Research Assessment for EMC-2018-003 Alternative Meadow Restoration

Oriana Ramirez – CAL FIRE Watershed Protection Program

Acknowledgements

- Dr. Christopher Surfleet - Associate Professor - California Polytechnic State University
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- Simon Marks - Graduate Student - California Polytechnic State University
- Oriana Ramirez - Graduate Student - California Polytechnic State University
- Numerous other graduate and undergrad students

- Collaborators:
  - Collins Pine Co.
  - Plumas Corp

*McIntire-Stennis Grant

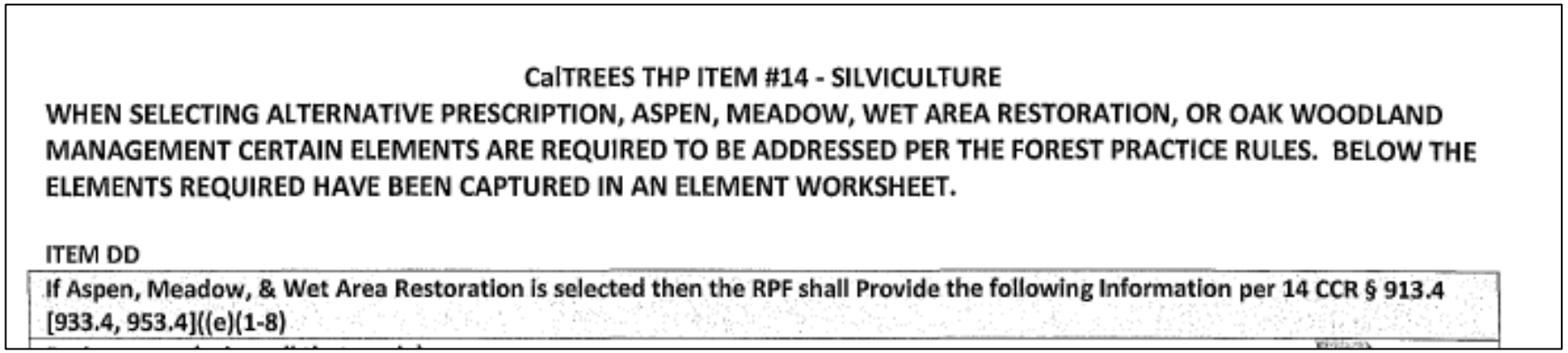
Meadow and Wet Area Restoration Rules

913.4, 933.4, 953.4 Special Prescriptions

(e) Aspen, and Meadows and Wet Areas restoration. All trees within aspen stands (defined as a location with the presence of living aspen (*Populus tremuloides*), Meadows and Wet Areas may be harvested or otherwise treated in order to restore, retain, or enhance these areas for ecological or range values.... Projects using this prescription shall be designed to balance the protection and regeneration of aspen stands, Meadows and Wet Area habitats in California's forest ecosystems with the other goals of forest management as specified in 14 CCR § 897…

Meadow and Wet Area Restoration Requirements

- RPFs must provide a condition assessment of the project area.
- RPFs must state project goals and measures of success as they pertain to the condition of the area and causes of problematic Meadow and Wet Area conditions.
- CAL FIRE will review post-harvest field conditions and prepare a monitoring report of the Meadow and Wet Area every five (5) years for the Board.
- **Exempt from silvicultural standards for opening size, adjacency requirements, or conifer stocking; Minimum resource conservation standards; and Timberland productivity and MSP requirements.**



CalTREES THP ITEM #14 - SILVICULTURE

WHEN SELECTING ALTERNATIVE PRESCRIPTION, ASPEN, MEADOW, WET AREA RESTORATION, OR OAK WOODLAND MANAGEMENT CERTAIN ELEMENTS ARE REQUIRED TO BE ADDRESSED PER THE FOREST PRACTICE RULES. BELOW THE ELEMENTS REQUIRED HAVE BEEN CAPTURED IN AN ELEMENT WORKSHEET.

ITEM DD

If Aspen, Meadow, & Wet Area Restoration is selected then the RPF shall Provide the following Information per 14 CCR § 913.4 [933.4, 953.4]((e)(1-8)

Article 6 Watercourse and Lake Protection

916.1, 936.1, 956.1 In Lieu Practices [All Districts]

(a) The in lieu practice(s) must provide for the protection of the beneficial uses of water to the standards of 14 CCR§§ 916.3, 936.3, 956.3 and 916.4(b), 936.4(b), 956.4(b).

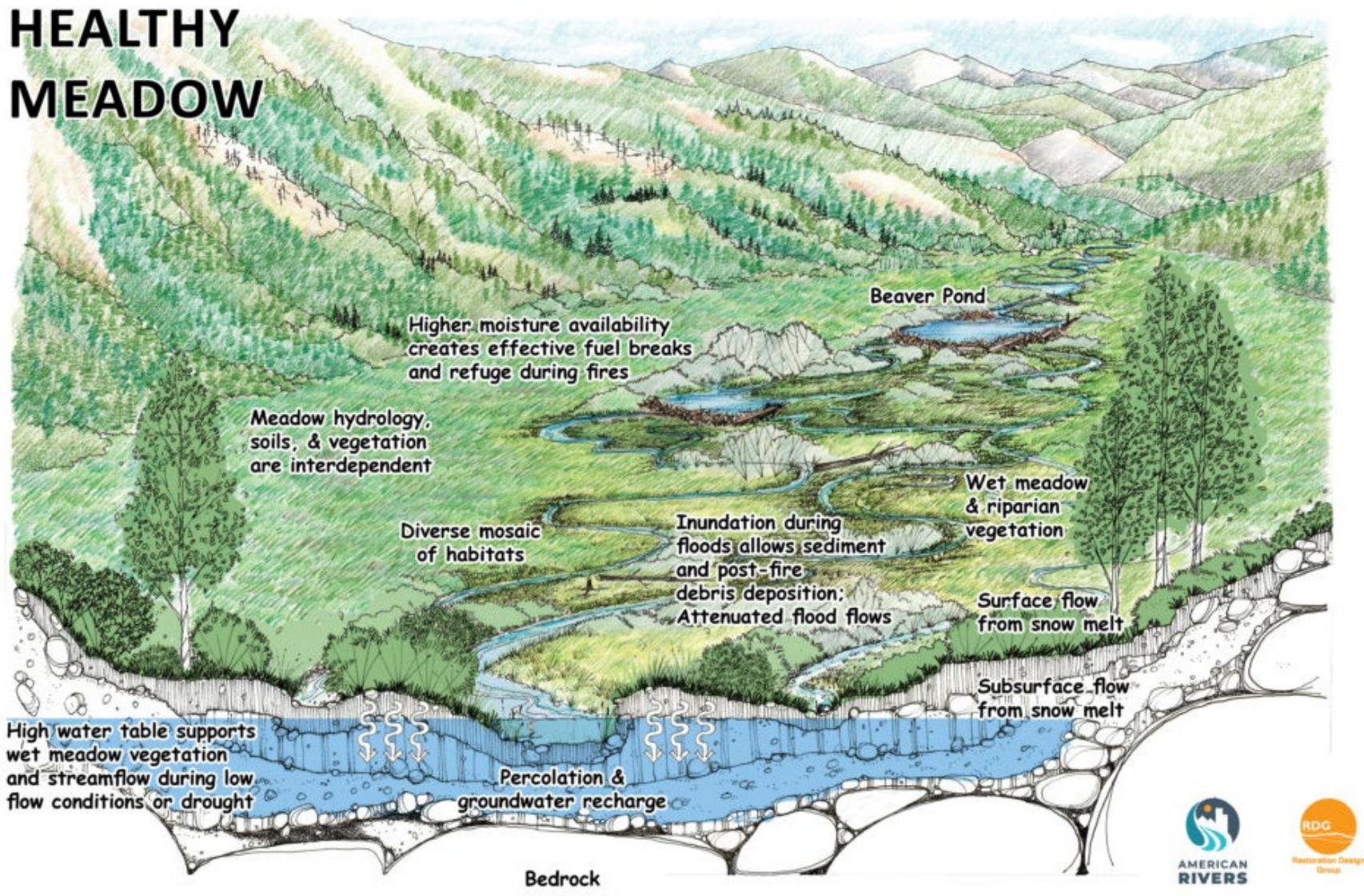
Avoid This!

916.3, 936.3, 956.3 General Limitations Near Watercourses, Lakes, Marshes, Wet Meadows and Other Wet Areas [All Districts]

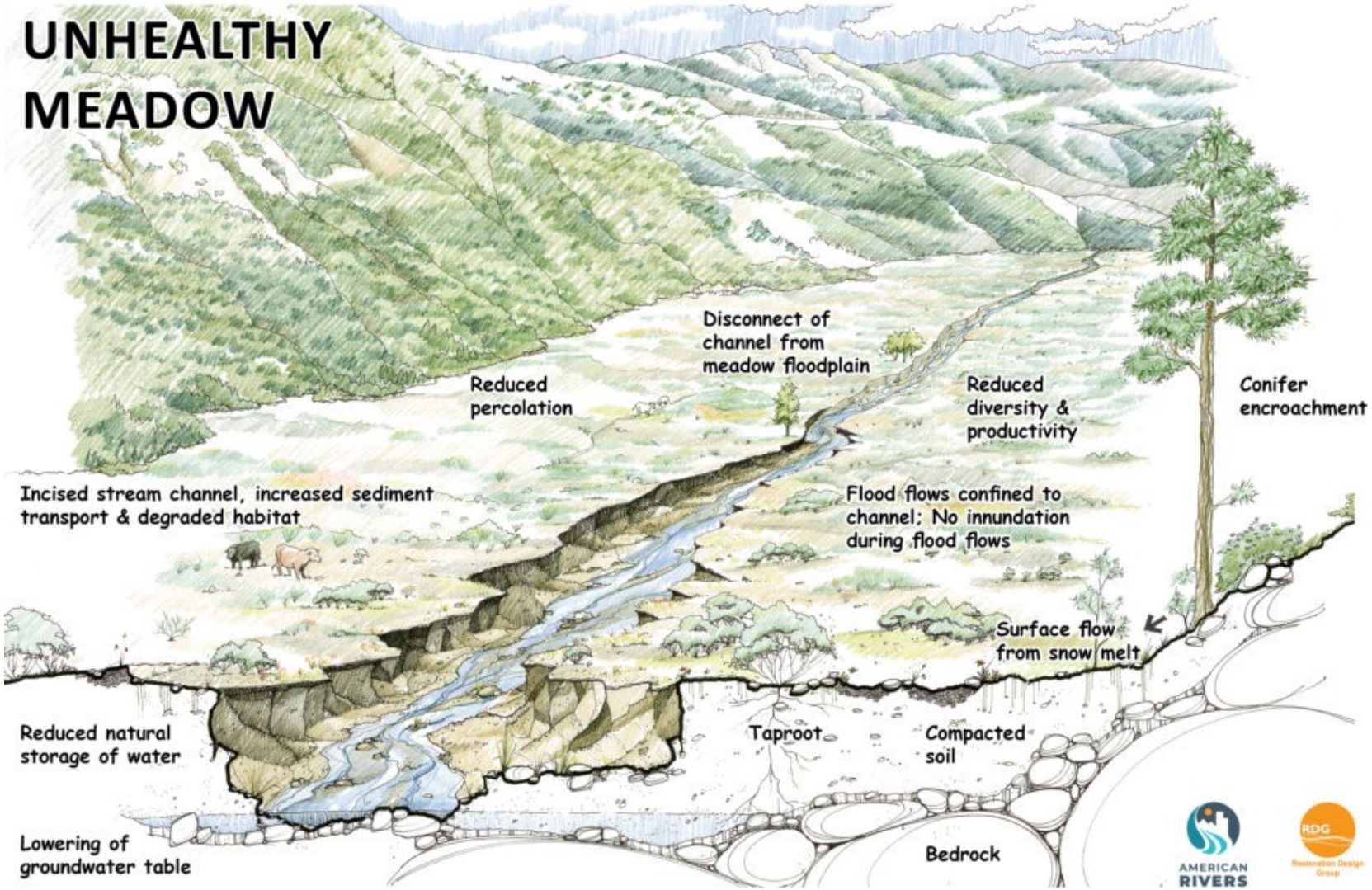
- Tractor roads cannot be constructed or used in Wet Meadows unless justified in the plan and approved by the Director.
- Non-commercial species of vegetation boarding and covering Meadows and Wet Areas shall be retained and protected.
- Soil within the Meadows and Wet Areas shall be protected to the maximum extent possible.
- Trees cut within the WLPZ shall be felled away from the Watercourse.

Why are meadows important?

- Facilitate water cycling
- Help with sediment capture
- Create natural fire breaks in forested regions
- Diverse vegetation and wildlife habitat
- Carbon sequestration



https://www.americanrivers.org/threats-solutions/restoring-damaged-rivers/mountains-meadows/



https://www.americanrivers.org/threats-solutions/restoring-damaged-rivers/mountains-meadows/

The Problem

- Meadow habitat has been decreasing in the Sierra Nevada and Cascades.
- Forest densification caused by:
  - Fire suppression
  - Poor grazing practices
  - Climate change
- Lodgepole Pine (*Pinus contorta*) tends to colonize meadow habitats due to its ability to grow in wetter environments.
- FPRs more suited for passive rather than active restoration

Areas of Uncertainty Regarding Meadow Restoration and WLPZ Operation Rules

- How effective are Meadows and Wet Area restoration activities as an alternative silviculture prescription?
- Are alternatives to the standard FPRs effective in maintaining and restoring stream water temperature?
- How do class I WLPZ rules apply during vegetation removal for Meadows and Wet Areas restoration?
- Can restoration objectives still be met when restoration activities intersect with low frequency, high magnitude disturbance events (i.e., fire, flood, etc)?

