the volume of water to which the right applies. Many existing storage reservoirs have a water right permit, but not a licensed water right. Some reservoirs and diversions may not have a permit and are still in the permit application process. Appropriative right holders must report their water use in monthly increments on an annual basis.

Contract Surface Water Supply

The Mendocino County Russian River Flood Control and Water Conservation District (RRFC) sells water to agricultural diverters. The RRFC holds an appropriative water right to approximately 8,000 AF of water stored in Lake Mendocino. This water is sold via contract to both agricultural and municipal users. The RRFC allows mainstem diverters to take water from the Russian River and all diverters have meters on their diversions that are read by the RRFC.

Groundwater

Many surface water users also have wells and use groundwater. There is no inventory of wells or groundwater use in Ukiah Valley and no water rights are issued to the landowner with a well.

Recycled Water

The City of Ukiah provides recycled municipal water to farmers along its distribution lines on the western side of the Russian River. In 2022 the City provided 883.23 AF of recycled water to agriculture and additional water to parks.

Water Right Reporting

All surface water right holders, both public and private, are required to report their water use to the State Water Resources Control Board (SWRCB). CLSI collected the reporting data for all diversions on the mainstem Russian River from the confluence of the East and West Forks of the Russian river to the Hopland gage. We worked with the staff of SWRCB to evaluate and sort the reporting data (SWRCB 2020) into municipal water uses and agriculture water uses. The primary period of interest is the summer months of May to October when the flows in the Russian River are primarily made up of release from Lake Mendocino which holds water from the PVP and local runoff.

The data collected is for 2017-2019 encompassing a dry year, normal year and wet year. Table 49 summarizes by month all mainstem Russian River diversion data for agricultural uses showing a range of 4693 AF to 6357 AF of water use during the May to October irrigation season for an average of 5496.75 AF.

Table 50 outlines the water diversion for municipal use for the 2017-2019 period totaled by month. A range of 6126 AF to 7107 AF for the May to October season for an average of 4686.35 AF. Municipal uses are higher during the spring and summer due to outdoor watering.

Figures 147-149 depict the locations of all the agricultural diversion along the mainstem Russian River. The numbers refer to the parcels associated with the owner of the water right so there may be a number of locations with the same number. Appendix 6 lists the owners using these numbers. Each individual owner/company has one number but may have numerous separate sites and water rights.

We further evaluated the water reporting by identifying the type of water rights associated with each site. Many agricultural owners have appropriative rights, riparian rights and a contract with RRFC. They may also have groundwater wells.

Typically, a grower will use riparian rights in spring when natural runoff makes a large proportion of river flows. During spring winegrape growers use sprinkler applications of water on freezing nights to avoid having new buds freeze and die and thus lose their crop (Table 51). Riparian diverters cannot divert from the Russian River if natural flows are not present as in summer and fall. An indicator of when natural flow in the mainstem river end are flows at the West Fork Russian River gage managed by the US Army Corps of Engineers.

Appropriative right permits typically have a season of diversion listed. The SWRCB issued many appropriative rights along the Russian River based upon the abandoned water that went through the PVP tunnel for power production and was released into the Russian River from Lake Mendocino. Appropriative water rights are used throughout the irrigation season.

Table 52 breaks down the reported amounts between riparian, individual appropriative water rights and RRFC contract water (based on an appropriative right). Table 53 shows reported water diversions under appropriative water rights including RRFC contracts. Table 54 shows reported water diverted under riparian water rights. The figures show an average of all the water rights types of 5496 AF for the May-October period. Table 51 shows reported water use for frost control from March 15-May 15 as an average of 149.5 AF over 7 years. As can be seen in Table 51 frost water use varies significantly from year to year. Adding frost water use to irrigation season water use shows an average of 5646 AF of surface water for agricultural use per year.

The Groundwater Sustainability Plan (GSP) estimated groundwater pumping for agriculture between 4429-4630 AF/year. All of these estimates are based on acres of farmland and per acre crop water use. The majority of agricultural groundwater use occurs between May and Oct. Municipal pumping is estimated at 1233-2130 AF/year. The safe yield of the Ukiah groundwater basin is estimated at 6500 AF/year.

RECENT CHANGES TO THE POTTER VALLEY PROJECT (PVP)

PG&E began the process of extending the FERC license for the PVP in 2017 through consultations with various agencies and stakeholders. However, in 2018 PG&E announced their desire to sell the project and set up a process to submit a bid. A group of agencies and stakeholders in Sonoma and Mendocino began meeting in order to consider purchase, but could not reach agreement on future actions for the project. No one submitted a bid to purchase the PVP. In 2019 PG&E announced it would abandon the PVP. In April 2022 FERC provided notice to PG&E that it could operate the PVP on a year-to-year license and in May 2022 FERC requested a surrender plan and schedule for the PVP from PG&E. In July 2022 PG&E submitted a brief surrender plan and schedule to FERC and stated that 30 months (Jan 2025) after FERC approval it would file a decommissioning plan. The surrender and decommissioning plan would address removal of both the Cape Horn and Scott dams, removal of the diversion works and the powerhouse.

In 2023 Sonoma Water, Sonoma County, the Mendocino County Inland Water and Power Commission and the Round Valley Indian Tribe formed a joint powers authority named the Eel Russian Project Authority (ERPA) for the purposes of taking over portions of the PVP such as the diversion tunnel and install a new water diversion works. The diversion would direct flows during winter into the tunnel and into Lake Mendocino. The original diversion works was gravity powered, but the new diversion works may consist of large diesel pumps. Part of the acquisition of the diversion and tunnel will include the water rights associated with the project which would also be purchased from PG&E.

Table 49. Reported Agricultural Water Use Mainstem Russian River

	YEAR			
MONTH	**2017**	**2018**	**2019**	**AVERAGE**
MAY	477.26	460.21	325.16	420.88
JUNE	1,140.54	1,194.10	744.03	1,026.22
JULY	1,862.91	1,430.38	1,201.48	1,498.25
AUGUST	1,381.13	1,206.84	1,234.25	1,274.07
SEPTEMBER	1,058.60	806.60	917.80	927.67
OCTOBER	436.44	342.55	269.97	349.66
TOTALS	**6,356.88**	**5,440.68**	**4,692.68**	**5,496.75**

Table 50. Reported Municipal Water Use Mainstem Russian River

	YEAR			
MONTH	**2017**	**2018**	**2019**	**AVERAGE**
MAY	522.99	534.37	423.48	**493.61**
JUNE	823.15	870.11	641.49	**778.25**
JULY	1037.13	1089.05	900.34	**1008.84**
AUGUST	1191.39	1131.97	902.85	**1075.40**
SEPTEMBER	649.45	944.49	702.69	**765.54**
OCTOBER	638.91	519.01	536.20	**564.71**
TOTALS	**6880.02**	**7106.99**	**6126.05**	**4686.35**

Surplus water deliveries from Lake Mendocino to Redwood Valley are not included

Table 51. Summary of Reported Mainstem Frost Diversions

Year	**Total Frost Water Use All Diverters in Acre-Feet**	**Frost Water Use in May Already in Water Rights Reporting Data**	**Corrected Frost Water Use All Diverters in Acre-Feet**
2017	45.2	0	45.2
2018	74.1	0	74.1
2019	0	0	0.0
2020	331	-6.46	324.5
2021	126.4	0	126.4
2022	450.4	-128	322.4
2023	154.4	-0.63	153.8
Total	1181.5	-135.09	1046.4
average per year	168.8		**149.5**

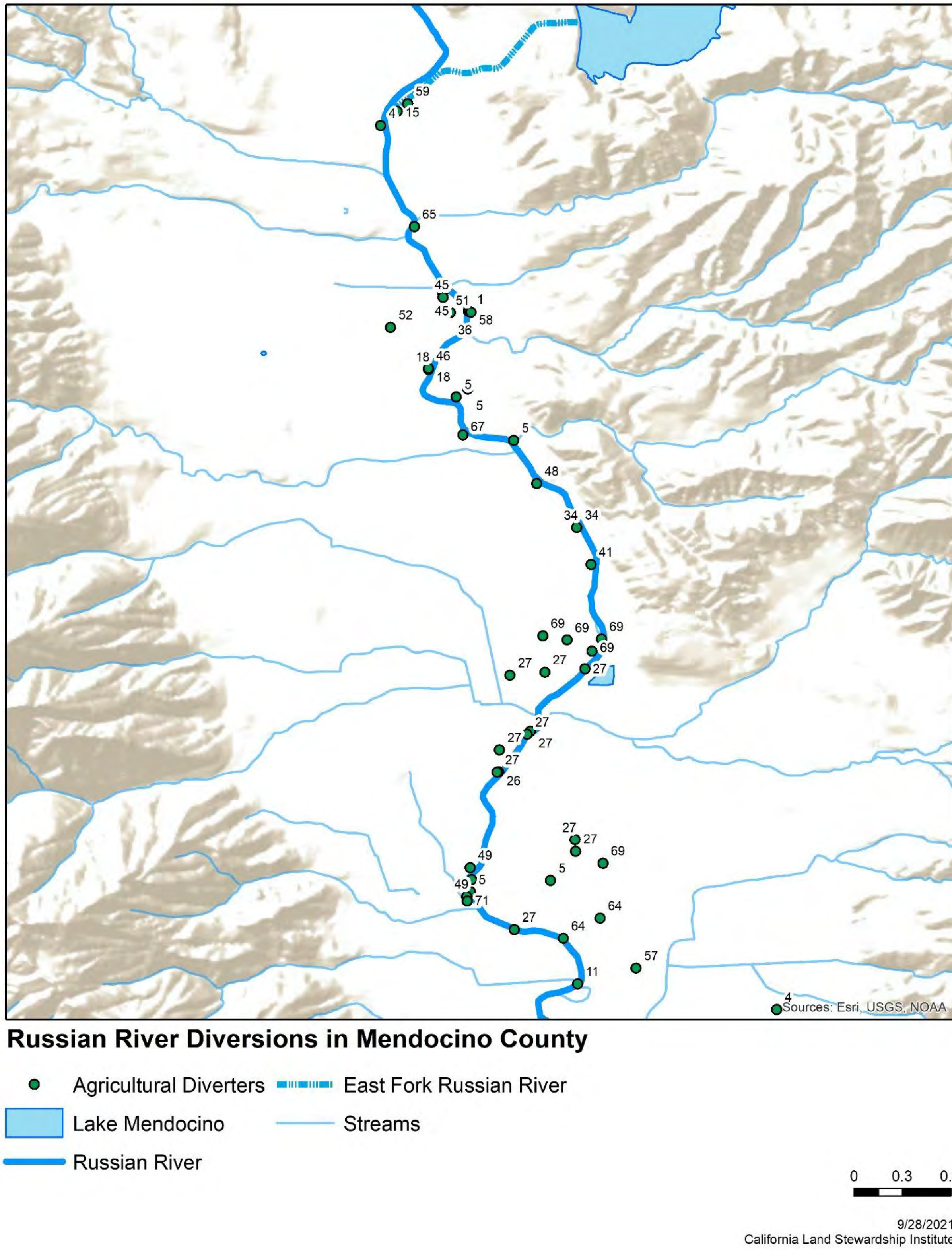


Figure 147. Location of surface water diversions along northern mainstem of Russian River

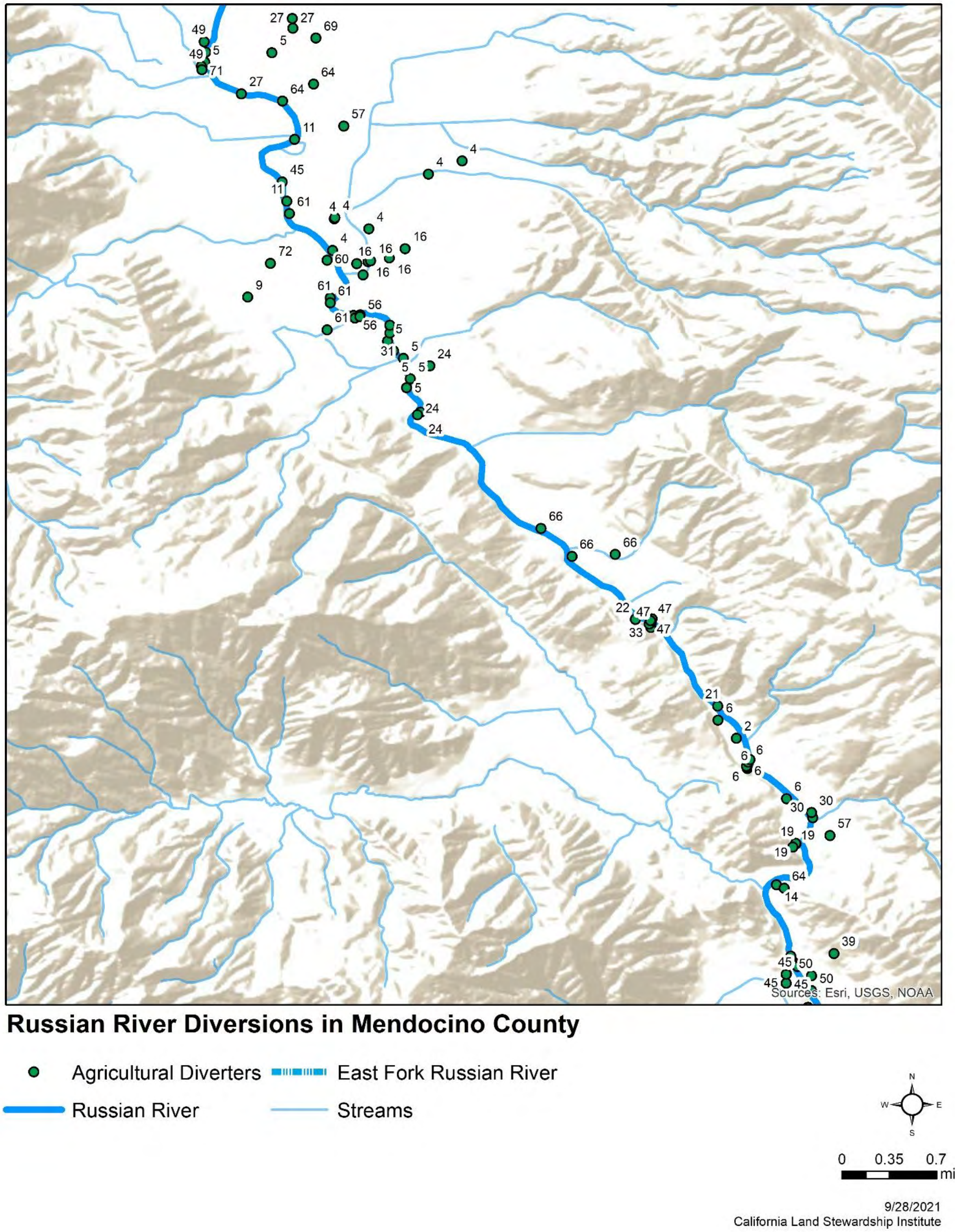


Figure 148. Location of surface water diversions along middle mainstem of Russian River