EMC Project Proposal Research Objectives

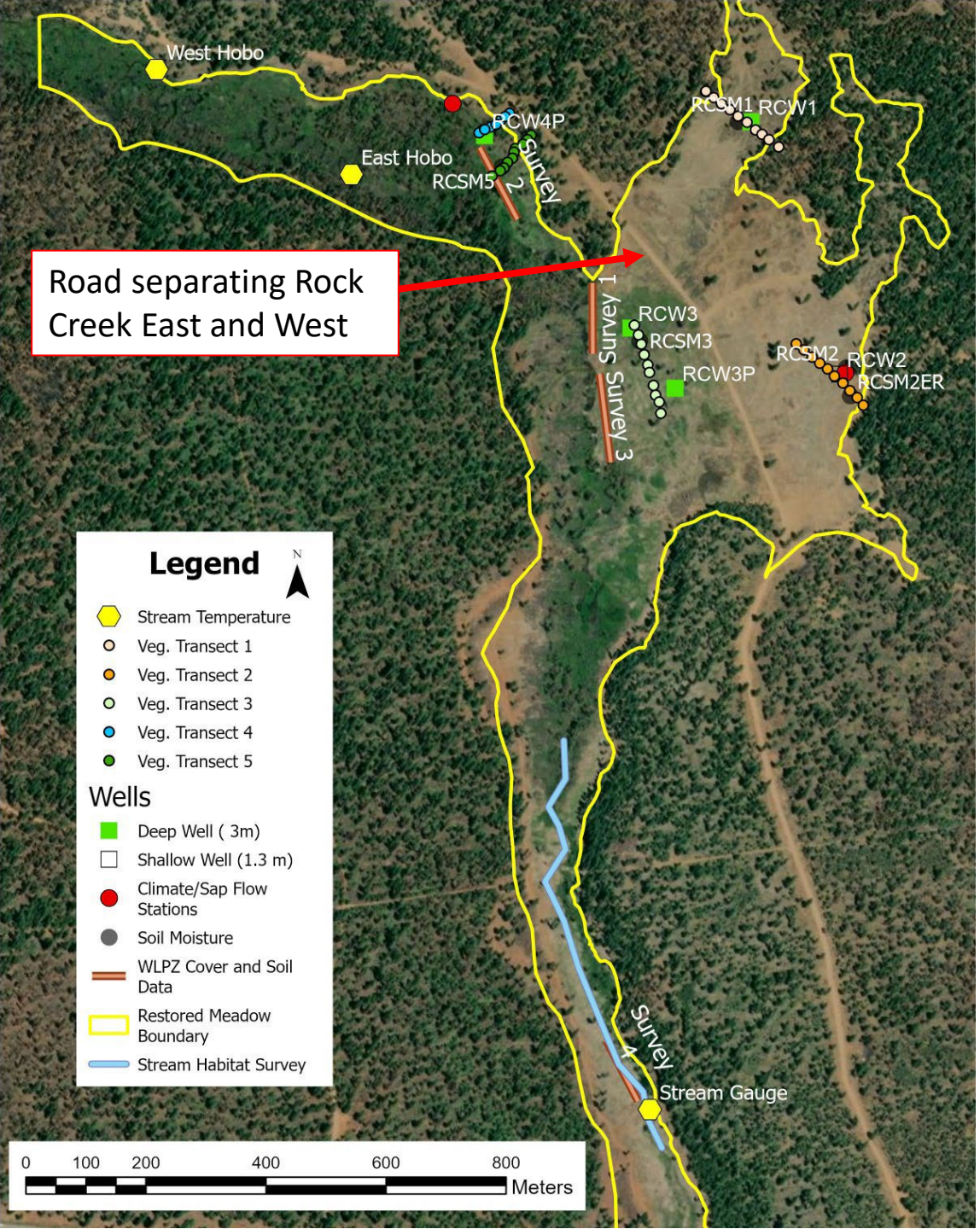
Objective 1. Quantify the hydrologic and vegetative response from removal of encroached *Pinus contorta* to restore meadow and wet area habitat across varied locations.

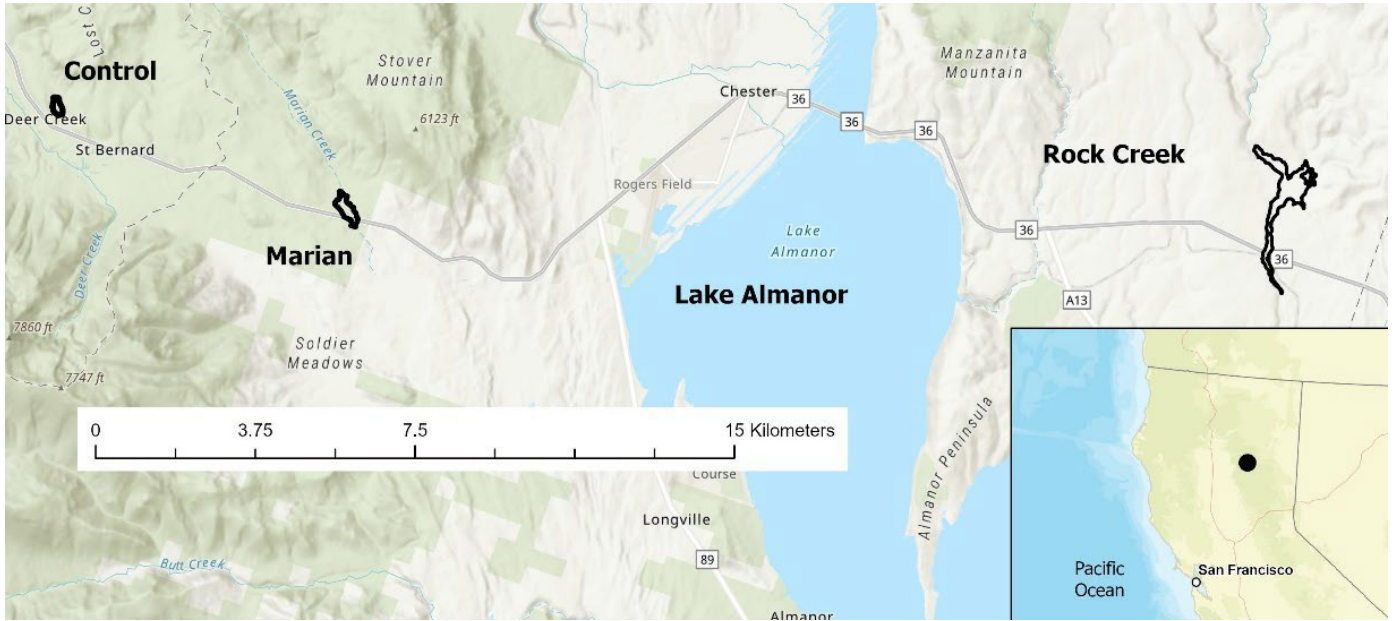
Objective 2. Determine if a key water quality metrics are affected by meadow restoration and WLPZ removal in Rock Creek Meadow by evaluation of streambed sediment and stream temperatures within or downstream of the restoration site.

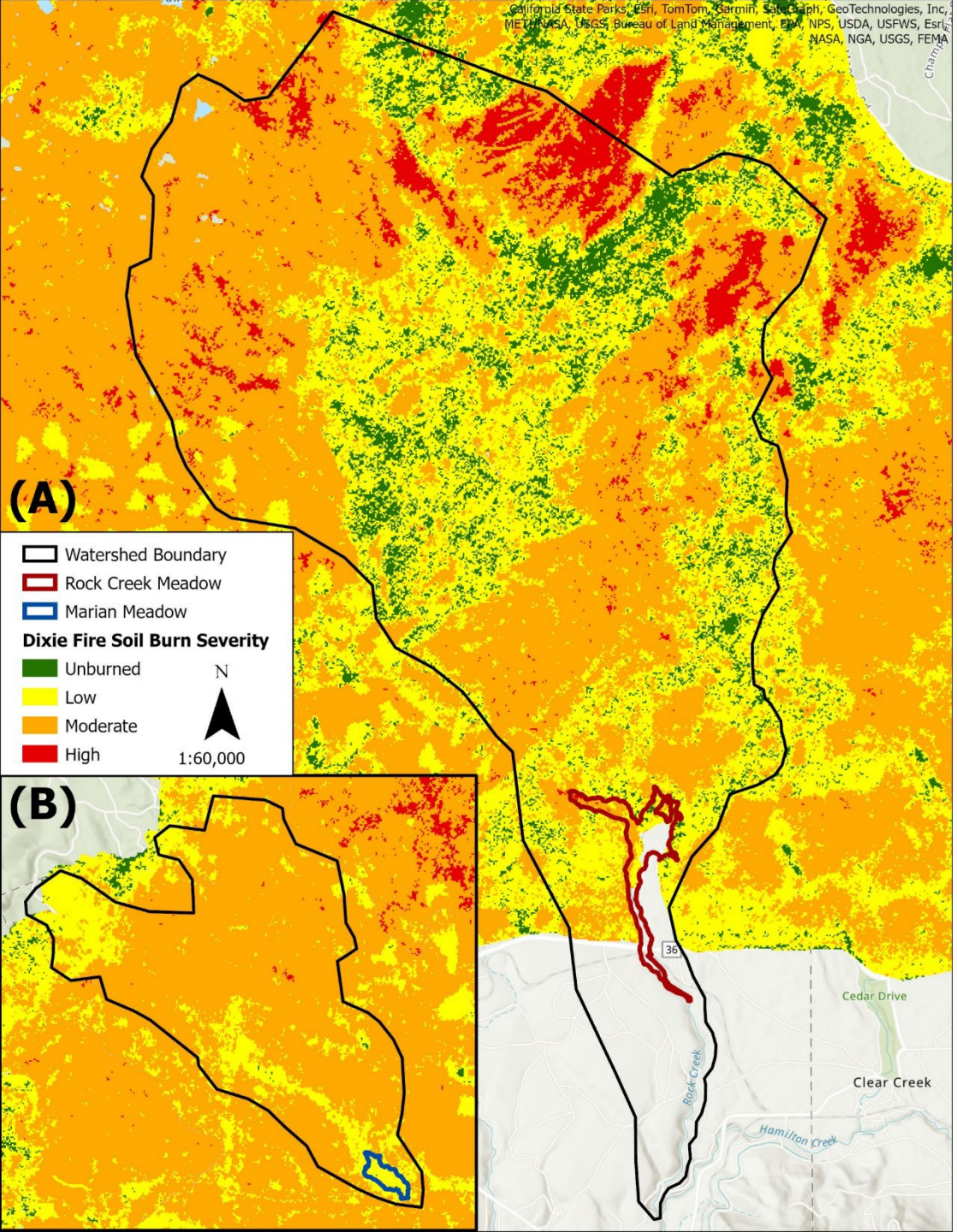
Objective 3. Quantify the amount of soil disturbance and compaction within the WLPZ and meadow following meadow restoration.

General Study Design

- Before-After Control-Intervention (BACI)
- Marian Meadow (MM) was used as a control for Rock Creek Meadow (RCM)
  - MM was previously restored via *Pinus contorta* removal in 2015
- Timber harvest occurred at the end of 2020
- Water Year (WY) is from Oct. 1st of previous year to Sept. 30th of reported year.







2021 Dixie Fire

- Between July and September 2021, the Dixie Fire burned 963,309 acres in California's Butte, Plumas, Shasta, Lassen, and Tehama counties (Cal Fire, 2022).
- Consumption of herbaceous meadow vegetation and the surrounding forested area will influence the meadow hydrology.

Meadow	Watershed Contributing Area km² (mile²)	Percentage Moderate and High Burn Severity in Watershed	Meadow Vegetation Post Fire
Rock Creek Meadow (RCM)	70.3 (27.2)	57%	Patches of burned vegetation with varied burn severity.
Marian Meadow (MM)	13.5 (5.2)	78%	Low burn severity in the meadow.

Objective 1. Quantify the hydrologic and vegetative response from removal of encroached *Pinus contorta* to restore meadow and wet area habitat across varied locations.

913.4, 933.4, 953.4 Special Prescriptions

(e) Aspen, and Meadows and Wet Areas restoration. All trees within aspen stands (defined as a location with the presence of living aspen (*Populus tremuloides*), Meadows and Wet Areas may be harvested or otherwise treated in order to restore, retain, or enhance these areas for ecological or range values….

(5) The RPF shall state the project goals and the measures of success for the proposed aspen, meadow, or wet area restoration project. For purposes of this subsection, measures of success means criteria related to a physical condition that can be measured using conventional forestry equipment or readily available technology to indicate the level of accomplishment of the project goals.

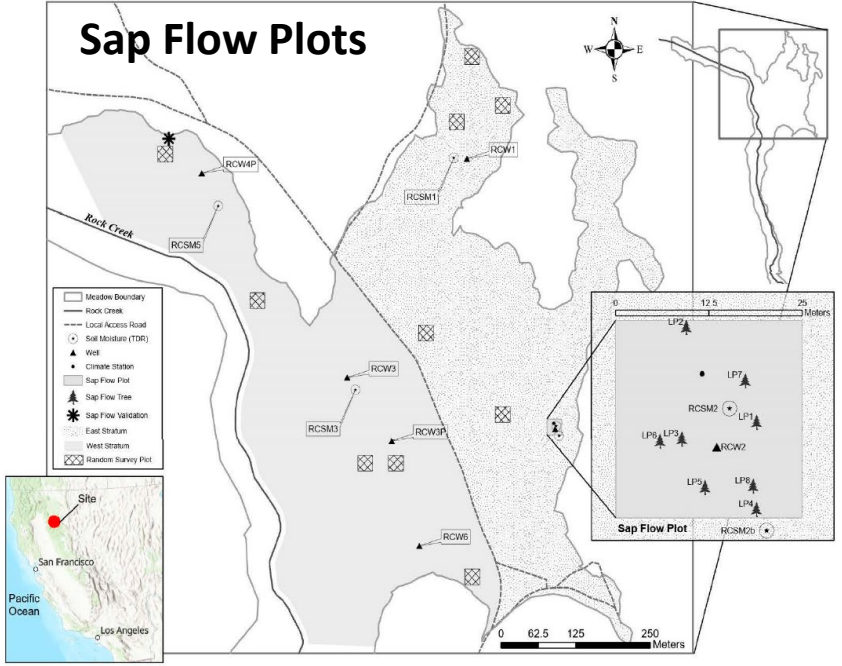
916.3, 936.3, 956.3 General Limitations Near Watercourses, Lakes, Marshes, Wet Meadows and Other Wet Areas [All Districts]

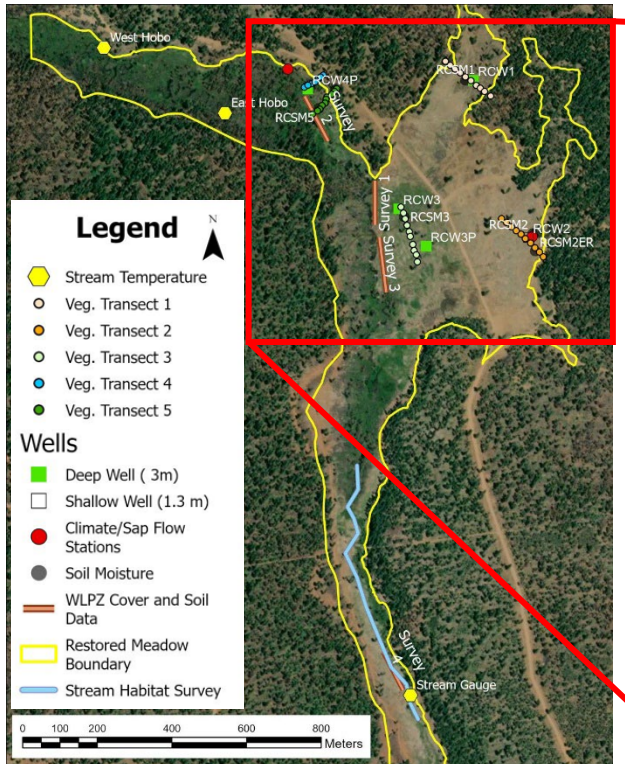
(d) Vegetation, other than commercial species, bordering and covering Meadows and Wet Areas shall be retained and protected during Timber Operations unless explained and justified in the THP and approved by the Director. Soil within the Meadows and Wet Areas shall be protected to the maximum extent possible.

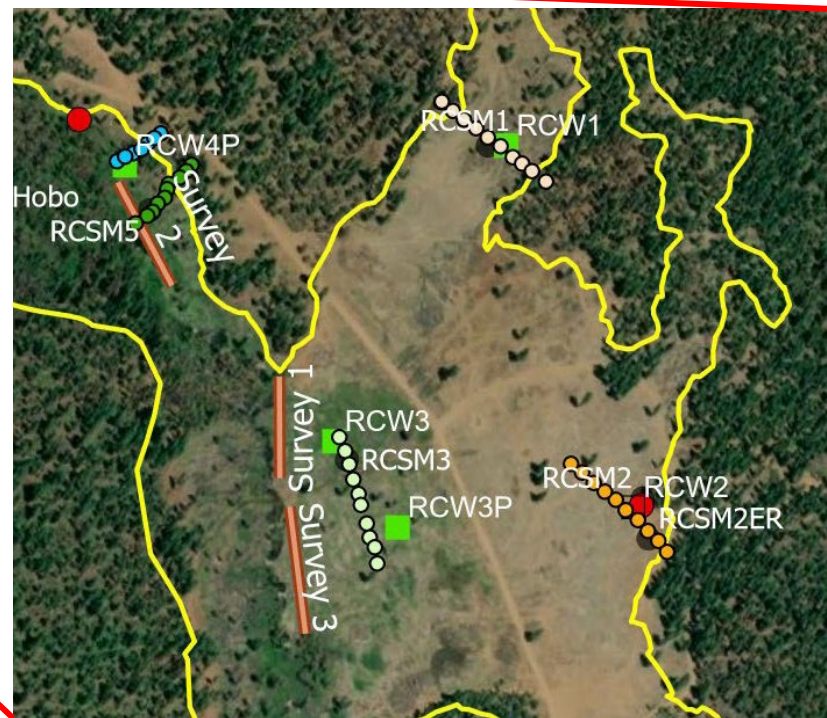
Objective 1. Study Design

- 6 Groundwater Wells
  - 1.3 to 3 m deep

  *One was crushed during harvest
- 4 Soil Moisture Probes
  - 10 to 100 cm deep
- Electrical resistivity 3-D and 2-D
- Sap flow (2019-2020)
- 5 Vegetation transects with 10 – 1 m^2 plots.







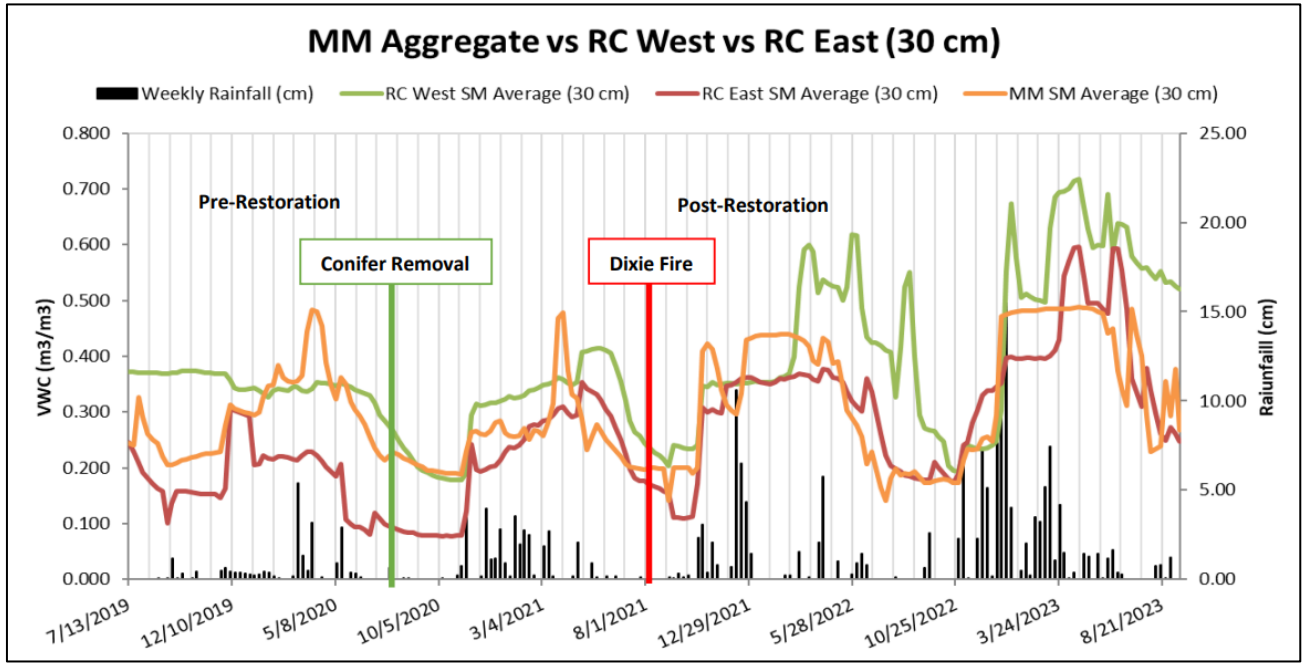
Hydrologic Response Key Results

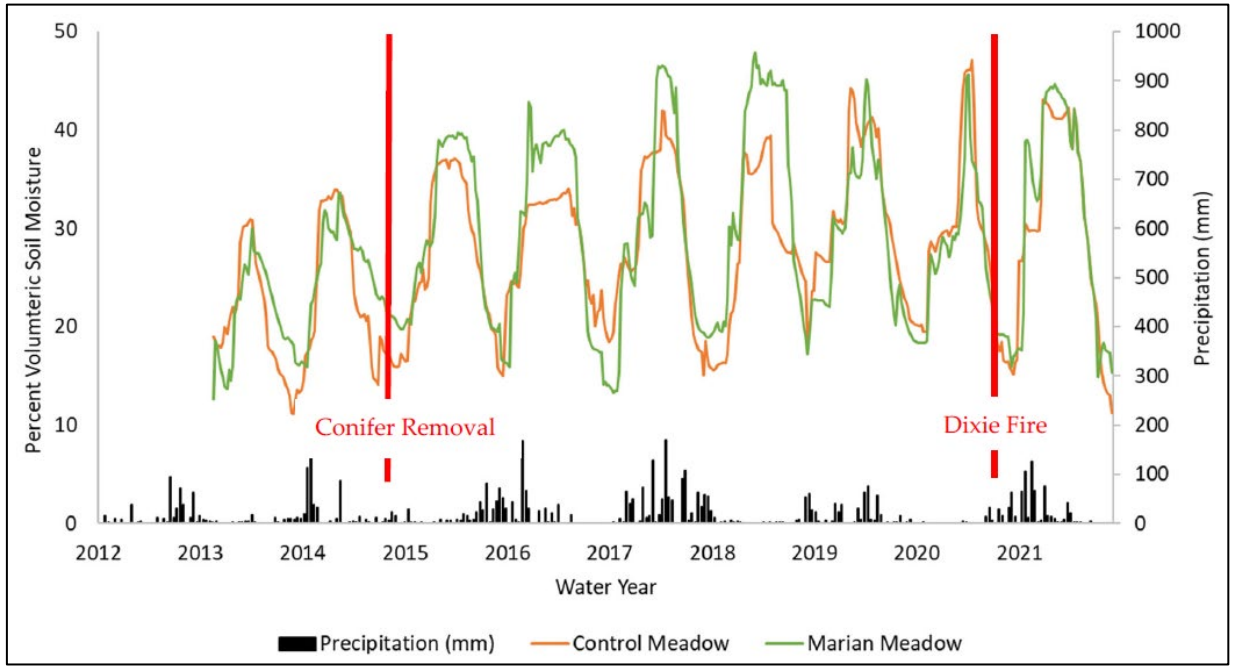
RCM Soil Moisture at 30 cm

- Increased soil moisture in RCM following *Pinus Contorta* removal.
- RCM west maintains a higher soil moisture content than RCM east almost year-round.
- Soil moisture significantly increased from 20% Year 1 post-restoration to 37% Year 2 post-restoration.

MM Soil Moisture at 30 cm

- Increased soil moisture in MM following *Pinus Contorta* removal.
- Each year post-restoration was significantly different than the pre-restoration model.



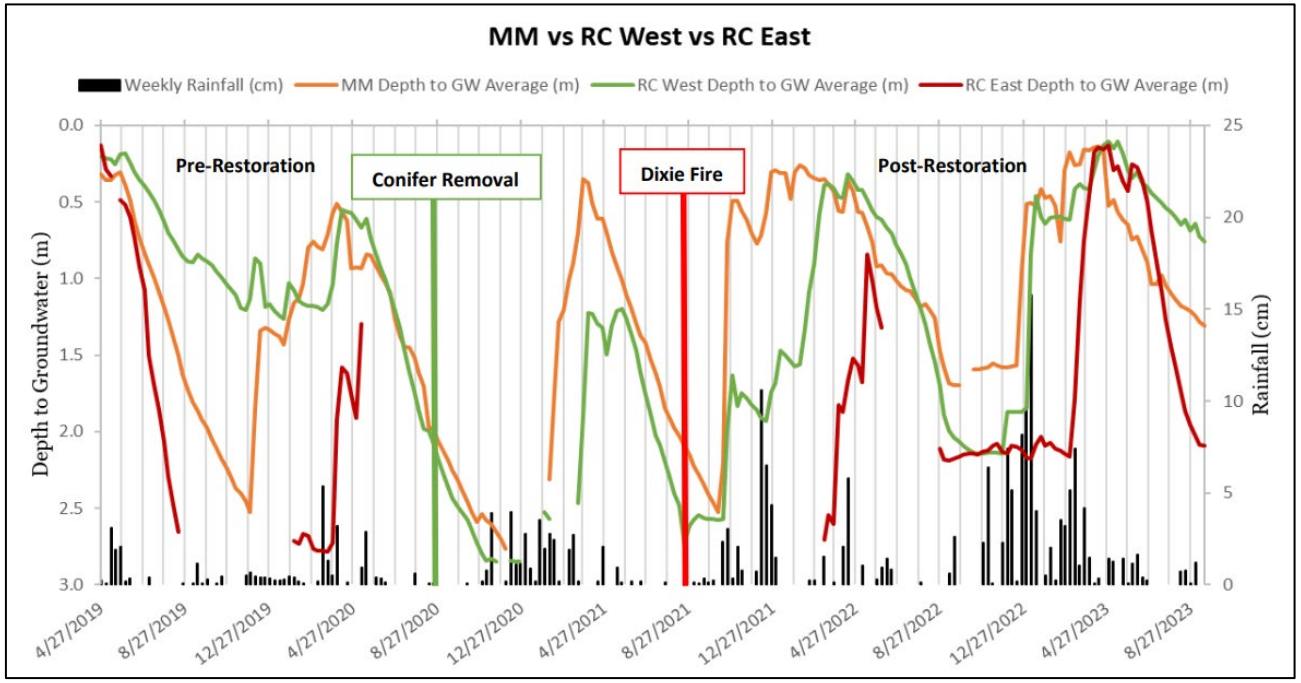


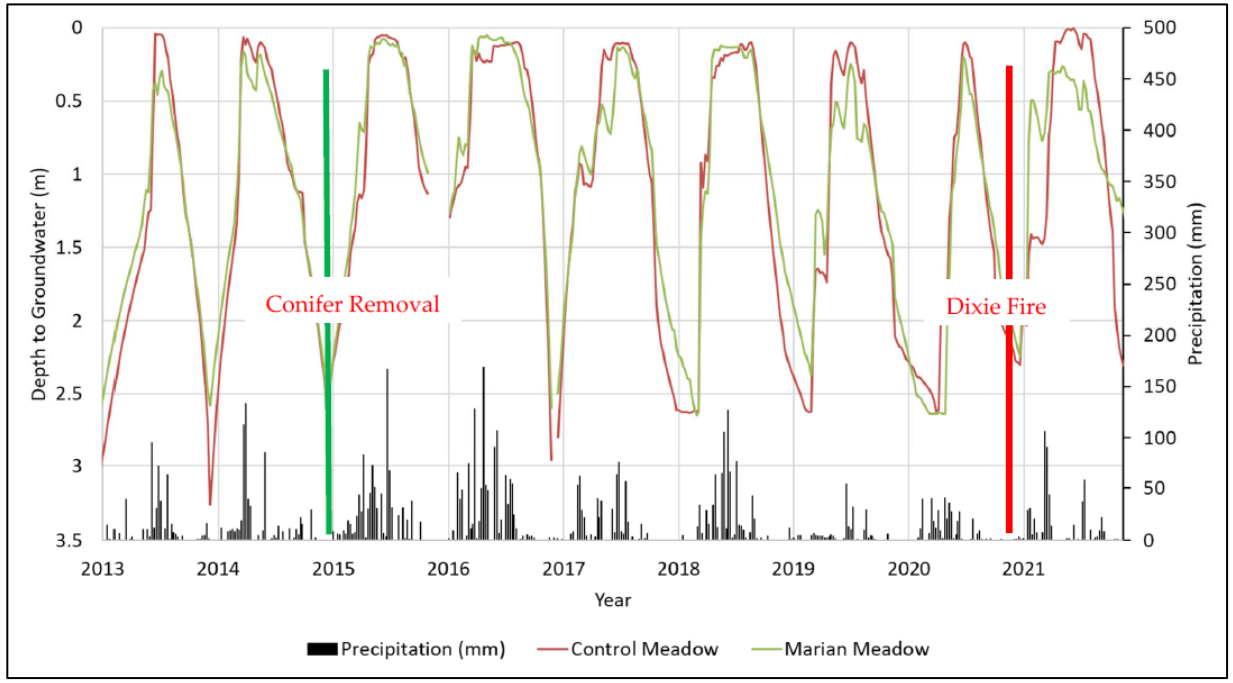
RCM Depth to Groundwater

- Significant increase in depth to groundwater from 1.04 m pre-restoration to 1.81 m Year 1 and 1.56 m Year 2 post-restoration.
- Year 3 post-restoration depth to groundwater decreased to 1.37 m from Year 1 post-restoration, which shows improvement in groundwater levels.