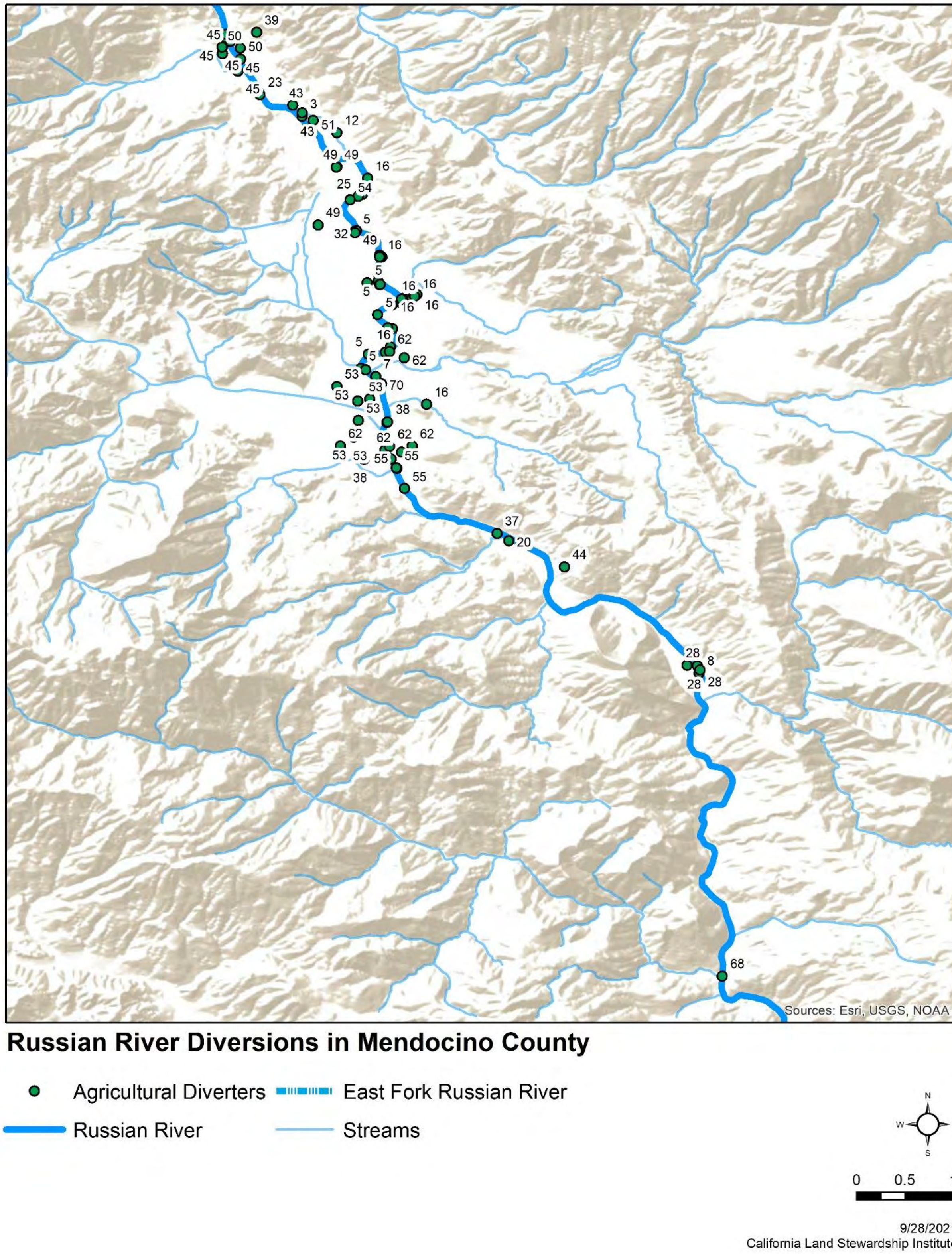


Figure 149. Location of surface water diversions along south mainstem of Russian River

Table 52. Reported Agricultural Water Diversions along Mainstem Russian River by Water Right Type

WATER RIGHT TYPE	2017	2018	2019	AVERAGE
APPROPRIATIVE	3659.5	3158.3	2535.1	3117.6
CONTRACT (RRFC)	2011.8	1736.0	1467.4	1738.4
OTHER (STOCK POND)	1.2	3.1	3.1	2.5
RIPARIAN	684.4	543.3	687.1	638.3
TOTAL	**6356.9**	**5440.7**	**4692.7**	**5496.7**

Table 53. Agricultural Water Diverted under Appropriative Water Rights including contract supplies from RRFC in AF

MONTH	2017	2018	2019	AVERAGE
MAY	413.07	384.46	258.39	351.97
JUNE	1,010.29	1,108.25	646.12	921.55
JULY	1,639.82	1,230.96	1,056.28	1,309.02
AUGUST	1,234.95	1,121.05	1,056.89	1,137.63
SEPTEMBER	981.82	745.13	773.43	833.46
OCTOBER	391.35	304.38	211.41	302.38
TOTALS	**5,671.29**	**4,894.23**	**4,002.51**	**4,856.01**

Table 54. Agricultural Water Diverted under Riparian Water Rights in AF

MONTH	2017	2018	2019	AVERAGE
MAY	64.00	75.14	66.77	106.38
JUNE	129.95	84.85	96.56	113.93
JULY	222.78	198.62	144.38	220.82
AUGUST	145.98	85.29	176.64	228.88
SEPTEMBER	76.68	61.37	144.27	259.85
OCTOBER	44.99	38.07	58.46	342.72
TOTALS	**684.38**	**543.34**	**687.08**	**638.27**

The future of PVP diversion into the Russian River is not certain. If all PVP diversions are stopped it is unlikely there will be inadequate water supply in many years to fulfill appropriative rights for water stored in Lake Mendocino (SCWA 2015) let alone water rights along the Russian River downstream of the reservoir. Climate change predictions for the Ukiah Valley call for longer periods of drought and higher summer temperatures.

Currently there are negotiations between ERPA and PG&E for purchase of the water rights associated with the PVP. As currently envisioned this water right would be exercised in the winter when the Eel River water would flow through a new diversion works at the tunnel and into Potter Valley. A portion of this water would likely be stored in Lake Mendocino for use by Sonoma Water and RRFC. Another portion would likely be used by the Potter Valley Irrigation District and a third portion would likely be used for appropriative right holders on the mainstem Russian River. If the water from the Eel River is not diverted into the Russian River, remaining supplies will be inadequate for all uses. In this case the use of groundwater will greatly increase and possibly exceed the basin's safe yield.

AGRICULTURAL WATER INFRASTRUCTURE PROJECTS

Offstream Ponds

Currently the water supply infrastructure for agricultural diversions needs to be upgraded to allow each farm to divert the winter time new water. Each farm needs an off-stream pond to store water that is available during winter for summer irrigation.

In 2012 CLSI applied for a U.S. Department of Agriculture Agricultural Water Enhancement Program (AWEP) grant to build offstream ponds along the Russian River for growers in Mendocino, Sonoma and Napa counties. The ponds were a solution to the effects of water diversions for frost control on water levels along the Russian River. Since frost occurs at all locations at the same time numerous direct diversions from the Russian River can drop the water level and affect juvenile salmon. The offstream ponds allow for water to be diverted when freezing conditions are not occurring and stored for later use for frost control. Ponds allow for a rate of diversion that is slow and has less effect on juvenile salmonids. A fish screen is required on all diversions. A total of 20 ponds were built holding 424 AF. A total of 143 cfs of direct frost diversions were removed from affecting flows in the Russian River during frost events through the construction of the ponds (McGourty et al 2020).

CLSI reviewed the water rights for the mainstem diverters depicted in Figures 147-149 to determine the sites that already have an offstream pond and the sites that do not have a pond. We separated the no pond sites into those with appropriative rights (Figures 150-152), and those with contracts with RRFC (Figures 153-155) and those with riparian water rights (Figures 156-158). It should be noted that the same site may appear on more than one of these figures as the site has more than one type of water right and no pond.

Riparian rights do not allow for long-term water storage, but if these sites only have riparian rights the owner may need to seek a contract from the RRFC for summer diversion and will need a storage pond. Table 55 depicts the volumes diverted by water right type and with or without a storage pond. Table 56 lists the number of sites for each water right type that do not have an offstream pond. Duplicates were removed from the data for Table 56.

Table 55. Reported diversion volumes with and without storage ponds

	Reported Volume Diverted		
Water Right Type	2017	2018	2019
Appropriative			
Storage Pond	1478.70	1368.89	1257.99
No Storage Pond	2180.84	1789.37	1277.13
Contract			
Storage Pond	1305.29	1437.07	1141.05
No Storage Pond	706.46	298.90	308.14
Riparian			
Storage Pond	457.04	311.37	465.86
No Storage Pond	227.34	231.98	221.22
Total	**6356.88**	**5440.68**	**4692.68**

Table 56. Sites without offstream ponds

Water right type	Number of sites without an offstream pond
Appropriative	31
Contract	10
Riparian	6
Grand Total	**47**

While growers may be able to use the Eel River water to fill their ponds during the winter, there will be a need to refill the ponds in the summer. This situation will likely require use of water stored in Lake Mendocino, possibly through the water right that RRFC holds or the new water administered by a different entity. Figure 159 shows the extent of the service area of the RRFC. The RRFC district boundary may need to be revised to accommodate all the farms that will need additional water.

Off stream ponds are typically constructed from on-site material and are square or rectangular. A dense plastic or other type of liner is needed. Pumps and pipelines also have to be changed for most sites. Smaller farms may want to build a pond that is shared between several sites. There are a number of growers in Ukiah Valley who want to install an offstream pond if some matching grant funds can be provided.

Pond 1

Pond 1 would store 44 AF and cover between 3-4 acres. Figure 160 shows an outline of the pond on a fairly large vineyard site near the mainstem Russian River. The pond would be filled from the Russian River.

Pond 2

Pond 2 would store 46 AF and cover around 4 acres. Figure 161 shows an outline of the pond and the vineyards that would use the water. There is pipeline from the Russian River to this site that would fill the pond.

Pond 3

Pond 3 would store 35 AF and cover 2-3 acres. Figure 162 shows an outline of the pond and the vineyards that would use the water. The pond would be filled from Robinson Creek or the Russian River.

Figures 163-165 show the stages of construction for an offstream pond.

Cost

Based on the cost evaluation for recharge ponds on page 54 we estimated the cost of each pond as: pond 1 will cost about $567,700, pond 2 will cost about $593, 500 and pond 3 will cost about $451, 560 in built in 2024.

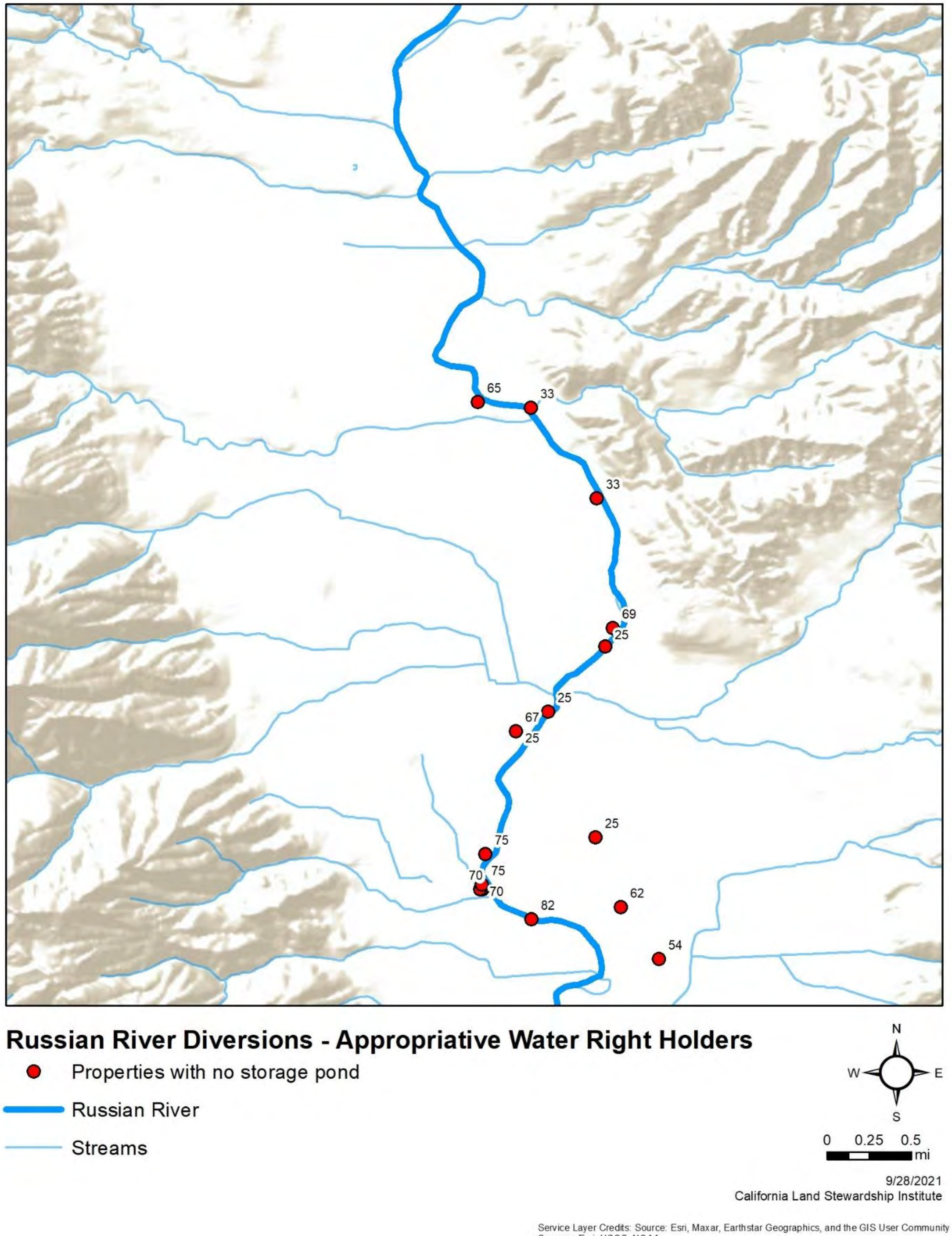


Figure 150. Location of appropriative water rights without a storage pond along northern mainstem of Russian River