MM Depth to Groundwater

- Each year post-restoration was significantly different than the pre-restoration model.
- Average of 0.06 m closer to the surface following restoration.
- The water years of 2020 and 2021 had a greater depth to groundwater in MM compared to the control meadow.



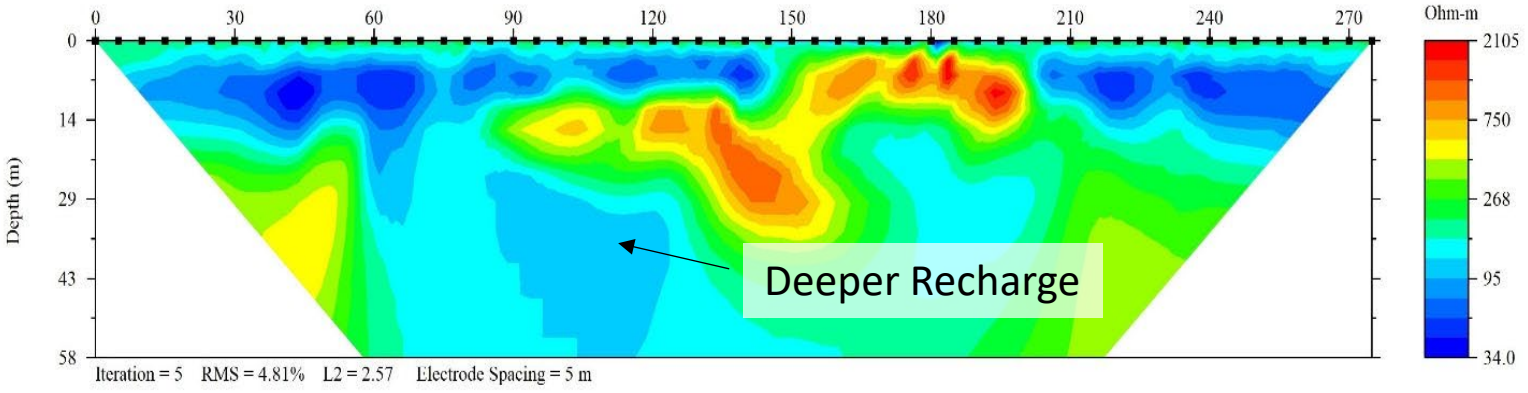


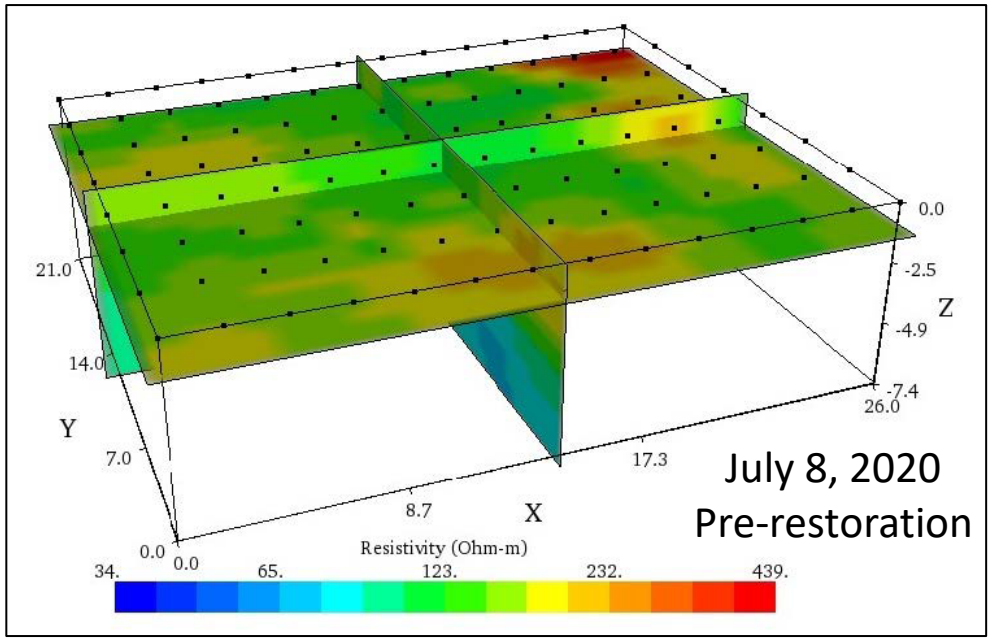
RCM Three-Dimensional Electrical Resistivity

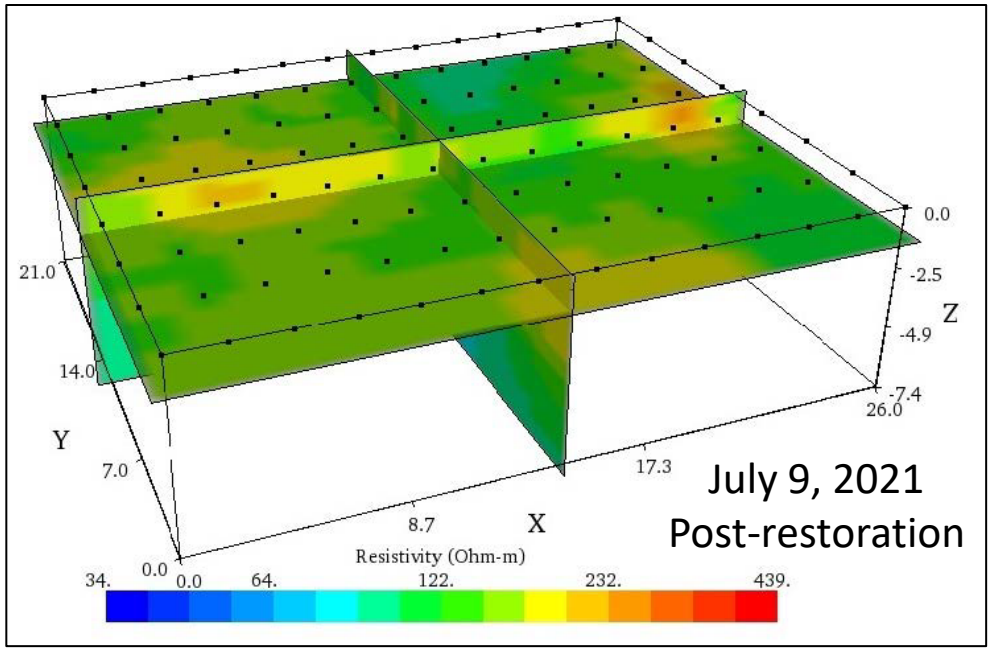
- Higher resistivity values (shown in red contours) are located where the thickest tree clumps of *Pinus contorta* existed prior to restoration.
- Moderate electrical resistivity values in green contours indicate sediments with varying amounts of saturation.

RCM Two-Dimensional Electrical Resistivity

- Large regions of high resistivity values (red contours) indicates igneous rock.
- Low resistivity values (blue contours) indicates sediment with varying amounts of clay minerals.





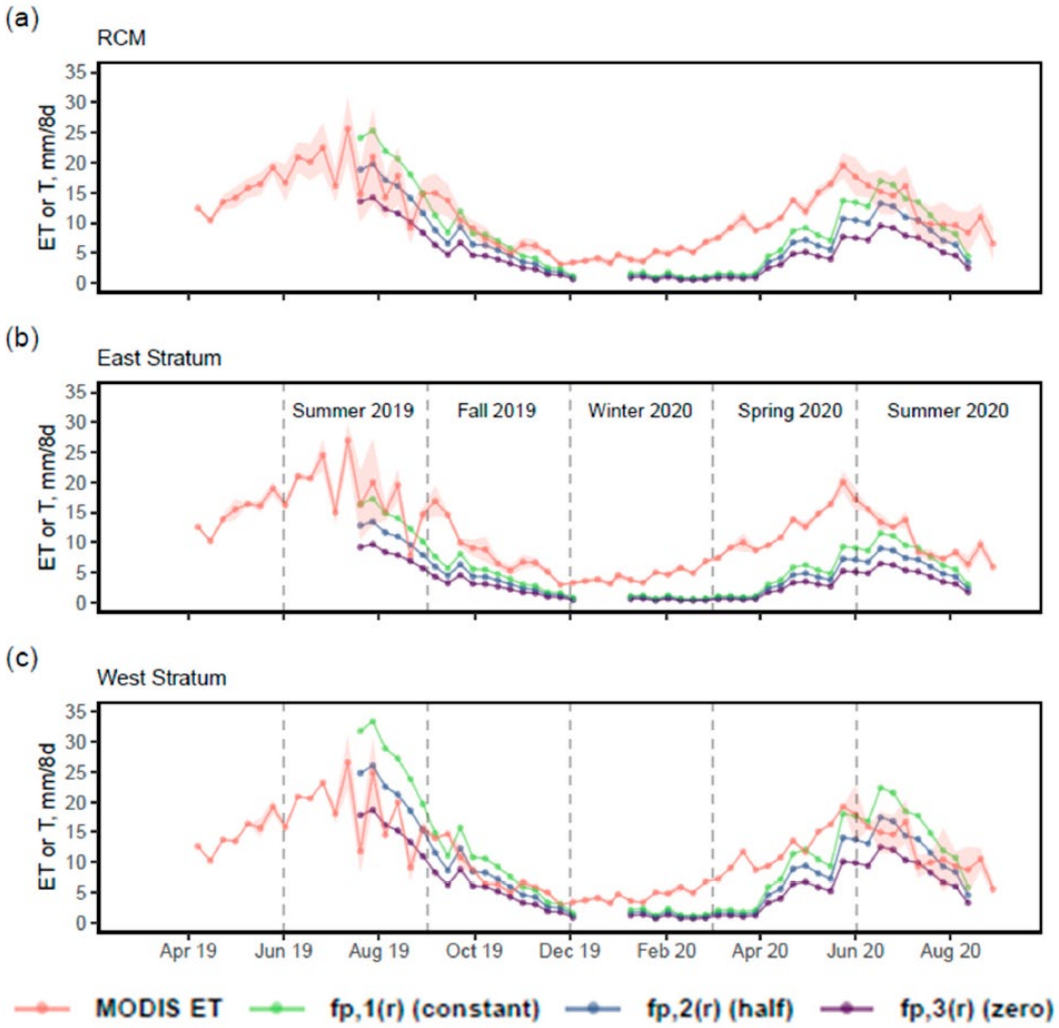


Note: Electrical Resistivity is negatively correlated with soil water content, so lower resistivity values indicate higher water content.

RCM *Pinus contorta* Transpiration by Sap Flow

- Monitored between mid-July 2019 to mid-August 2020
  - Eastern Stratum: 149.7 ± 12.1 mm
  - Western Stratum: 288.6 ± 54.7 mm
  - Average total: 220.5 ± 25.3 mm

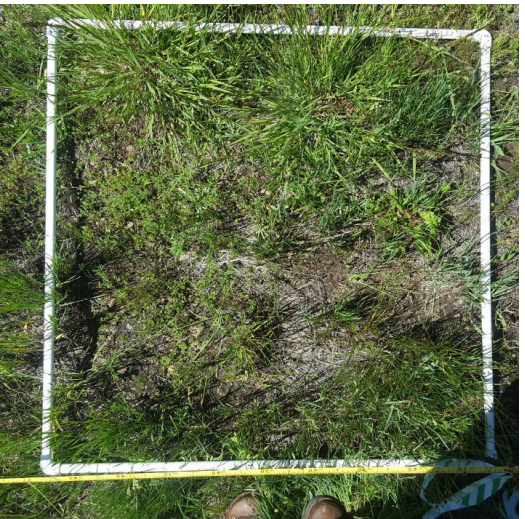
- **Indicates greater water gained by removal of *Pinus contorta*.**
- Validates western stratum being wetter than eastern stratum
- Indicates *Pinus contorta* near wilting point towards the end of the growing season in the Eastern Stratum



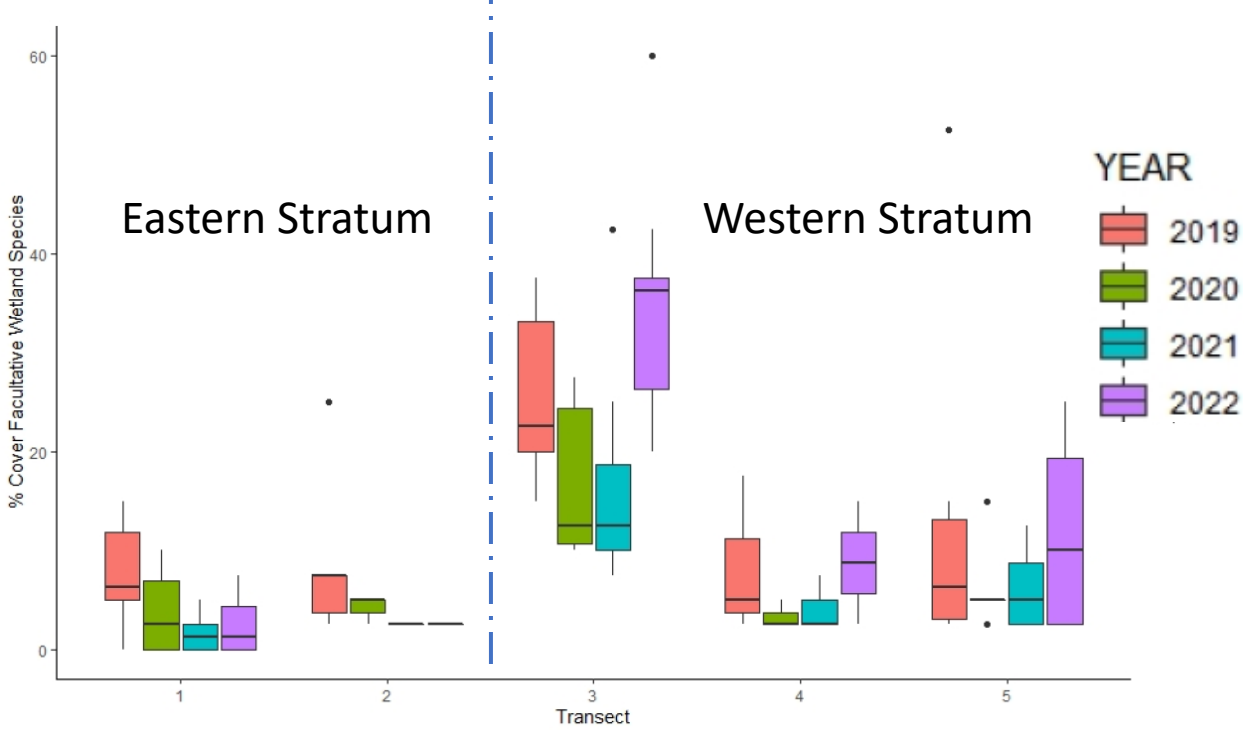
*Time series of 8-day composite MODIS ET estimates compared with 8-day composite *Pinus contorta* transpiration (T) estimates (Marks et al., 2024).

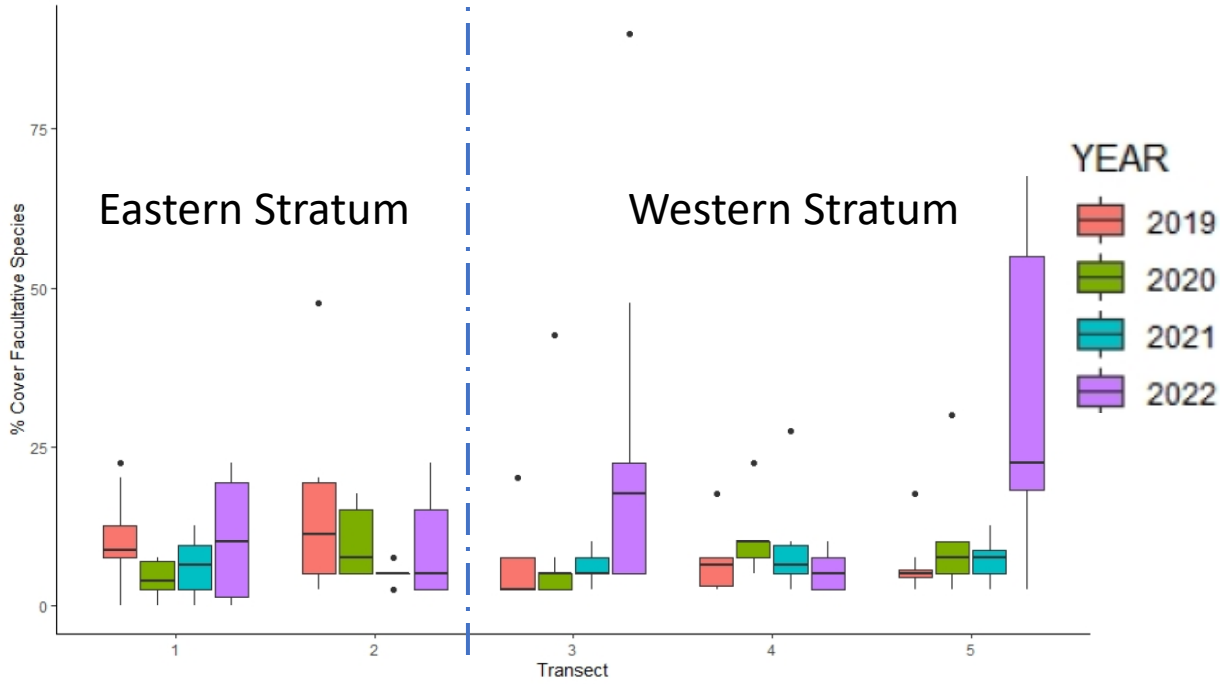
Vegetative Response Key Results

- Decrease in % cover of facultative wetland species first year post-restoration across the meadow.
- Increase in % cover of facultative wetland species by the third-year post-restoration in the Western portion.
- **Overall increase in total facultative vegetation cover across transects**
- Transect 2 had the greatest ground disturbance following tree removal (2021) and there was a fire road bulldozed through it during Dixie Fire suppression activities (2022).



- 2019 and 2020 surveys were pre-restoration.
- No seeding was done post-harvest.
- Precipitation in WY2019 was almost equal that of WY 2020 – 2022 combined.

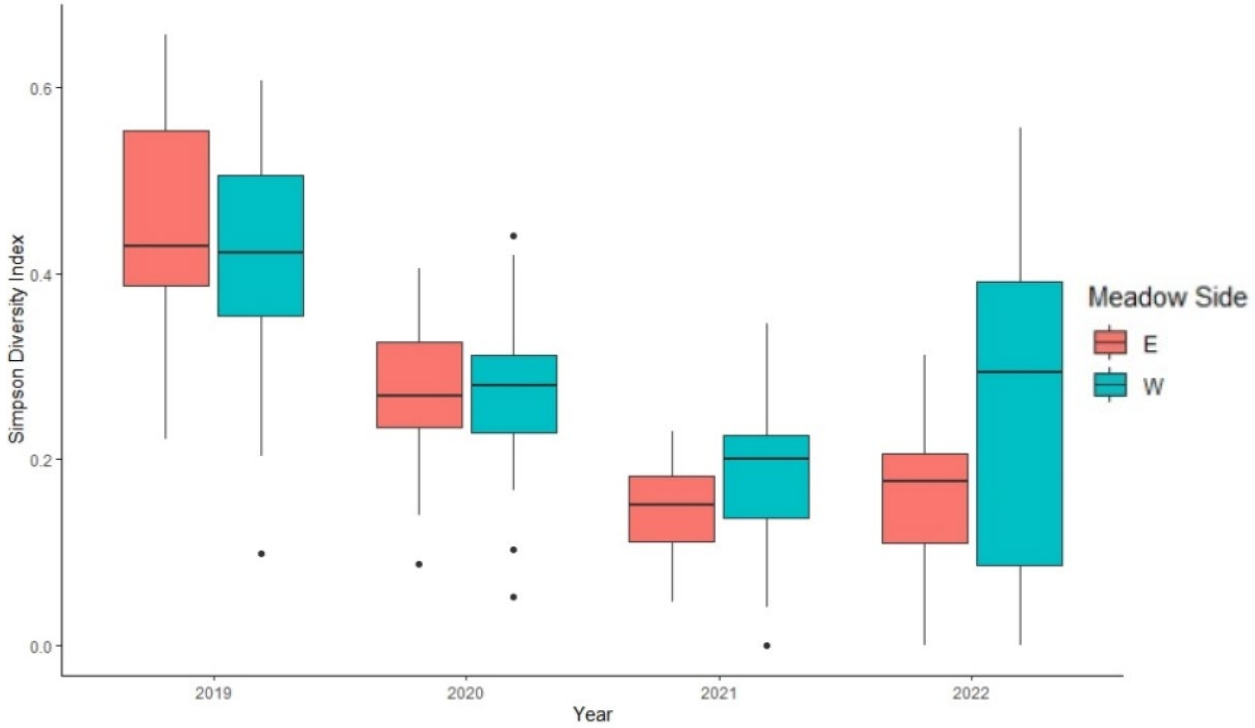


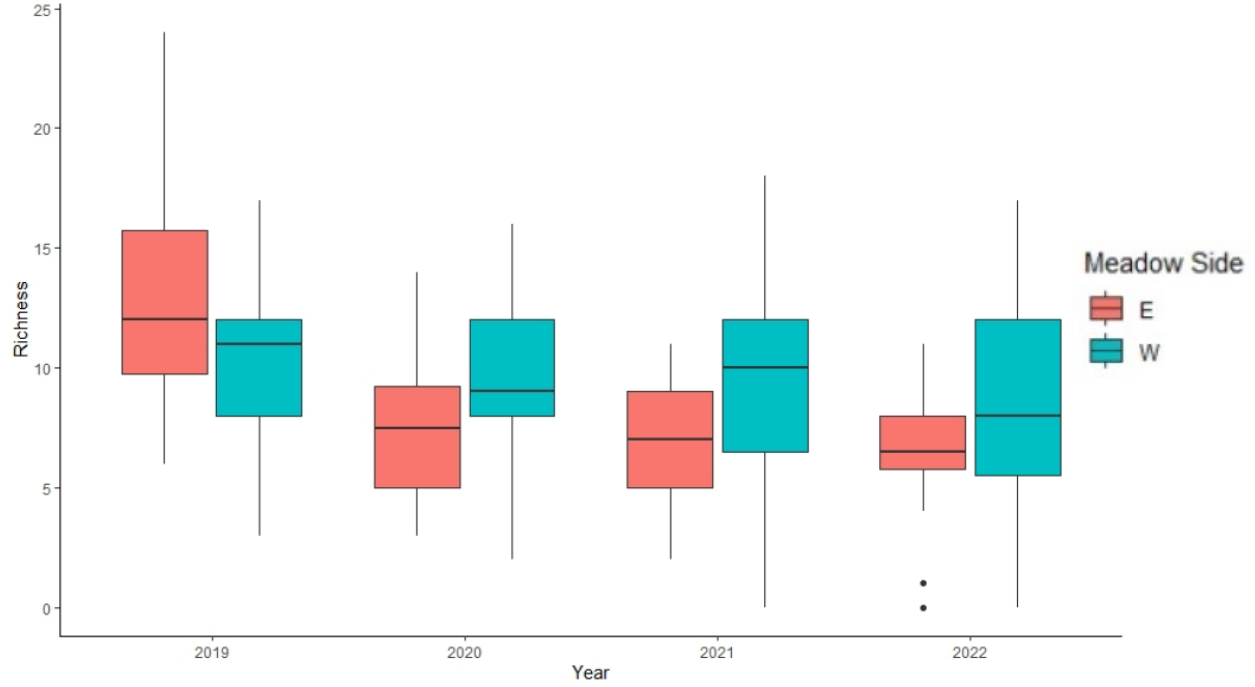


Vegetative Response Key Results

- Slight decrease in species richness in the eastern portion, with little change in the western portion.
- Reduction in Simpson and Shannon-Weiner Diversity indices with some recovery in 2022.
- Meadow vegetative recovery appears to be limited due to dry weather and disturbance from the 2021 Dixie Fire.

Fire road through meadow (fall 2021)





Limitations

- Only one year of pre-restoration data (WY 2020)
- Extreme drought conditions between WY 2020-2022

WY	Total Precipitation (mm)	Min Temp. (°C)	Max Temp. (°C)	Average Temp. (°C)
2019	1,019.05	-17.78	36.11	8.00
2020	210.31	-15.00	37.22	8.96
Restoration				
2021	350.52	-17.78	38.33	9.17
2022	500.89	-17.78	38.89	9.20
2023	1,035.30	-17.78	37.78	7.49

*Data was collected from the USFS's *Chester* climate station (40.283°, -121.233°) in Chester, CA (DWR, n.d.).

Limitations

- While MM was a reasonable control; a 500 ft elevation difference could impact recharge timing (snow melt timing).
- Differences in watershed size and meadow size could also impact water inputs and outputs

	Marian Meadow	Rock Creek Meadow
Area of Meadow	111 ha (45 ac)	457 ha (185 ac)
Area of contributing watershed	1,943 ha (7.5 mi^2)	6,735 ha (26.0 mi^2)
Elevation	1,375 m (4,500 ft)	1,525 m (5,000 ft)
Surface soil texture	Clay	*West side: Loam *East side: Gravelly Sandy Loam
Pre-restoration *Pinus contorta* basal area	25 m^3/ha (109 ft^2/ac)	*West side: 29 m^3/ha (127 ft^2/ac) *East side: 25 m^3/ha (109 ft^2/ac)

*Table adapted from EMC-2018-003 Alternative Meadow Restoration Final Report (Surfleet, 2023).

Objective 2. Determine if a key water quality metrics are affected by meadow restoration and WLPZ removal in Rock Creek Meadow by evaluation of streambed sediment and stream temperatures within or downstream of the restoration site.

916.3, 936.3, 956.3 General Limitations Near Watercourses, Lakes, Marshes, Wet Meadows and Other Wet Areas [All Districts]

The quality and beneficial uses of water shall not be unreasonably degraded by Timber Operations. During Timber Operations, the Timber Operator shall not place, discharge, or dispose of or deposit in such a manner as to permit to pass into the water of this state, any substances or materials, including, but not limited to, soil, silt, bark, Slash, sawdust, or petroleum, in quantities deleterious to fish, wildlife, or the quality and beneficial uses of water. All provisions of this article shall be applied in a manner which complies with this standard.