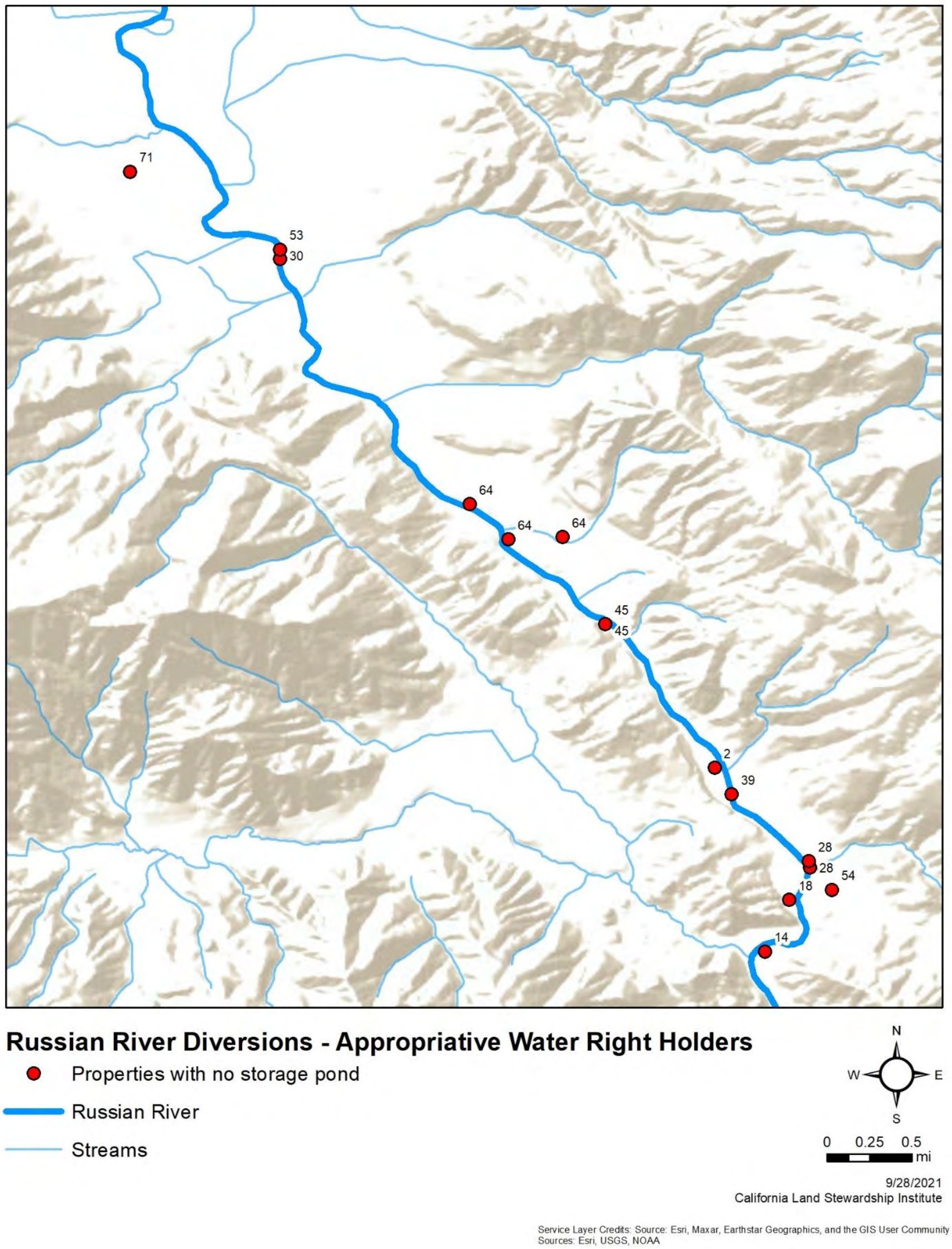


Figure 151. Location of appropriative water rights without a storage pond along middle mainstem of Russian River

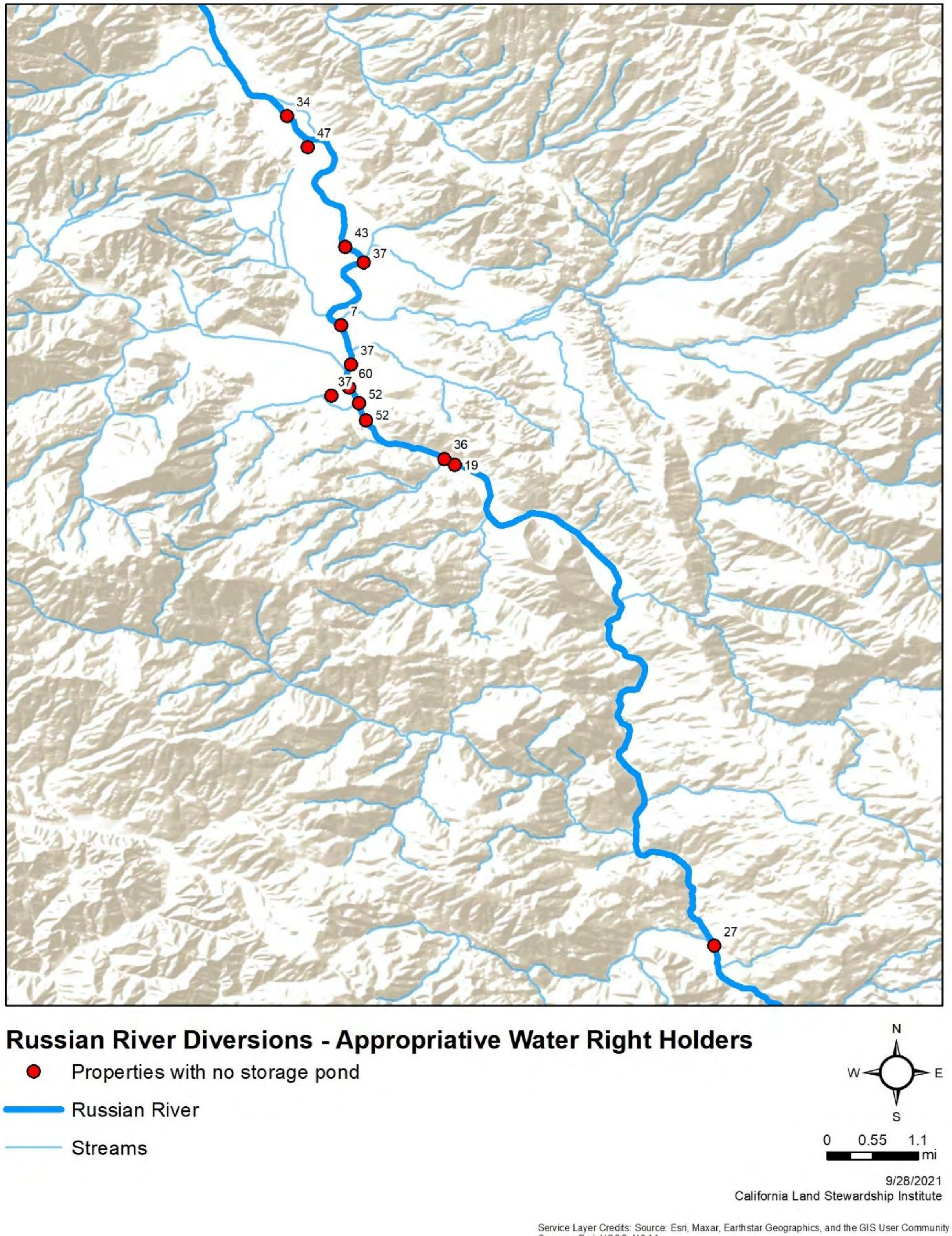


Figure 152. Location of appropriative water rights without a storage pond along southern mainstem of Russian River

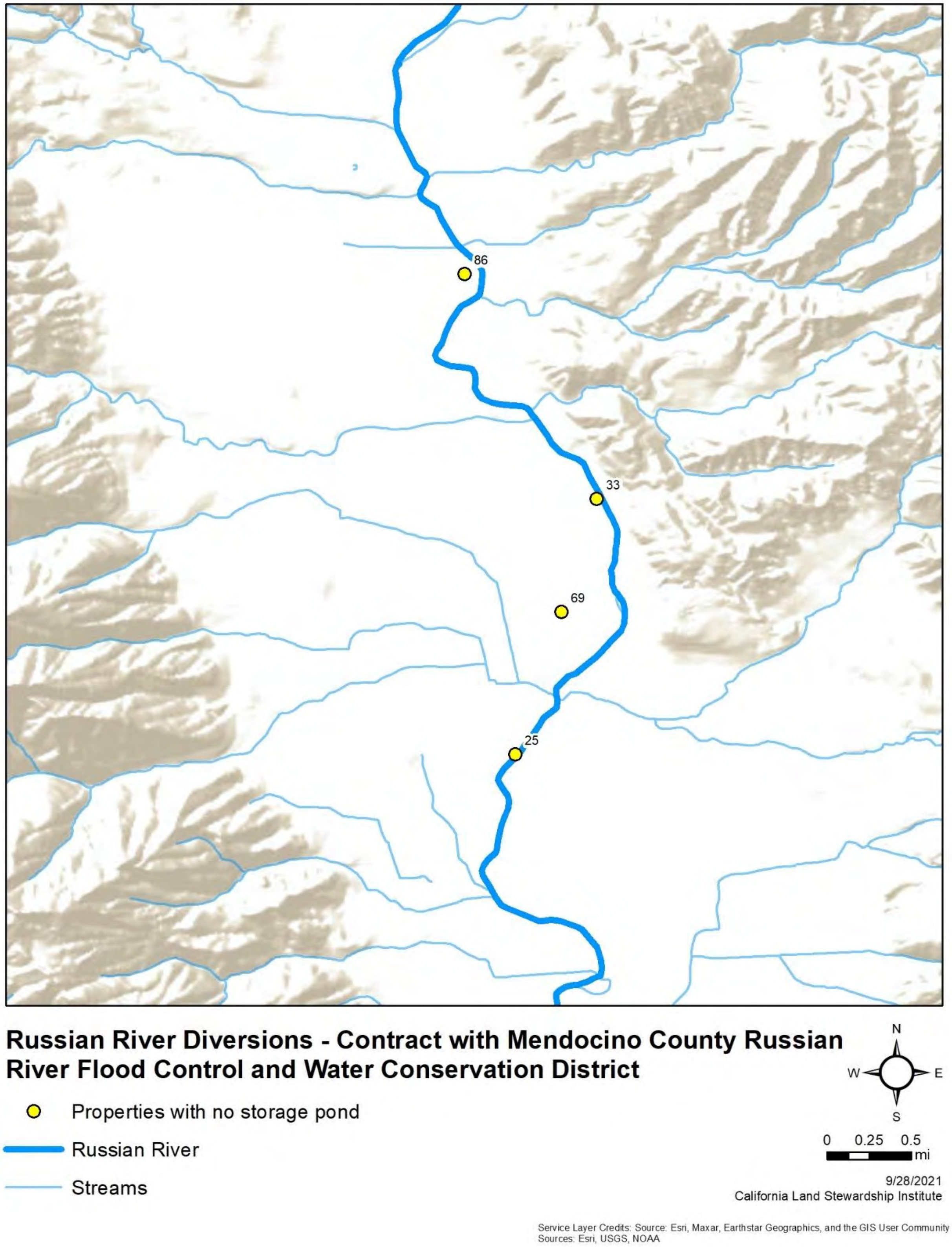


Figure 153. Location of sites with a RRFC contract without a storage pond along northern mainstem of Russian River

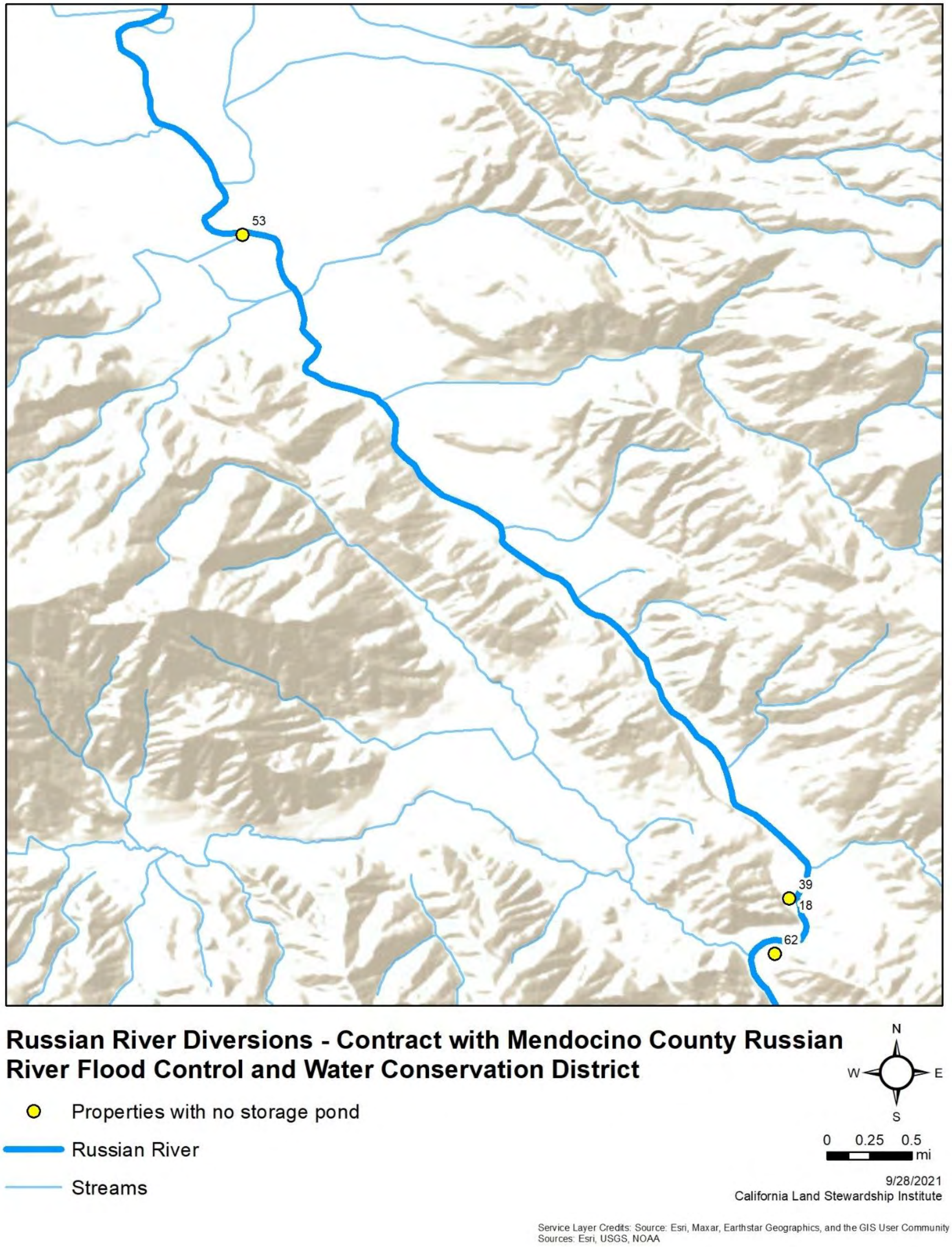


Figure 154. Location of sites with a RRFC contract without a storage pond along middle mainstem of Russian River

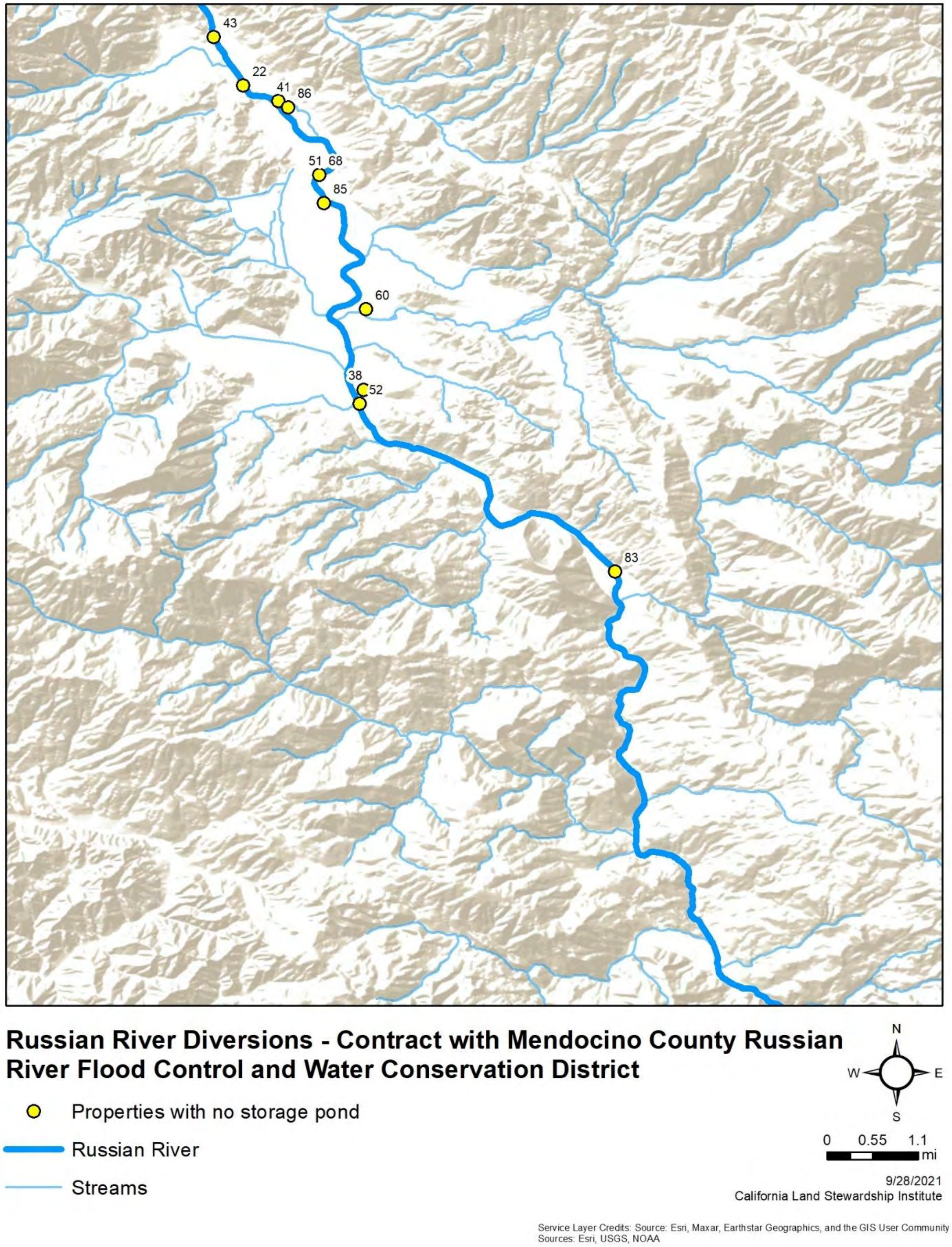


Figure 155. Location of sites with a RRFC contract without a storage pond along southern mainstem of Russian River

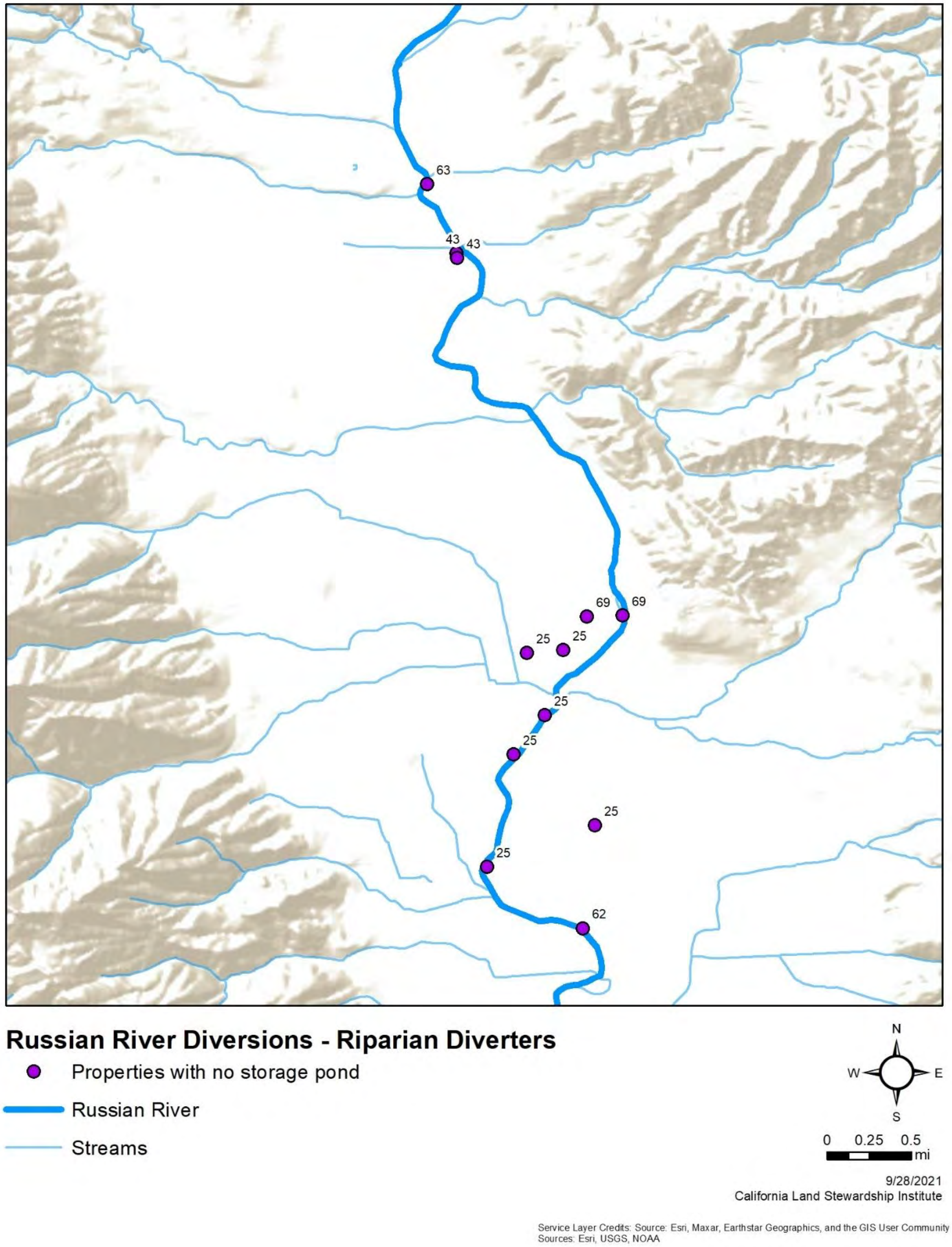


Figure 156. Location of sites with riparian rights without a storage pond along northern mainstem of Russian River

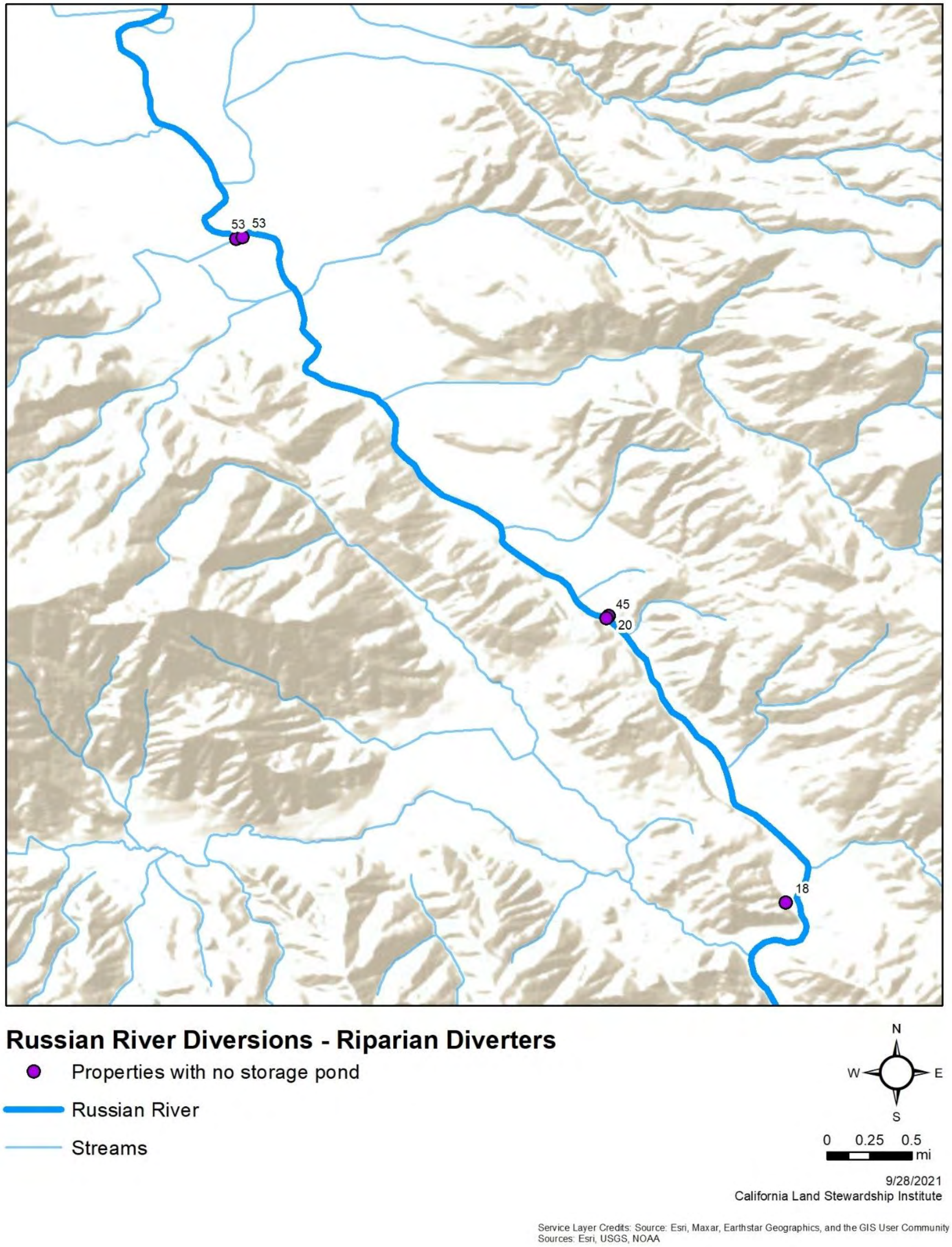


Figure 157. Location of sites with riparian rights without a storage pond along middle mainstem of Russian River

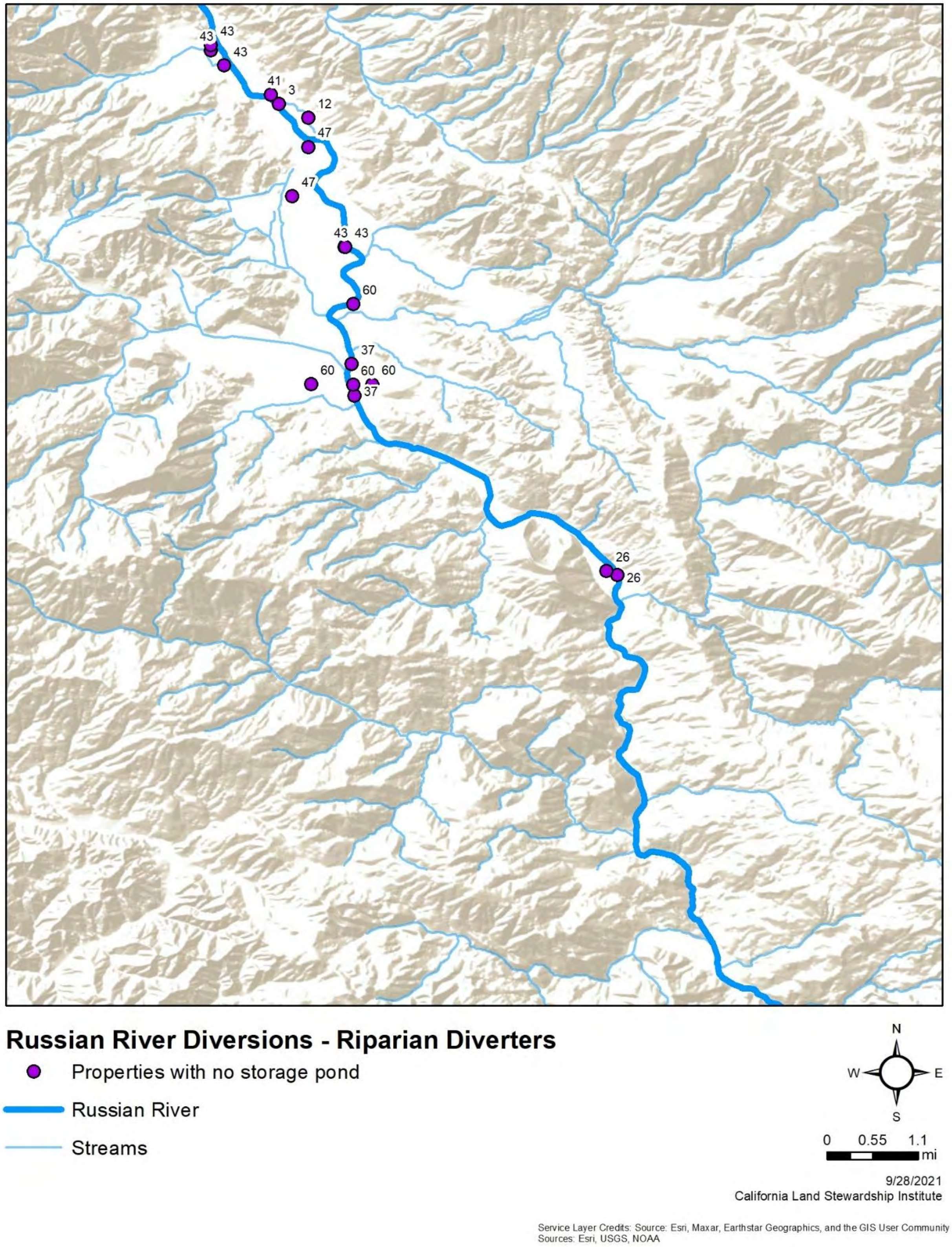


Figure 158. Location of sites with riparian rights without a storage pond along southern mainstem of Russian River