916.4, 936.4, 956.4 Watercourse and Lake Protection [All Districts]

(b) The standard width of the WLPZ and/or the associated basic protection measures shall be determined from Table I (14 CCR §§ 916.5, 936.5, 956.5) or §§ 916.4(c), 956.4(c), 956.4(c), and shall be stated in the plan. A combination of the Rules, the plan, and mitigation measures shall provide protection for the following:

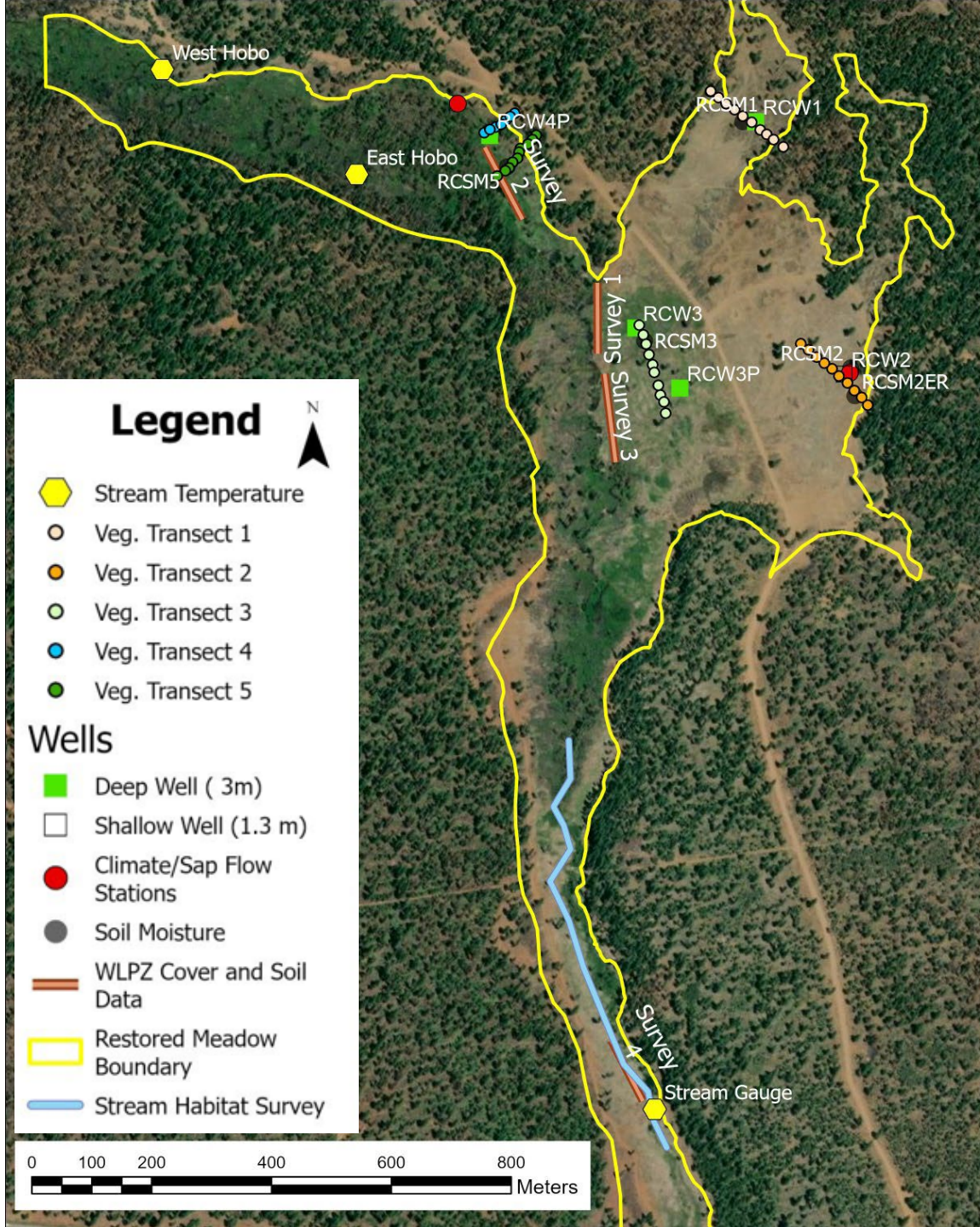
a. Water temperature control.

…

f. Spawning and rearing habitat for salmonids

Objective 2. Study Design

- 3 Stream Temperature Gauge (2017-2022)
  - 2 upstream of harvest (East & West Hobo)
  - 1 downstream stream gauge
- A pre-restoration (July 2019) and post-restoration (April 2022) 2,215 foot Habitat Survey included:
  - Pool:riffle percentage
  - Residual pool depths
  - Five 100 ft Particle size measurements
    - Cobble embeddedness for cobble sized particles (64-256 mm) were collected during this portion.
- Methodologies for monitoring water temperature and streambed condition consistent with Technical Rule Addendum #2.



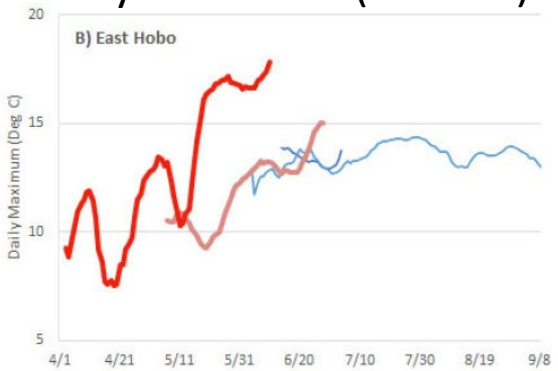
Stream Temperature Response

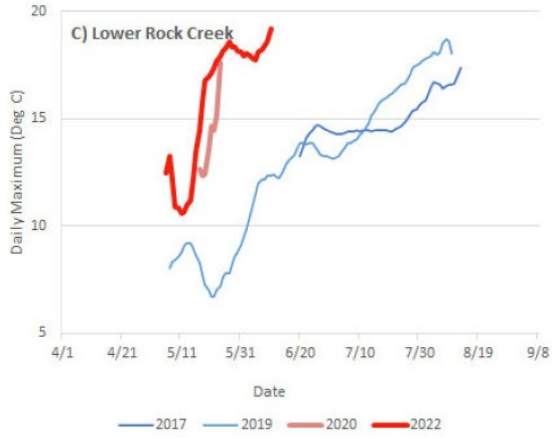
- 2017-2020 were pre-restoration.
- 2022 was post-restoration and post-fire.
- There was no streamflow in 2021 due to drought.
- Impacts from harvest are largely inconclusive regarding meadow restoration due to fire.
- Stream temps post Dixie Fire exceeded 18°C (target for steelhead trout) .

Upstream after fire (summer 2022)

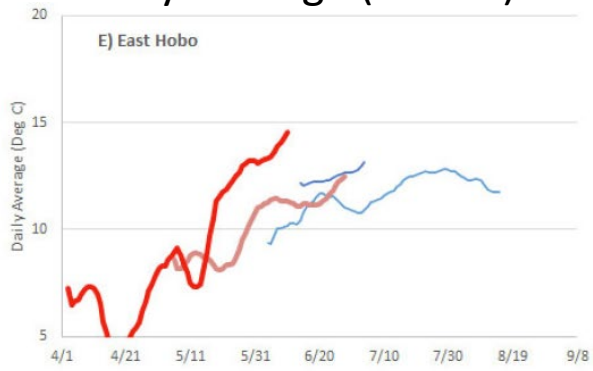
Year	Location	MWAT (C°)	MWMT (C°)
2017	Upstream - East, West Hobos	-	-
	Downstream – Lower Rock Creek	13.8	17.4
2018	Upstream - East, West Hobos	13.2, 11.3	13.9, 13.0
	Downstream – Lower Rock Creek	-	-
2019	Upstream - East, West Hobos	13.0, 13.1	14.4, 16.9
	Downstream – Lower Rock Creek	14.9	18.7
2020	Upstream - East, West Hobos	15.7, 15.7	15.2, 14.7
	Downstream – Lower Rock Creek	14.2	17.6
2022	Upstream - East, West	14.6, 14.1	17.8, 16.1
	Downstream – Lower Rock Creek	15.4	19.2

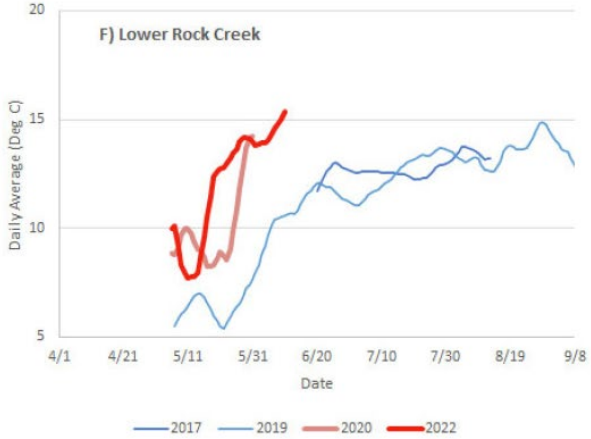
Daily Maximum (MWMT) C°





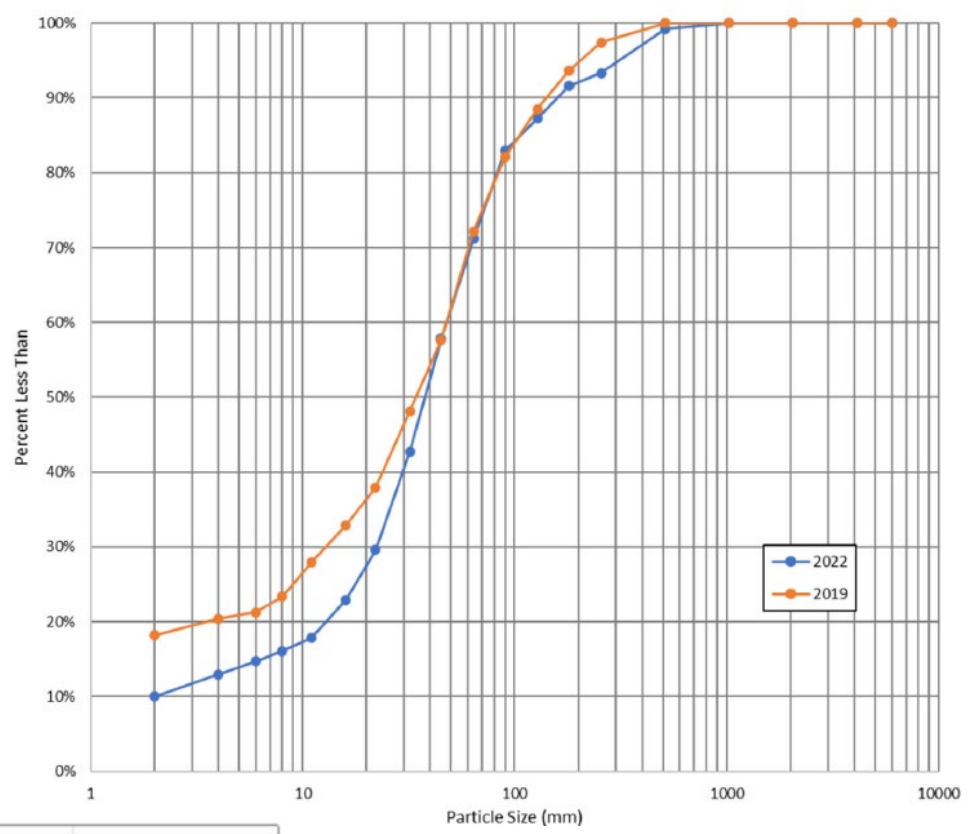
Daily Average (MWAT) C°

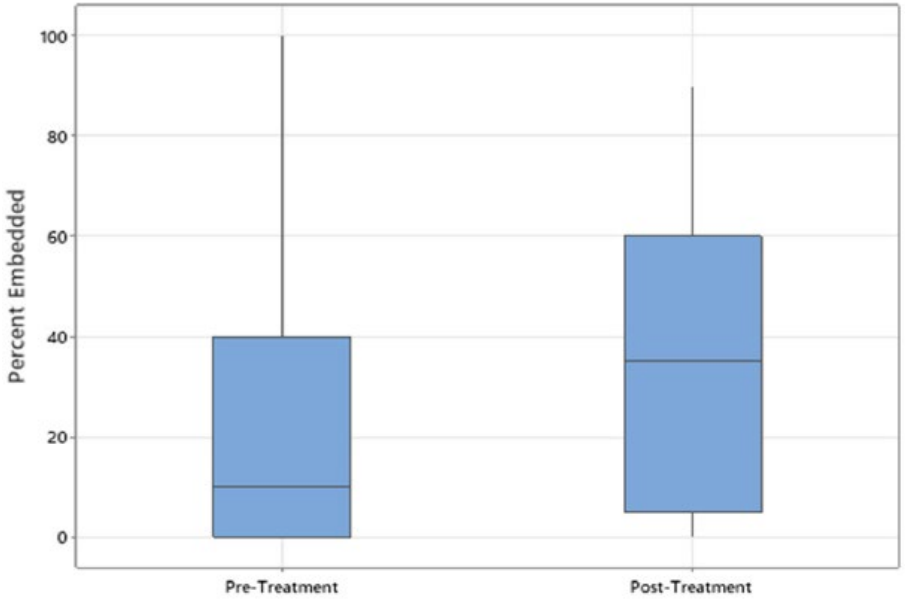


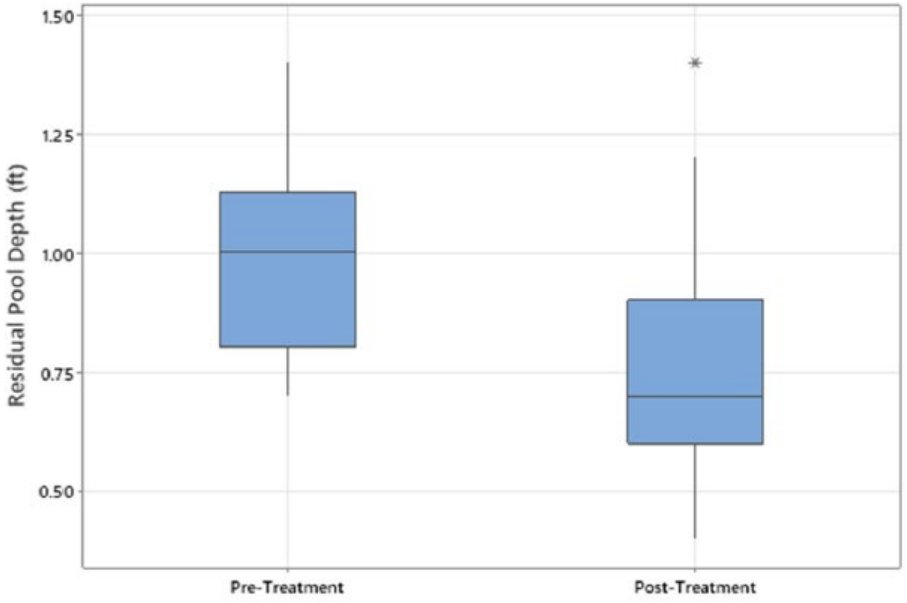


Stream Sediment & Habitat Response

- Post-treatment data was collected in 2022 after the 2021 Dixie Fire, so findings are largely inconclusive regarding meadow restoration.
- Significant increase in cobble embeddedness by 14%.
- Significant decrease in residual pool depth by 0.24 ft.
- Sediment distribution became coarser.
- Findings indicate reduced pool habitat and increased sediment supply (mostly coarse sediment) following treatment and fire







Objective 3. Quantify the amount of soil disturbance and compaction within the WLPZ and meadow following meadow restoration.