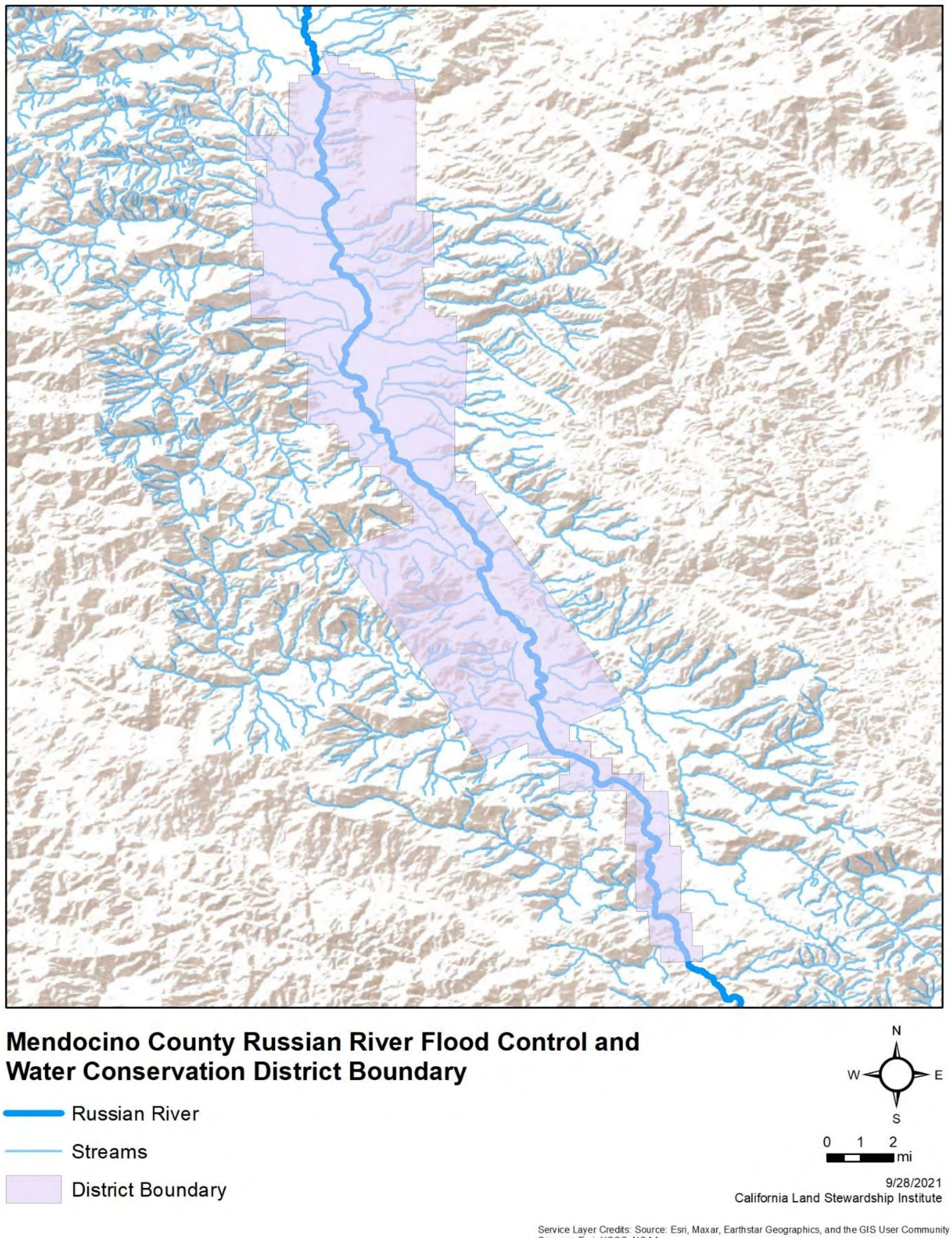


Figure 159. Boundary of the Mendocino County Russian River Flood Control and Water Conservation District (RRFC)

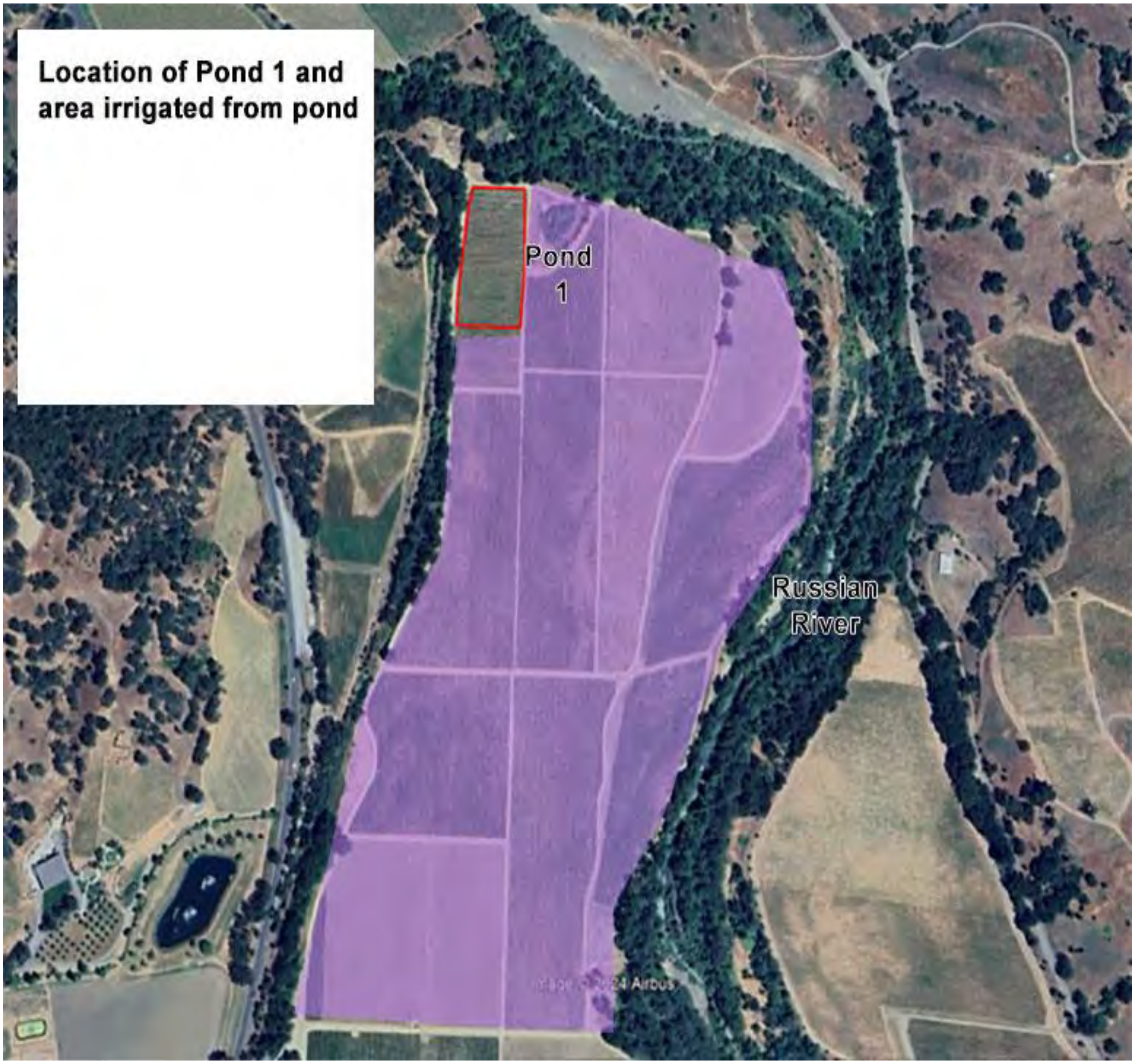


Figure 160. Location of proposed offstream pond 1 and area irrigated

Figure 161. Location of proposed offstream pond 2 and area irrigated

Figure 162. Location of proposed offstream pond 3 and area irrigated

Figure 163. Offstream pond before and during grading

Figure 164. Installation of liner on offstream pond

Figure 165. Offstream pond partially filled with freshwater

V. URBAN STORMWATER

INTRODUCTION

Urban stormwater runoff carries metals such as lead, copper, zinc, nickel, and mercury; oil and gas residues or polyaromatic hydrocarbons (PAHs); trash, coliform, pesticides, herbicides, nutrients and fine sediment. Many contaminants are carried on clay particles in fine sediment. Typically, urban runoff carries high concentrations of contaminants during the first flush, or the runoff from the first rainstorm of the winter season. After a first flush storm washes contaminants from roofs, streets, parking lots and gardens, most of the subsequent runoff will have lower concentrations of contaminants. If there is a long dry period, the next storm can be a second first flush event. These pollutants negatively affect aquatic life in creeks and downstream in the Russian River.

Impervious surfaces of concrete and asphalt cover urban areas. When rainfall hits these surfaces, it does not infiltrate into the ground, but instead rapidly runs off into storm drains and creeks. Runoff from urban areas delivers large volumes of stormwater into creeks at one time. This large volume of flow tends to erode natural creek channels and remove habitats.

CITY OF UKIAH

The City of Ukiah is the main urban area in the Ukiah Valley groundwater basin watershed. The City of Ukiah is the largest city in Mendocino County and the county seat. The population in 2020 was 16,600 residents. The city covers approximately 5 square miles.

Figure 166 depicts Orrs, Gibson and Doolin Creeks that cross through the City of Ukiah and carry urban stormwater to the Russian River. Houses, streets, businesses and parks line the three creeks. There are narrow strips of riparian trees along the tree creeks often with invasive nonnative plants (Figure 63). The City has completed enhancement plans for Gibson and Doolin Creeks but has not implemented them.

Figure 167 shows the land uses in the drainage basins of the creeks. Table 57 summarizes the acres of various land uses in each watershed. All three of the creek watersheds are primarily natural vegetative cover with urban uses of 9 to 26% of the watershed area. The small areas of purple (urban) indicated in the watersheds are rural residences. Agriculture takes up very small areas of these watersheds.

Figure 166 shows most of the streets, buildings roofs, parking lots, sidewalks, landscaping and gardens discharge runoff into storm drain pipes. This network of pipes moves stormwater into the closest creek channel for eventual discharge into the Russian River (Figures 168 and 169).

Table 57. Land uses in Ukiah Creek Watersheds

WATERSHED	LAND USE	ACRES	PERCENT OF WATERSHED
Doolin Creek	Agriculture	12.5	0.73%
	Natural	1,492.1	86.03%
	Urban	229.6	13.24%
Gibson Creek	Agriculture	71.5	4.24%
	Natural	1,183.1	70.09%
	Urban	433.4	25.67%
Orrs Creek	Agriculture	81.4	1.38%
	Natural	5,306.9	89.95%
	Urban	511.1	8.66%

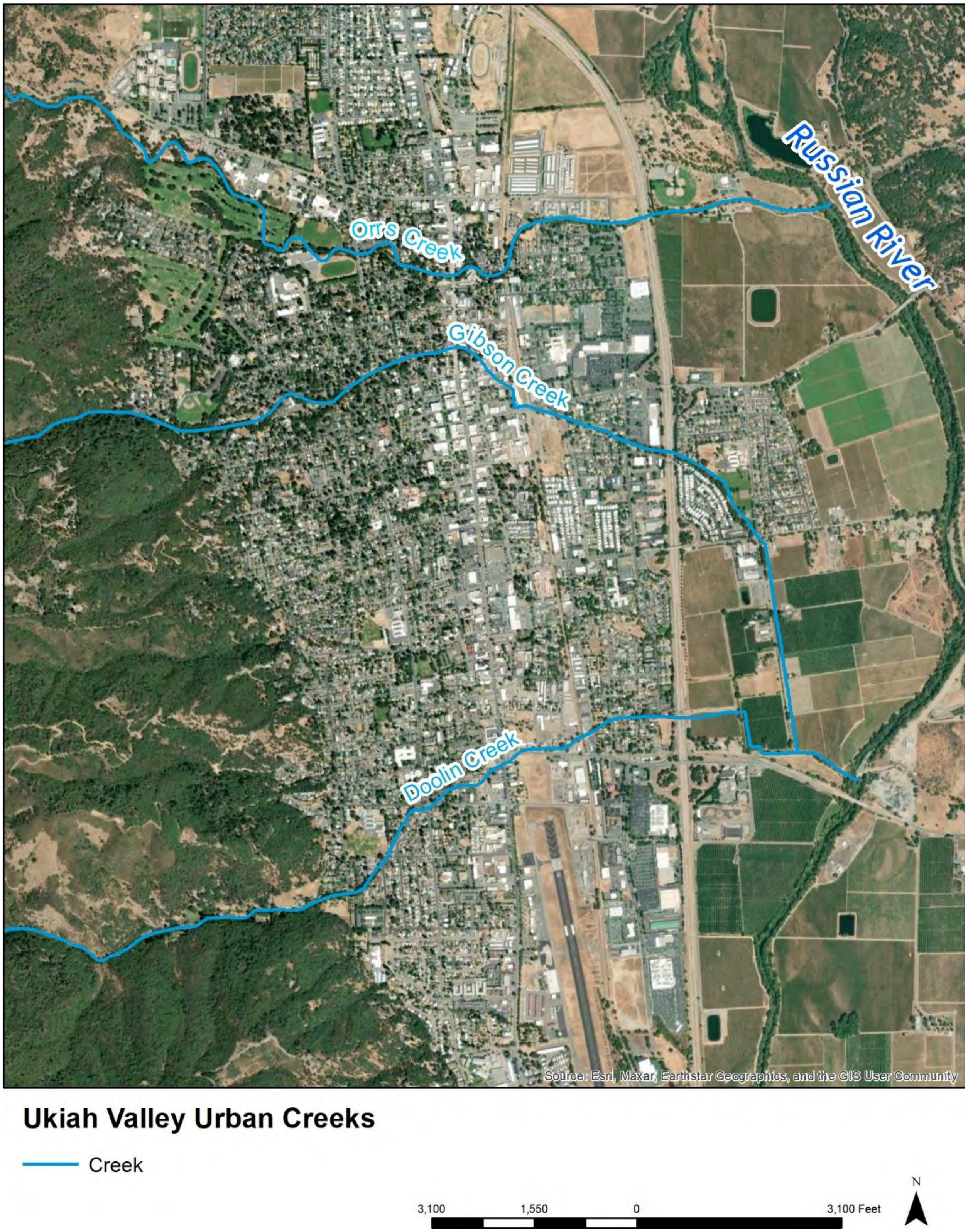


Figure 166. Urban creeks in the City of Ukiah

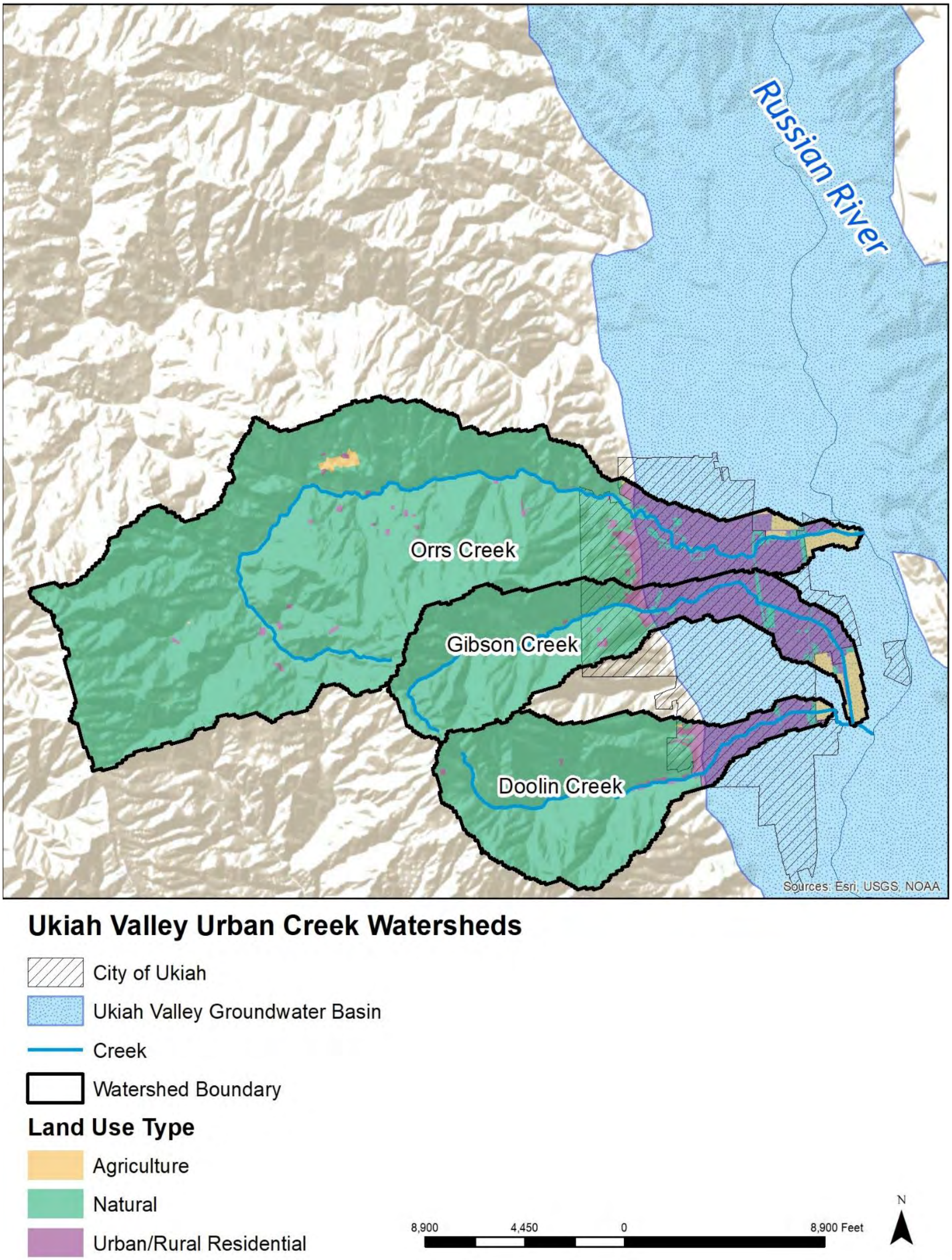


Figure 167. Ukiah urban creek watersheds and land uses

Figure 168. Stormwater from urban impervious streets and sidewalks washes pollutants into storm drains or large underground systems of pipes and then discharges into creeks

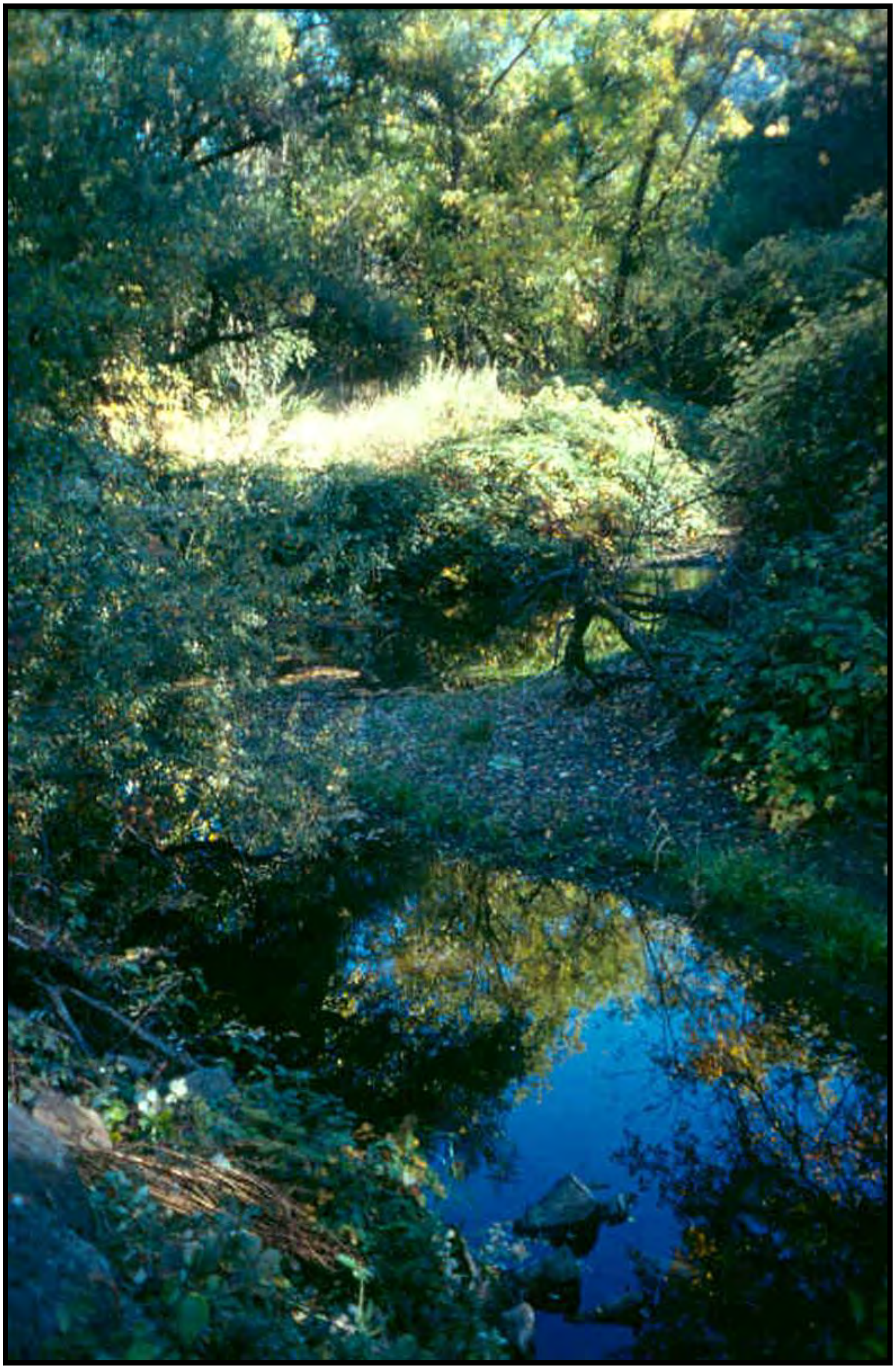


Figure 169. With no rain in the summer, streams need to be kept free of urban stormwater pollutants in order to protect aquatic life

SOURCE CONTROL OF POLLUTANTS

The best way to reduce pollutants in urban stormwater is to control pollutants at their source in urban areas. This approach involves individual residents reviewing their household and garden management practices and changing these practices to reduce pollutants washed into creeks.

Inside the House

Insects

Typical residential pests include cockroaches, ants and spiders. The primary way to avoid ants and cockroaches is to store food and garbage property and use baited traps. These traps attract insects with a sweet material that has pesticide in it. Ants or cockroaches take the poison back to their nests to share and kill others. Orange-based sprays are also effective and not toxic to children or pets. Spiders can be easily removed and should not be sprayed due to the risk of exposure to the person doing he spraying (Figure 170).

Cleaning Products

Many household products are hazardous materials including bleach, old paint and thinner, lacquer, varnish, all batteries and many cleaning solutions. Florescent light bulbs, old thermometers with mercury and used motor oil are also hazardous waste. Instead of putting these items in the trash or pouring down the stormdrain these items need to be taken to the Household Hazardous Waste Facility at MendoRecycle 3200 Taylor Drive Ukiah, 707 234 6400. Old computers and monitors, cell phones, printers TVs and other electronics should be taken to an e-waste facility. Check info@mendorecylce.org for e-waste drop off locations.

Recycling

Recycling paper, aluminum cans, glass containers and many plastic containers keeps these items off streets and also their reuse. Curbside recycling pick up is available in the City of Ukiah. Outside city boundaries residents must bring recycling to the Ukiah Valley Transfer Station 3151 Taylor Drive Ukiah 707 234 6400.

Unfortunately, some residents simply dump various types of garbage along roadsides. Contact MendoRecycle at 707 234 6400. Trash is a major pollutant in Russian River waterways.

Water Conservation

Reducing the use of water inside and outside the home should be a concern for all residents. Fixing leaks, turning off running water and limiting water use in all aspects of life are essential especially in dry years (Figures 171-173).

Water from roof and gutter systems can be collected and used in the garden through the installation of rain barrels at downspouts (Figure 173). Grey water from washing machines, bathroom sinks and showers can be piped to a filtration system and then used for irrigation in the garden (Figure 174). These two added sources of water can reduce the need for city or well water.

Outside the Home

By far the largest use of water in most urban areas is outdoor watering mostly of lawns. Water applied to lawns and gardens using sprinklers often washes fertilizers and pesticides off the garden and into stormdrains (Figures 175-176). This process also wastes water.

SAFETY TIPS FOR THE USE OF PESTICIDES IN THE HOME

If you do decide that use of insecticides inside your house is needed follow these precautions:

- Remove children and pets from the area where the insecticide will be sprayed and keep them out of the area for 1-2 days or longer.
- Remove food, toys, bedding or other items which might be exposed to the insecticide and which children might come in contact with.
- Always read and carefully follow all precautions and safety recommendations given on the container label.
- Direct ingestion, inhalation, or dermal contact with insecticides can cause serious health effects. Any child or adult who directly inhales or ingests pesticides should be immediately taken to an emergency room.
- Store all chemicals in the original labeled containers in a locked cabinet or shed, away from food, and out of the reach of children and pets.
- Dispose of empty containers or leftover products properly
- Never reuse or burn containers.
- Never dispose of containers where they may contaminate water supplies or creeks.
- Do not pour leftover pesticides down the sink, toilet or in the yard or stormdrain.

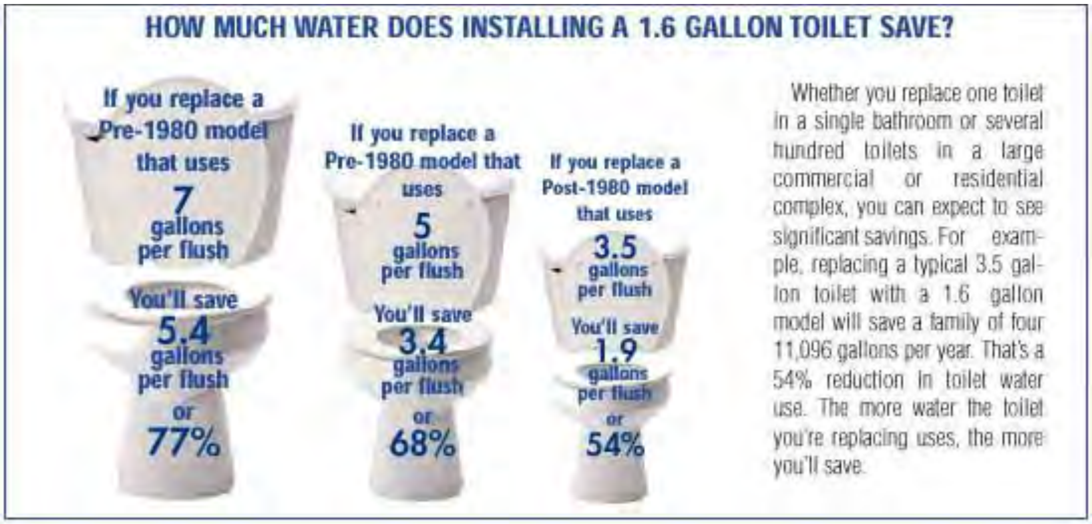
Figure 170. Pesticide use precautions

For vegetable and flower gardens some chemicals and nutrient applications maybe needed. However chemical use can be reduced by use of integrated Pest Management (IPM) methods (Figure 177). In addition to the garden plants other plants can be installed to host beneficial insects that will prey on pest insects (Figures). The UC Master Gardner program is an excellent place to learn more about beneficial insects and IPM (cemendocino.ucanr.edu/Master_Gardner/).