916.3, 936.3, 956.3 General Limitations Near Watercourses, Lakes, Marshes, Wet Meadows and Other Wet Areas [All Districts]

(c) The Timber Operator shall not construct or use tractor roads in Class I, II, III or IV Watercourses, in the WLPZ, marshes, Wet Meadows, and Other Wet Areas unless explained and justified in the plan by the RPF, and approved by the Director…

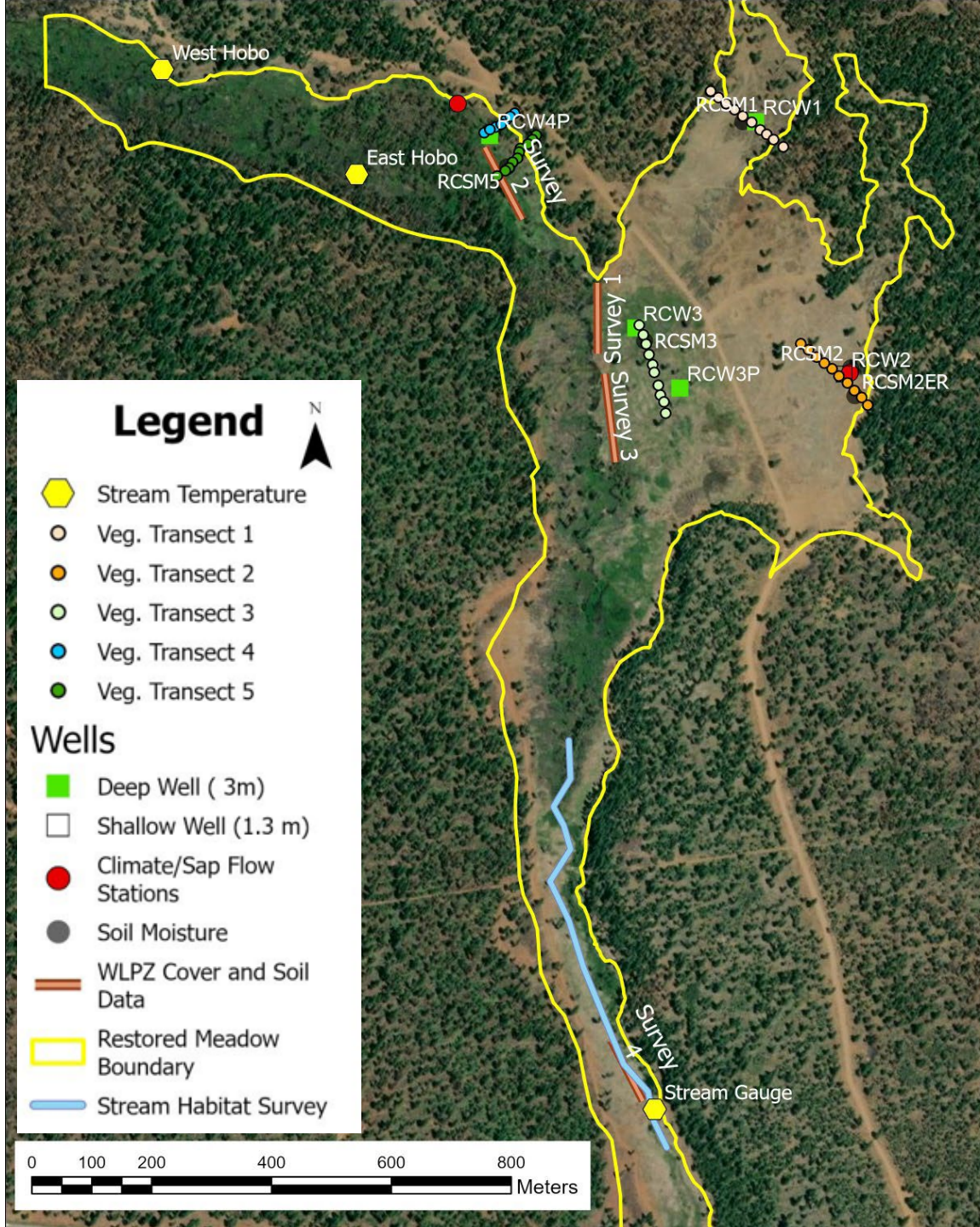
(d) Vegetation, other than commercial species, bordering and covering Meadows and Wet Areas shall be retained and protected during Timber Operations unless explained and justified in the THP and approved by the Director. Soil within the Meadows and Wet Areas shall be protected to the maximum extent possible.

916.4, 936.4, 956.4 Watercourse and Lake Protection [All Districts]

(6) Within the WLPZ, at least 75% surface cover and undisturbed area shall be retained to act as a filter strip for raindrop energy dissipation, and for wildlife habitat. This percentage may be adjusted to meet site specific conditions when proposed by the RPF and approved by the Director or where Broadcast Burning is conducted under the terms of a project type burning permit and in compliance with 14 CCR §§ 915.2(b), 935.2(b), 955.2(b).

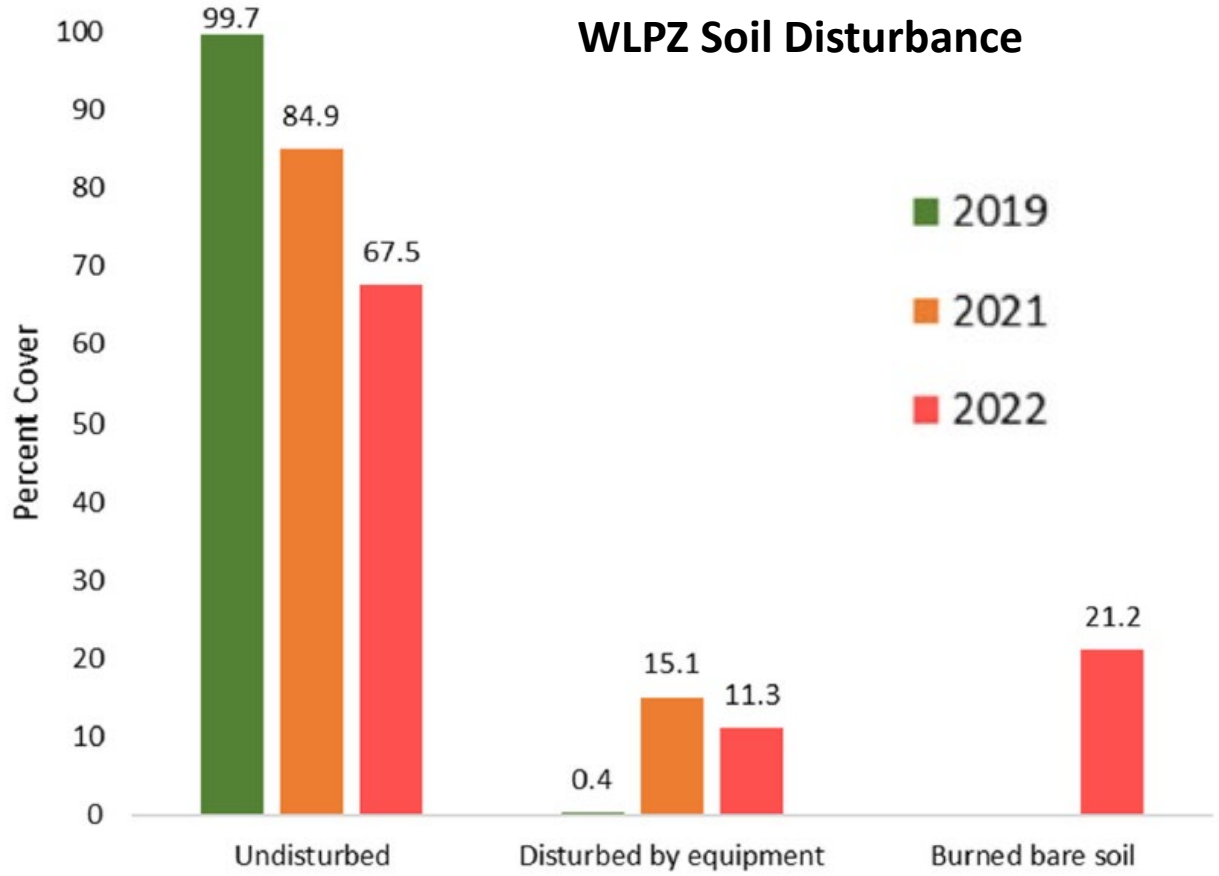
Objective 3. Study Design

- 4 ground cover surveys in the WLPZ
  - At each location three 500 foot transects were made parallel to the watercourse at 30, 50 & 70 ft.
  - Ground cover was collected in 1-foot increments
- Soil bulk density samples were taken in the WLPZ along each line transect (30, 50, and 70 feet).
  - In each line two random samples were taken in undisturbed soils and two random samples were taken in disturbed soils.
  - Soil sampled was approximately 2 inches below the ground surface.
- The percentage of bare soil in the Meadow was collected along the 5 vegetation transects.



Soil Cover Impacts

- Soil cover in the WLPZ was slightly disturbed by logging equipment following treatment (2021).
- Evidence of equipment disturbance decreased by 4% in the following year (2022).
- There was greater disturbance due to burnt soil from the 2021 Dixie Fire.
- Post-treatment and pre-fire (2021) the western portion of the meadow had 2-3 times less bare soil than the eastern portion.



WLPZ Soil Disturbance (bare soil)

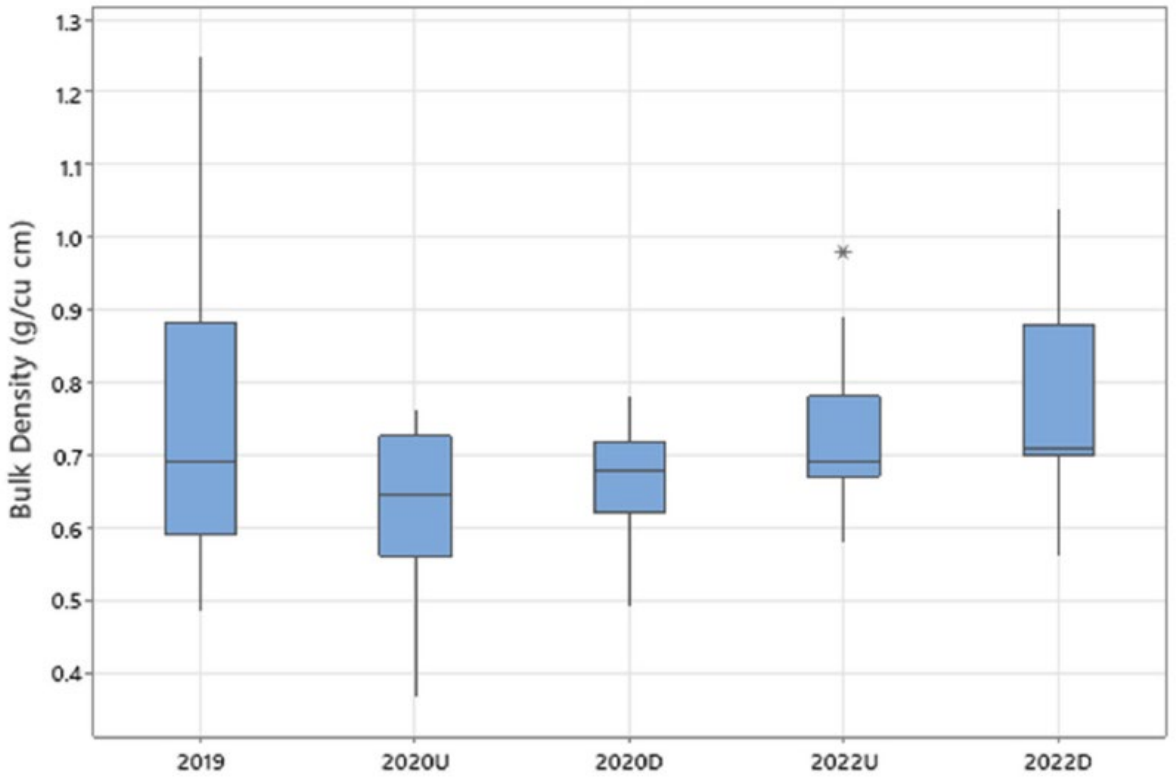
Year	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5
2019	9%	18%	0%	4%	1%
2020	7%	35%*	0%	2%	2%
2021	28%	39%	1%	4%	3%
2022	47%	48%	12%	25%	37%

*Field crew disturbed soil prior to measurement (Surfleet, 2023)

Undisturbed (fully covered)	Disturbed (uncovered)	Burnt
Vegetation	Equipment or vehicle tracks	Bare and scorched soil
Litter	Divots from tree yarding	Fire road – created for Dixie fire suppression
Rock or gravel	Road	
Bare soil from natural conditions		

Soil Compaction Impacts

- Soil bulk density values in the WLPZ remained relatively unchanged.
- No significant changes.
- This is partially attributed to high organic matter in the WLPZ.
- Equipment limitations within the WLPZ also focused on keeping the density of trails minimal, equipment tracks perpendicular to the watercourse, and off stream banks.



Measurement	Mean Bulk Density (g/cm^3)	Standard Deviation (g/cm^3)	Degrees of Freedom	P-Value
Pre-treatment	0.75	0.22	-	-
Post-treatment Undisturbed Fall 2020	0.63	0.12	22	0.35
Post treatment Disturbed Fall 2020	0.67	0.08	18	0.71
Post treatment Undisturbed Summer 2022	0.73	0.11	30	0.70
Post treatment Disturbed Summer 2022	0.77	0.13	32	0.76

Synthesis of Key Findings

Objective 1. Quantify the hydrologic and vegetative response from removal of encroached *Pinus contorta*…

- Hydrological effects of tree removal were generally positive across years.
  - Soil moisture consistently increased following treatment for RCM and MM.
  - Groundwater at RCM decreased in the first two years following restoration with some recovery in the third. This coupled with MM's increase in groundwater following treatment indicates there may be some drought response.
- Vegetation response seemed mixed, but generally positive or neutral.
  - The western portion of RCM saw an increase in facultative wetland vegetation in the third year following treatment. A lack of recovery in the first two years after treatment coincides with drought years.
- The drier eastern part of RCM appeared to have a slower and less significant recovery in vegetation and water availability.

Objective 2. Determine if a key water quality metrics are affected by meadow restoration and WLPZ removal…

- Effects of specific treatment on water quality metrics were difficult to disentangle from the effects of the Dixie Fire, and thus largely inconclusive.

Objective 3. Quantify the amount of soil disturbance and compaction…

- Vegetation cover surveys and soil bulk density analysis generally did not show substantial impacts of restoration treatment.
  - 15% WLPZ cover disturbed by treatment in 2021, an additional 21% by fire in 2022.
  - Greater impacts to soil cover were exhibited outside of the WLPZ in the eastern portion of RCM which had 2-3 times more bare soil than the western portion.
  - Soil bulk density values in the WLPZ remained relatively unchanged.

How does the study inform the Forest Practice Rules?

913.4, 933.4, 953.4 Special Prescriptions

(e) Aspen, and Meadows and Wet Areas restoration. All trees within aspen stands (defined as a location with the presence of living aspen (*Populus tremuloides*), Meadows and Wet Areas may be harvested or otherwise treated in order to restore, retain, or enhance these areas for ecological or range values….

(5) The RPF shall state the project goals and the measures of success for the proposed aspen, meadow, or wet area restoration project. For purposes of this subsection, measures of success means criteria related to a physical condition that can be measured using conventional forestry equipment or readily available technology to indicate the level of accomplishment of the project goals.

- **The results from Objective 1 validate the use of 14 CCR § 913.4, 933.4, 953.4 (e) to harvest of all trees within meadows "in order to restore, retain, or enhance these areas for ecological or range values".**
- Establishes that there can be some complexity in measuring the success of a project due to natural disturbances (e.g. wildfire and drought).
- Establishes some metrics related to various physical conditions "that can be measured using conventional forestry equipment or readily available technology."

916.1, 936.1, 956.1 In Lieu Practices [All Districts]

(a) The in lieu practice(s) must provide for the protection of the beneficial uses of water to the standards of 14 CCR§§ 916.3, 936.3, 956.3 and 916.4(b), 936.4(b), 956.4(b).

916.3, 936.3, 956.3 General Limitations Near Watercourses, Lakes, Marshes, Wet Meadows and Other Wet Areas [All Districts]

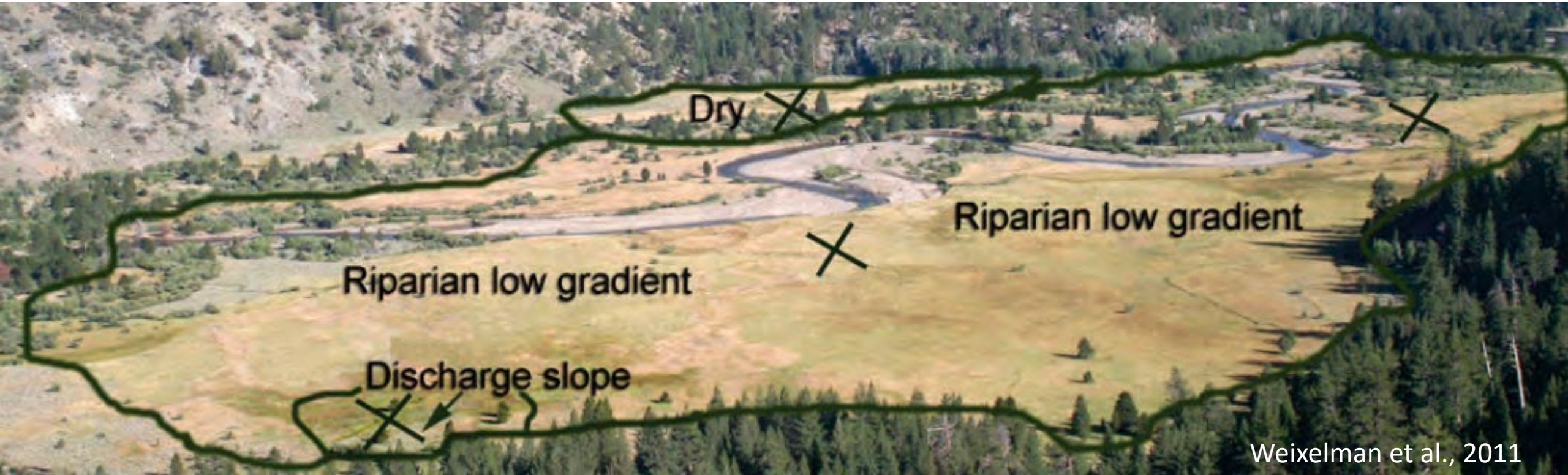
(c) The Timber Operator shall not construct or use tractor roads in Class I, II, III or IV Watercourses, in the WLPZ, marshes, Wet Meadows, and Other Wet Areas unless explained and justified in the plan by the RPF, and approved by the Director

(d) Vegetation, other than commercial species, bordering and covering Meadows and Wet Areas shall be retained and protected during Timber Operations unless explained and justified in the THP and approved by the Director. Soil within the Meadows and Wet Areas shall be protected to the maximum extent possible.

- **The results from Objective 3 validate the use of In Lieu Practices (14 CCR § 916.1, 936.1, 956.1(a)) to harvest trees within the WLPZ for meadow restoration.**
- Soil cover disturbance within the wetter meadow side was less than that of the drier portion, indicating more substantial precautions taken near the WLPZ. This is further validated by the lack of change in soil compaction within the WLPZ.
- Equipment limitations within the WLPZ also focused on keeping the density of trails minimal, equipment tracks perpendicular to the watercourse, and off stream banks appeared to work.
- Tractors and skidders allowed to operate within WLPZ during extended dry period or under hard frozen conditions.

Overlap between Meadow Restoration and WLPZ

- This study established that when a Class I watercourse overlaps with a meadow restoration project area, WLPZ regulations (e.g., buffer width, stocking & canopy cover requirements) will take precedent over meadow restoration requirements.
- It also establishes that there are alternative practices within the FPRs that allow for limited work within the WLPZ, such as “In Lieu Practices” (14 CCR § 916.1, 936.1, 956.1(a)).
  - Another potential avenue would be 14 CCR § 916.6, 936.6, 956.6 “Alternative Watercourse and Lake Protection [All Districts]”.

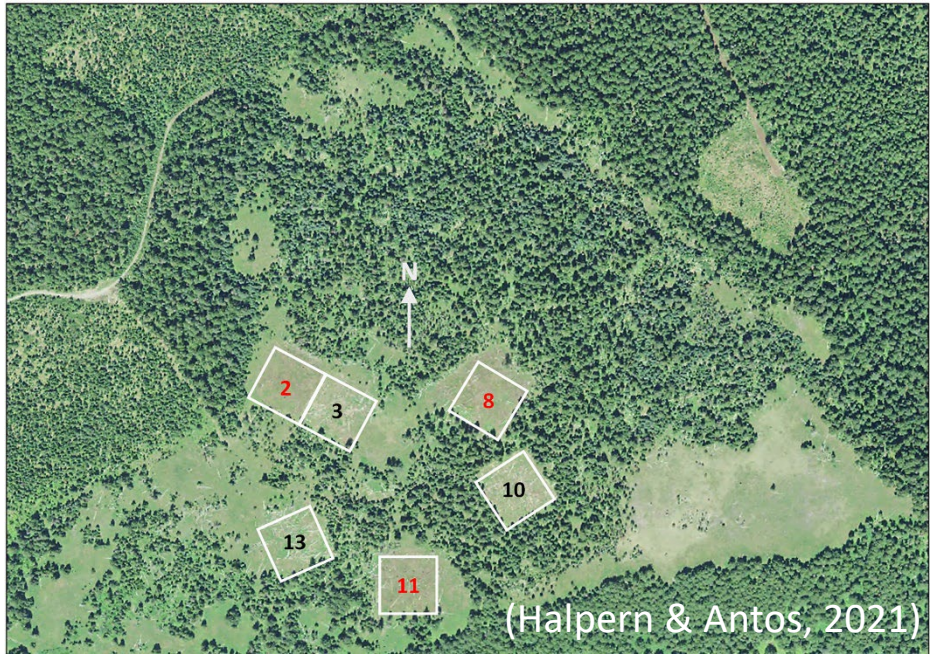


Weixelman et al., 2011

Further Areas of Uncertainty Regarding Meadow Restoration and WLPZ Operation Rules

Conifer Reinvasion

- A study examining the rate of conifer reinvasion 15 years after restoration in Oregon's Cascade Mountain Range, found that there was not a consistent increase in the frequency of trees on either plots mechanically thinned or burned (Halpern & Antos, 2021).
    - Notably, plots fully surrounded by forest saw higher rates of re-invasion than plots with forest absent or distant from the edge (Halpern & Antos, 2021).
- When Pinus is the dominant invader, earlier and more frequent cutting may be necessary due to the faster-growing nature of these species (Kremer et al., 2014)



(Halpern & Antos, 2021)

913.4, 933.4, 953.4 (e) Aspen, and Meadows and Wet Areas restoration

(7) The Department shall review post-harvest field conditions of the portions of plans using the aspen, Meadows and Wet Areas restoration silvicultural prescription and prepare a monitoring report every five (5) years for the Board. The monitoring report shall summarize information on use of the prescription including:

(i) The level of achievement of the measures of success as stated in the plan per 14 CCR §§ 913.4, 933.4, and 953.4, subsection (e)(5);

(ii) Any post-harvest adverse environmental Impacts resulting from use of the prescription;

(iii) Any regulatory compliance issues; and

(iv) Any other significant findings resulting from the review. The review shall include photo point records.

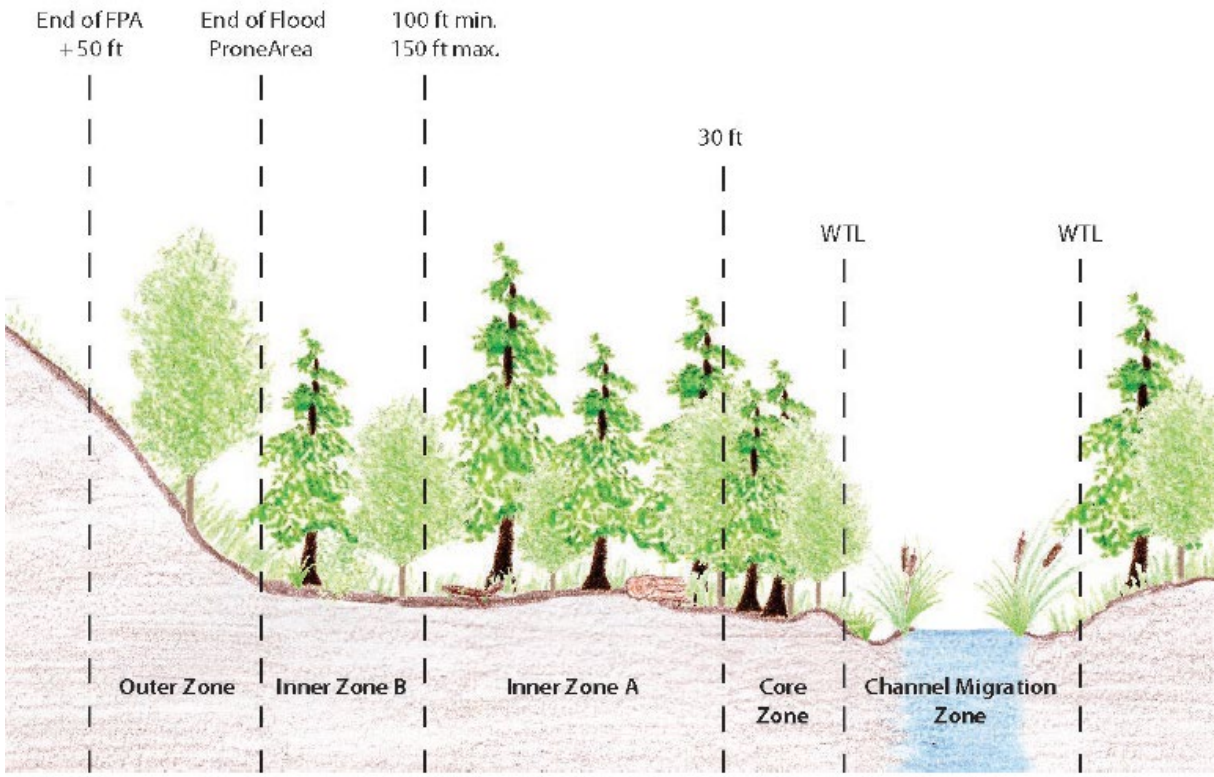
- There does not appear to be a limit or end date for monitoring aspen, Meadows and Wet Areas restoration.
  - **Is it intended that monitoring conclude when measures of success are met?**
- This study indicates that the meadows can stabilize after the first 3-5 years, however, with conifer re-invasion, it is unclear how many years post-restoration a meadow should be monitored.
- **How actively should these restored areas be managed for conifer re-invasion?**
  - May be appropriate to maintain these areas using other mechanisms (e.g., CAL-VTP).

916.9, 936.9, 956.9 Protection and Restoration of the Beneficial Functions of the Riparian Zone in Watersheds with Listed Anadromous Salmonids. [All Districts]

(f) Class I Watercourses –

(3) Class I Watercourses with flood prone areas or Channel Migration Zones

- Removal of encroached conifers for meadow restoration in ASP watersheds could be more complicated since flood prone areas have overstory canopy requirements, stocking requirements, and limitations on what silvicultural methods can be used.
- Would In Lieu Practices (14 CCR § 916.1, 936.1, 956.1) still be an acceptable approach to do meadow restoration in an ASP watershed?
- Would 14 CCR § 916.9, 936.9, 956.9 (v) "Site-specific measures or nonstandard operational provisions" be a better alternative for getting this work done?
- What are the impacts of doing meadow restoration in an ASP watershed?



Outer Zone:
50 ft. Outer Zone required only when even aged silv. system contiguous to WLPZ
Modified commercial thinning or single tree selection
50% overstory canopy (OSC)

Inner Zone B:
Modified commercial thinning or single tree selection
50% overstory canopy (OSC)
Retain 13 largest trees/ac.

Inner Zone A:
Modified commercial thinning or single tree selection
Increase QMD
No Sanitation Salvage
Retain 80% OSC in the Coast and Southern Forest Districts
of the coastal anadromy zone and 70% OSC in all other watersheds
Retain 13 largest trees/ac.

Further Areas of Uncertainty Regarding Meadow Restoration and WLPZ Operation Rules

- Scalability to other meadows in other geologic/edaphic/hydrological/ecological contexts remains uncertain.
    - A meta-study of other meadow restoration projects that have occurred could be of substantial value in the future.
- Outstanding questions remain about impacts of alternative practices for Meadows and Wet Areas on stream temperatures and stream habitat within the WLPZ.

In summary, this research project represents a partial validation of the current FPRs, particularly CFR § 933.4[e] regarding Meadows and Wet Areas restoration, but generally incremental progress in our understanding of how to balance meadow restoration ‘other goals of forest management’.

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