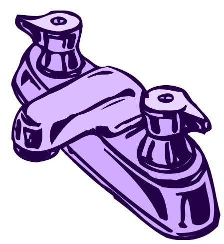
If you do have to use chemicals review the directions and warning on the label carefully, cover up to avoid exposure on your skin, eyes and through inhalation. Wash your clothes and shower after the application is completed. Never use more chemical than listed on the label and never spray when it is windy.

Water conservation in the garden can be improved through use of drip irrigation and the use of timers to avoid overwatering. Mulch placed over the soil surface between garden plants can both conserve water and reduce weed growth.

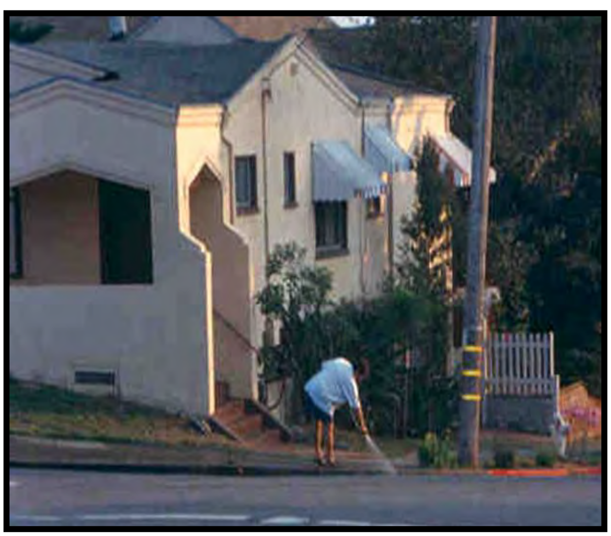
There are many alternatives to the front yard lawn. One of the most popular are native California plants/Mediterranean plant gardens (Figures 178-179). As long as the plants used are adapted to the conditions (full sun, afternoon shade etc.) of the site, native plants don't need fertilizer and for the first three summers following planting will need irrigation once a week. Once established no irrigation is needed. Replacing lawns with native plants greatly reduces water use and fertilizer and pesticide runoff. Appendix 7 provides lists and photos of native plants for urban gardens and Appendix 5 lists native plant nurseries



A front-loading machine uses up to 40% less water and 60% less energy than top-loading machines. They also use less detergent.



A faucet leaking a drop a second = 2,700 gallons/year of water waste



Hosing down driveway or sidewalk – 150 gallons of water waste

Figure 171. Water conservation in urban areas

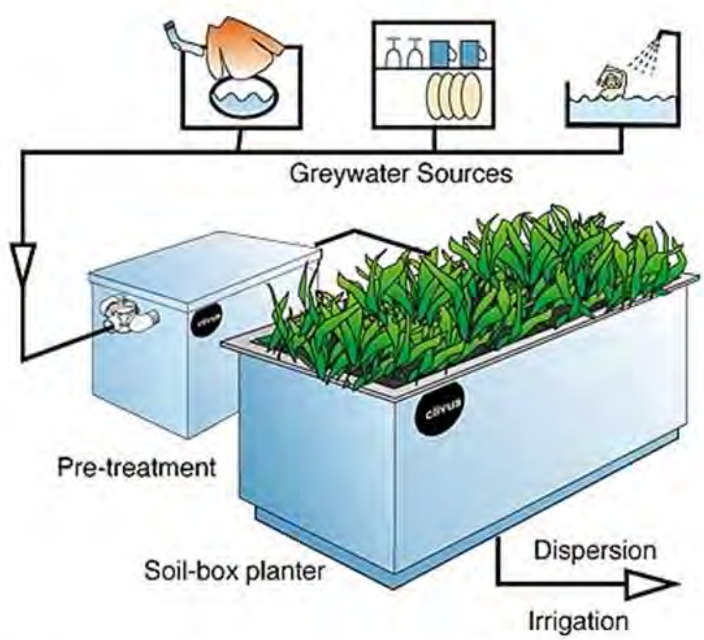
Wash paint brushes and rollers out onto grass or into a sink that drains to the sewer. Do not allow painting contractors to wash paint down the street and into storm drains

Washing cars on the street causes soap to runoff into creeks. Soap contains phosphates which causes algae to grow and reduces the viability of aquatic habitats. Take your car to a car wash or wash on the drive way if runoff spreads out on grass or the back yard

Figure 172. Avoiding polluting creeks in urban areas

Oil and gas runoff are a major source of pollutants in urban runoff. Oil leaks and spills should be covered with cat litter or dirt to absorb the oil and then the litter should be swept up and placed in the garbage.

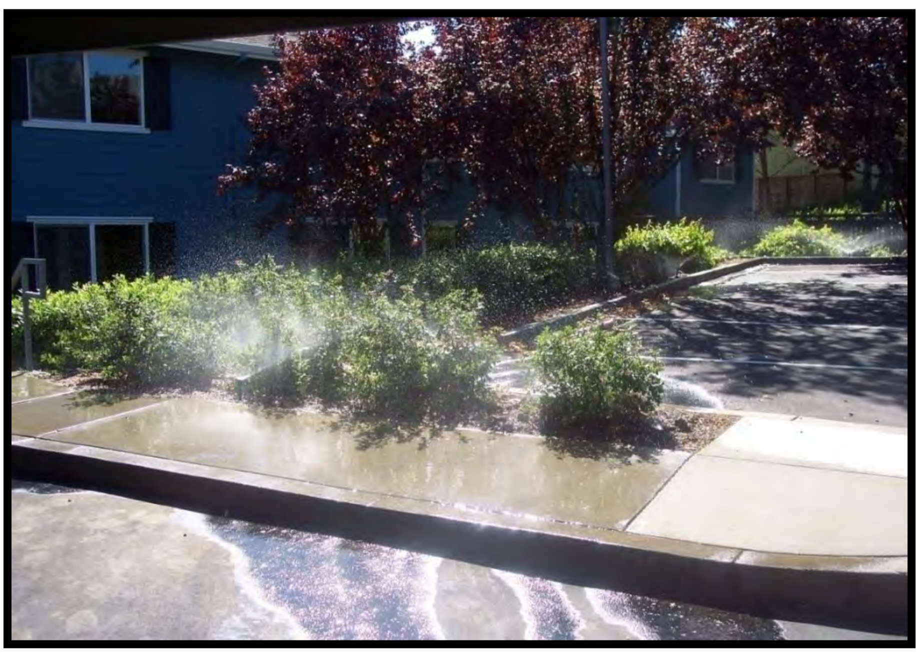
Figure 173. Oil and gas residues in urban areas and rain barrels



GREYWATER SYSTEMS

Greywater is any wash water that has been used in the home, except water from toilets. Dish, shower, sink, and laundry water comprise 50-80% of residential "waste" water. This water may be reused for landscape irrigation following filtration. A permit may be needed.

Figure 174. Greywater systems



30-60% of the freshwater supply in most urban areas is used to water lawns and landscaping. Lawns use more water and chemicals per acre than many agricultural crops. The bushes being over irrigated above should have drip irrigation not sprinklers.

Figure 175. Urban water waste

Many gardens need great amounts of nitrogen and phosphorous as well as herbicides to maintain year-round blooming flowers. Install plants in locations they are adapted for to reduce the need for chemicals

Runoff of nutrients from gardens and lawns can result in algae blooms

Figure 176. Pollutants from urban gardens

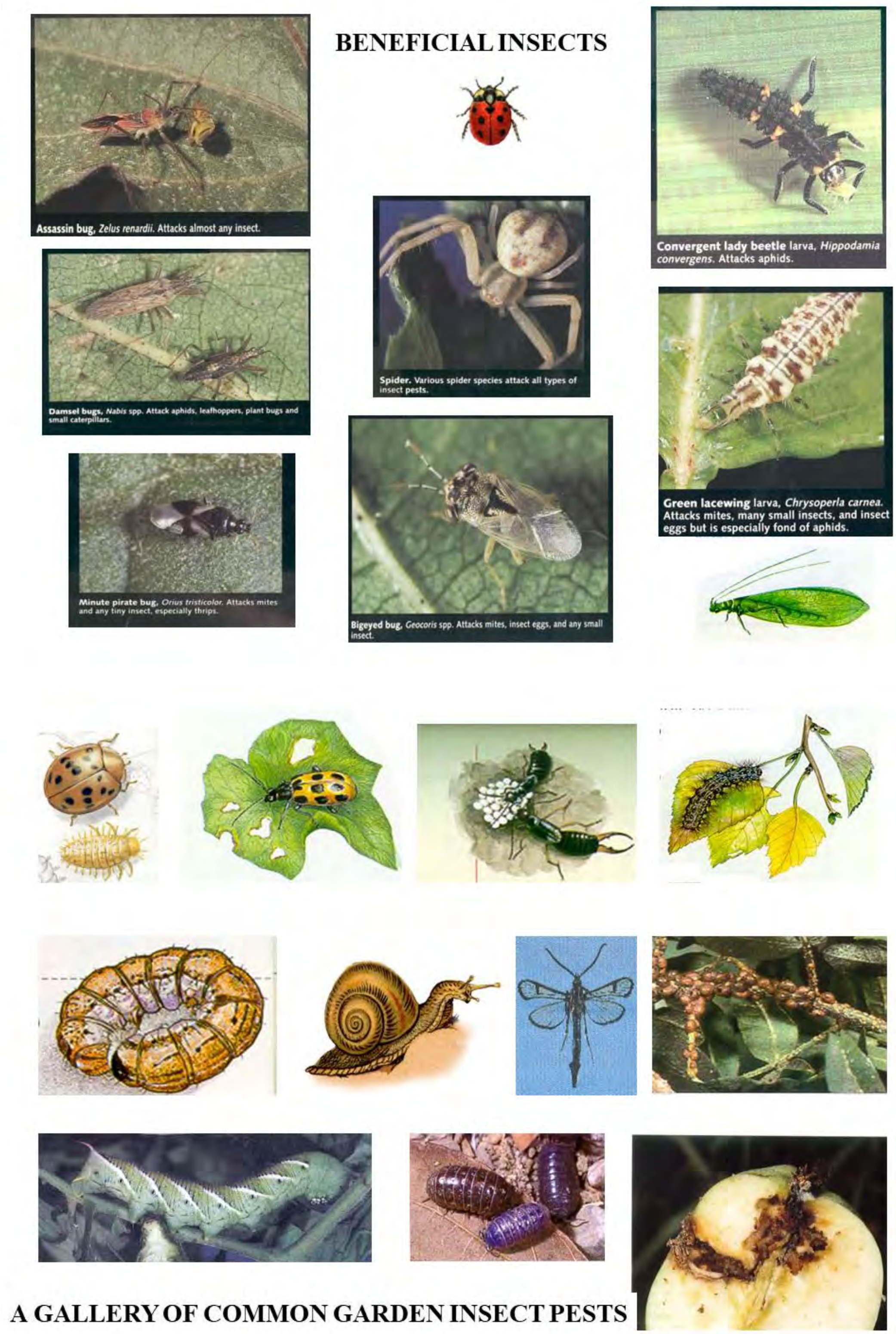


Figure 177. Common garden insect pests and beneficial insects

Figure 178. Native plant gardens. A Ca. native or mediterranean garden requires less water and is adapted to the local environment so will need less chemicals or fertilizers

Figure 179. Example native plant gardens replacing lawns

LOW IMPACT DEVELOPMENT (LID)

Another approach to reducing pollutants from urban areas is to intercept stormwater and filter out pollutants before it reaches storm drains and creeks. Urban streets, parking lots, and buildings can be retrofitted with engineered landscape areas. Biofiltration facilities are installed along sidewalks, in parking lots, and along street edges to catch and filter out trash and contaminants while also providing tree and planting areas. Biofiltration facilities provide a medium which can rapidly and effectively remove trash and a high percentage of the fine sediment particles, bacteria, and nutrients, and biologically treat these contaminants. The facilities are designed not to pond or detain stormwater but to infiltrate and/or bypass water and be an aesthetically pleasing amenity in the urban environment. Figures 180-183 show a variety of biofiltration facilities. Biofiltration facilities have been found to remove 80 percent or greater of the total suspended sediments (TSS) from stormwater and therefore have a high a level of effectiveness. The other function of LID facilities is to infiltrate runoff after it is filtered.

There are a number of types of LID facilities (Figures 180-183):

Planters along streets, parking lots and sidewalks where curb cuts allow storm runoff to flow into the planter and through the dense and highly absorbent material that catches sediment particles with pollutants attached. The water flows downward and into the ground or the stormwater system depending on site and groundwater conditions (Figure 180).

Planters at the end of roof downspouts with filtration materials

Rain gardens at the end of roof downspouts

Vegetated bioswales along the edges of streets and parking lots t collect and filter runoff

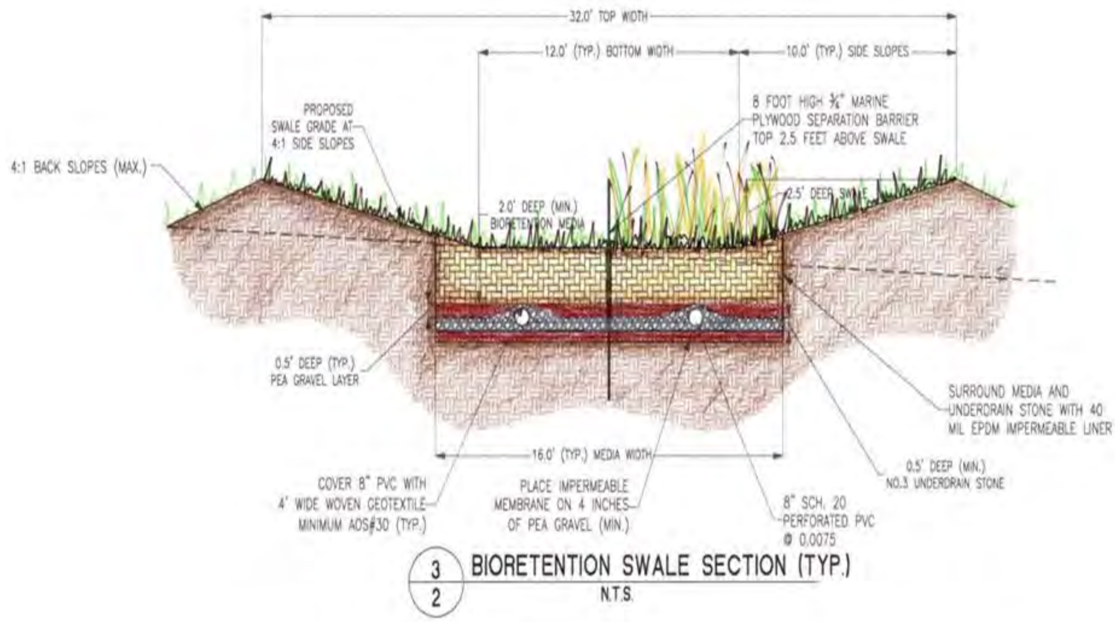
Infiltration trenches in parking lots and along streets to temporarily retain water and encourage movement into the ground

REGULATIONS

Biofiltration facilities are required under regional water quality permits for larger residential and commercial developments. Urban stormwater is regulated through National Pollutant Discharge Elimination System (NPDES) Order #R1-2015-0030 from the North Coast Regional Water Quality Control Board. This Order applies to all the major cities in the Russian River watershed. This order addresses both the effects of increased stormwater volumes on creeks and downstream area and the pollutants in urban runoff. This Order began applying to developments in the City of Ukiah in July 2014.

This permit places the regulatory responsibility on the City for requiring engineered LID facilities for developments that create or replace 10,000 square feet of impervious surfaces. Additionally the order requires that the City carry out a number of actions including: a residential outreach program that focuses on source control of pollutants; an industrial/commercial program with an inventory, education and inspection program for high risk facilities such as gas stations, auto service facilities, restaurants, auto dismantlers, nurseries and other sites; a retrofit program for existing public developments; a tracking and inspection program and oversight of water quality construction permits.

Developments proposed after 2014 must include LID facilities while those built prior to 2014 do not. Examples of developments in Ukiah that have implemented LID improvements are Costco near the



Bioretention is defined as filtering storm water through a terrestrial aerobic plant/soil/microbe complex to capture, remove and cycle pollutants through a variety of physical, chemical and biological processes

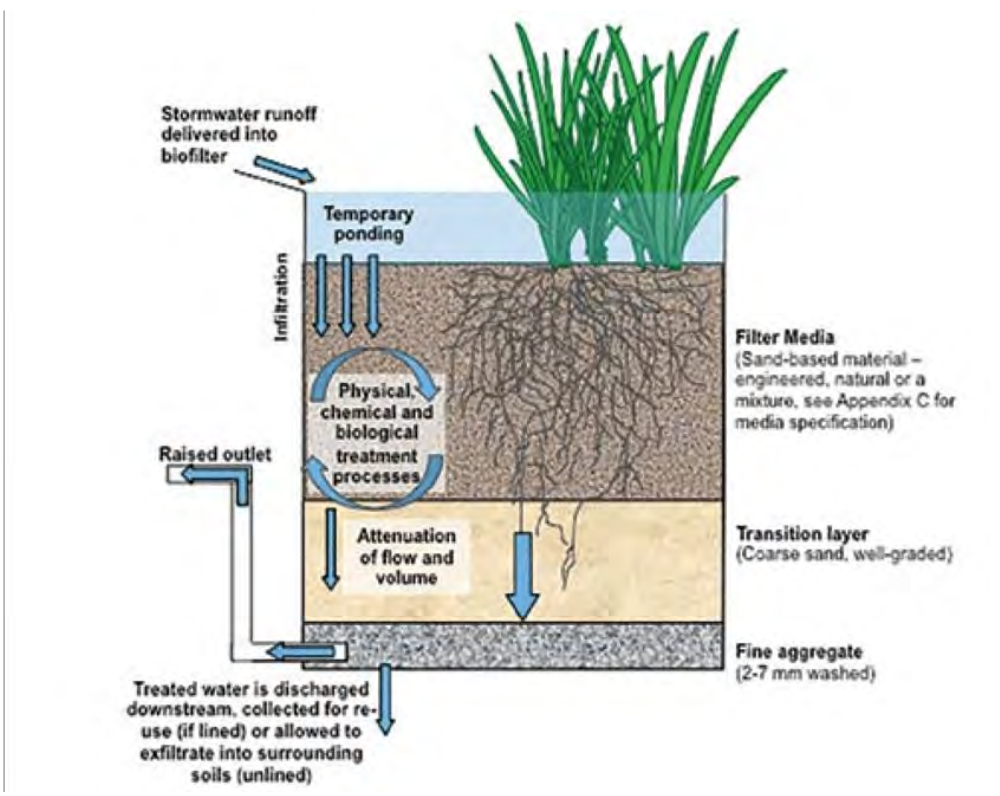
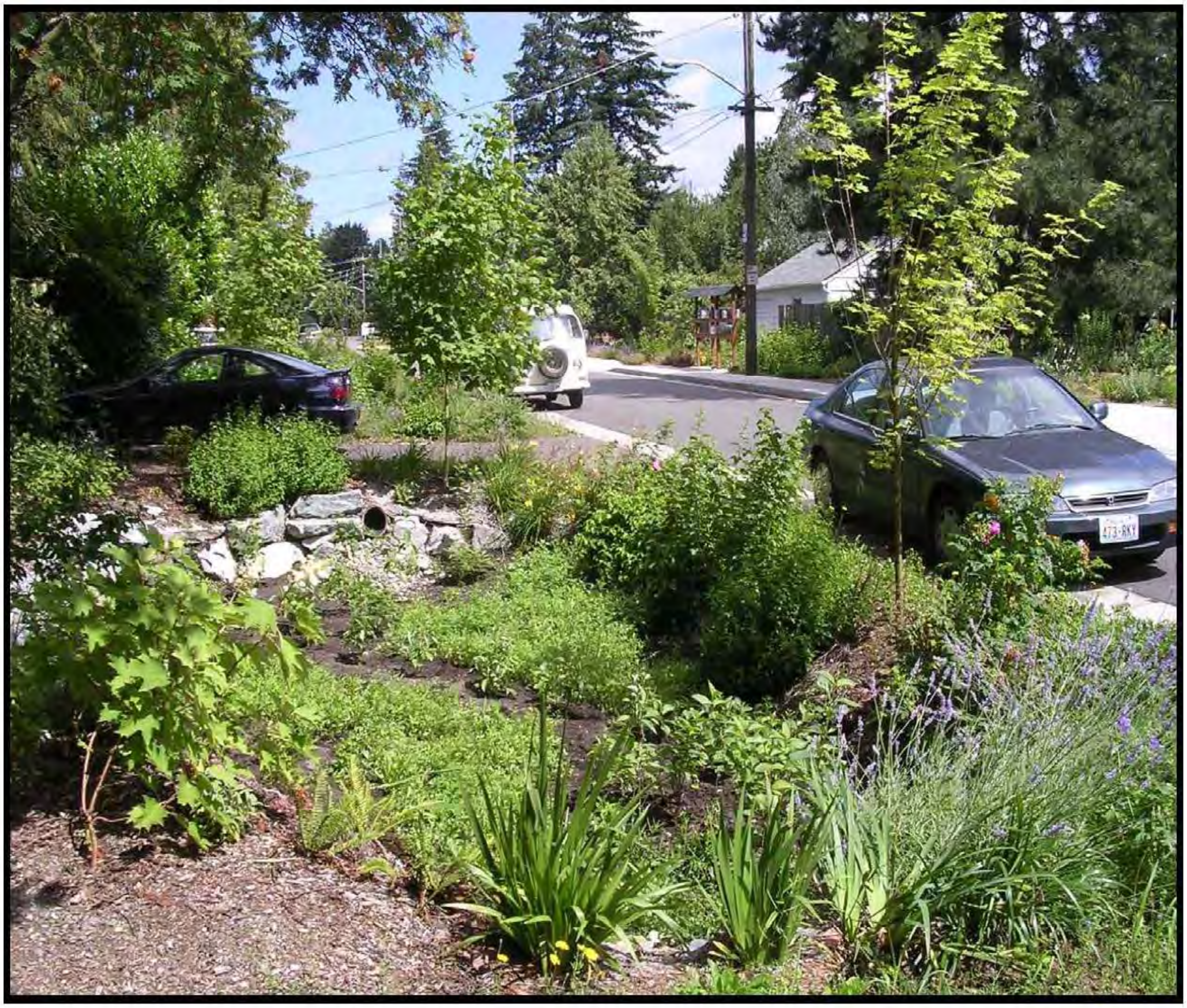


Figure 180. Diagrams of bioswales and bioretention



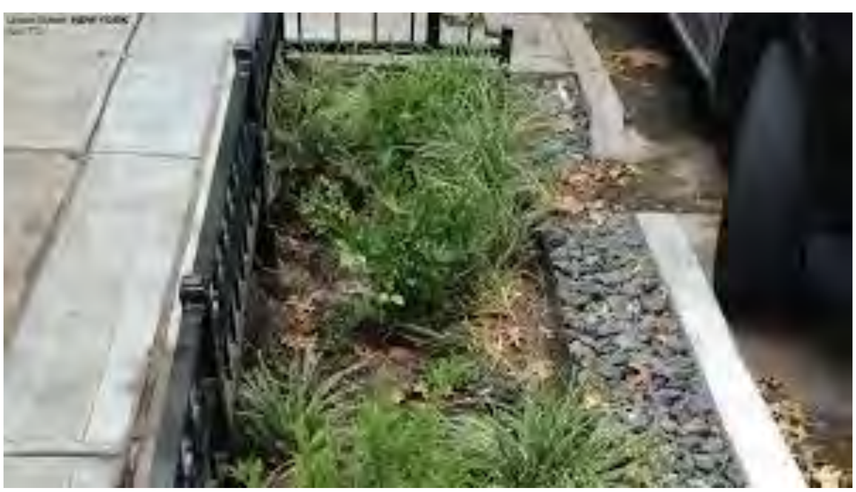


Figure 181. Two types of bioretention facilities

Figure 182. Bioretention facilities in downtown areas

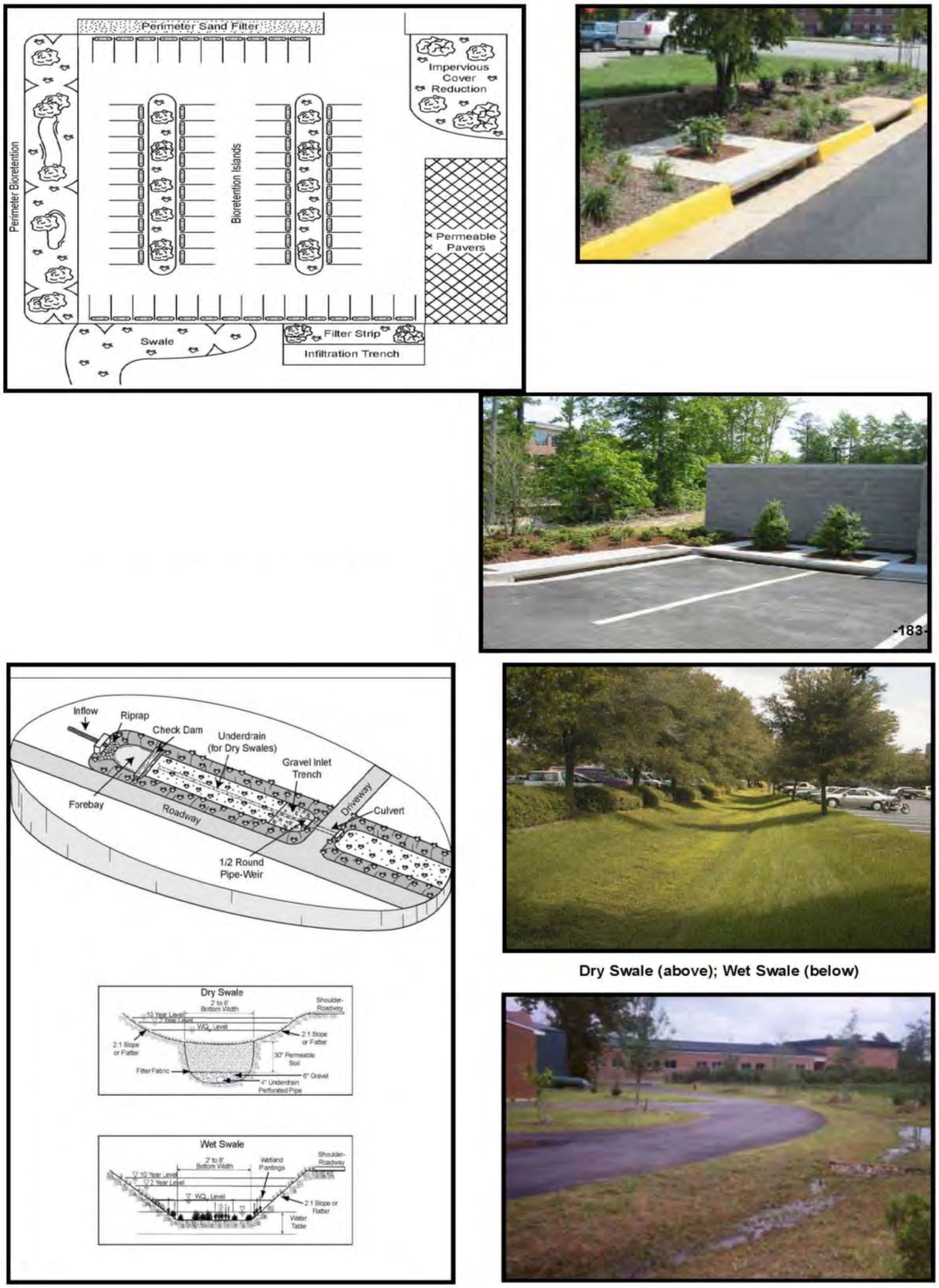


Figure 183. LID facilities for two developments

Airport. Nearby commercial areas where Friedman's, Kohl's and JC Penny's are located were built before 2014 and do not filter or control stormwater.

PROJECTS

We selected the Friedman's parking lot and adjacent area to describe a conceptual LID project. An engineer would have to design the project including site surveys to document exactly where stormwater flows on site and to calculate the volumes and therefore the size and number of LID facilities needed. Our project description is conceptual and a starting point for retrofitting this area to improve water quality.

Figure 184 shows the 21-acre parking lot next to Friedmans. Currently runoff from this large area discharges under Highway 101 and into a ditch on private property and then into the Russian River. The owner of the ditch has documented both erosion of the ditch from the increased stormwater volume produced by the impervious surface of the parking lot and significant amounts of trash after storms.

Figure 185 depicts a conceptual retrofit plan for the parking lot. A new biofiltration swale would be installed on the eastern side of the parking lot that would filter runoff and direct flow to the ditch discharge point. Along the western side of the parking lot planters would be installed that would filter and either infiltrate water or discharge it into the stormdrain system. Within the parking lot the current trees can be replaced by prebuilt planted units that will also have trees but will each have curb cuts so that water can filter into each planter and then either be infiltrated or discharged into the stormdrain system depending on the current drainage system.

Figure 184. Parking lot with direct discharge of stormwater and no filtration

Figure 185. Parking lot with concept design for LID facilities

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