Relationship between soil moisture and electrical resistivity in a native meadow and forest ecotone

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Introduction:

This study examines the relationship between soil samples collected from meadow and forest ecotones from Marian Meadow and a Control Meadow on The Collins Pine Company lands in the Sierra Nevada near Chester, California. Over one weekend electrical resistivity imaging was utilized to measure subsurface water flow as influenced by local vegetation and eco-tone. The site currently has conifer encroachment altering the native meadow ecotone, present before anthropogenic intervention. These conditions provide a valuable opportunity to explore the relationship between the vegetation and crucial vadose zone water capacity. The vadose zone is the area between the soil surface and the saturated zone of the water table, and is highly susceptible to the effects of human interaction. An electrical resistivity profile will be conducted across the project site at a transect that encompasses both the invasive tree species and native grassland eco-tones. This investigation into the relationship between vegetation cover and soil vadose zone moisture is critical for further understanding of aquifer recharge as well as changing eco-tones as a consequence of active restoration.

This study examined soil samples indicative of both present and future ecological environments for lab analysis of the relationship between electrical resistivity and soil moisture content at California Polytechnic State University at San Luis Obispo. The lab analysis will investigate the correlation between direct resistivity measurements and soil moisture. Establishing a relationship between these two components is crucial in allowing scientists to make more precise decisions about the location of the water table and changes in soil moisture influenced by different ecotones. Groundwater resources are pivotal to the California economy and the general wellbeing of Californians, yet little is known about the true extent of our groundwater resources. Electrical resistivity will allow researchers to bridge that gap between stakeholders and land managers who need to accurately decide how much water resources are available. In addition, electrical resistivity can also be used to track pollutants in subsurface water flow by tracking changes in resistivity along the profile. This type of digital mapping of the subsurface vadose water flow will allow for better mapping and remediation of pollutants from the area in question.

Hypothesis:

Soil samples collected from Chester, Ca. artificially saturated to 9.5%, 19%, 28.5%, 38%, 47%, 57%, and 66.6% soil moistures, will have a relationship between soil moisture and electrical resistivity.

Methodology:

Under the supervision of Dr. Christopher Surfleet, Dr. John Jasbinsek, and Master of Science student Greg VanOosbree, data was collected at Marian Meadow and Control Meadow. Fieldwork at Chester on the weekend of May 2nd to May 4th yielded soil samples near the locations that electrical resistivity imaging occurred. Five soil samples were collected at a depth of 30 cm from the sites for lab analysis in the link between resistivity field data and laboratory

field saturation similar to work by Jayawickreme and others (2008). Soil from site C1-3 (Figure 1 served as the control for laboratory analysis and soil excavated from site 9-3SM (Figure 2) served as the indicator of the treatment site.

Over the course of several weeks, laboratory analysis of the soil samples collected from Marian Meadow and the control meadow were analyzed to determine a relationship between resistivity and percent soil saturation. Using Wenner VES electrode array geometry and 0.07 meter node spacing, systematic saturation of the soil yielded resistivity for linking field data and percent soil saturation. A M.C Miller small soil box (Cat. # 37006), was packed initially with oven dry soil treated at 105 Celsius for 24 hours to ensure the soil sample was adequately dry. Loosing packing of the soil ensured the conditions inside the soil box were as close to field conditions as possible before saturating the soil. This was repeated for soils collected at sites: C2-3, 6-3 and 4-1 for further hydrologic analysis (Figures 1 and 2).

Results

Table 1 includes resistivity results on both runs of the Iris Instruments Syscal Kid Switch 24 Unit. Relationships between both manipulated and un-manipulated data were observed (Figures 6-11). Linear and exponential fits were both fit onto the graphs to yield an equation to best fit the data points. There exists a strong linear relationship between percent soil moisture and soil electrical resistivity among the soil samples collected from Marian Meadow and the control meadow when the oven dry condition is removed from the analysis. When the oven dry condition was included in the analysis, a proper relationship could not be assessed. Once the oven dry soil was removed from the analysis, a relationship was observed between soil moisture content and electrical resistivity. Our analysis revealed inconsistencies in the resistivity results at oven dry moisture conditions. This instability limits the effectiveness of electrical resistivity in measuring soil moisture at such dry conditions. However, as oven dry soil is not indicative of the soil conditions present in both of the test sites, this limitation will not affect the successfulness of the Marian Meadow restoration project monitoring.

Discussion

Soil samples collected from Marian Meadow and the control meadow yielded graphs with high correlation between percent soil moisture and the electrical resistivity, when oven dry soil was removed from the analysis. Systematic saturation of the soil samples to known quantities will allow for an establishment of a relationship between these two variables, and allow imaging of soil saturation as a part of the greater Marian Meadow restoration project. As the restoration project continues, and the invasive pine trees are removed from Marian Meadow, this relationship between soil moisture and resistivity will allow for careful analysis of changes in soil saturation as the vegetation changes.

As part of the resistivity analysis, instability in the results occurred at the oven dry soil sample testing. It can be hypothesized that at these low soil moistures, the electrical current was unable

to make an accurate connection across the Iris device and yielded unstable results. For the monitoring of the Marian Meadow restoration project, resistivity values for soil moistures below 10% should be analyzed for inconsistencies because of device limitations.

Conclusion

A relationship between soil electrical resistivity and percent soil moisture will prove invaluable in measuring the success of the Marian Meadow restoration project and interpreting the changes in soil resistivity and soil moisture in response to biotic conditions. Also, the established methodology of the electrical resistivity testing using the Iris Instruments Syscal Kid Switch 24 Unit is appropriate for measuring soil electrical resistivity as a result of the systematic saturation of soil samples.

References

Dushmantha H. Jayawickreme, Remke L. Van Dam, David W. Hyndman. “Subsurface imaging of vegetation, climate, and root-zone moisture interactions.” Geophysical Research Letters Vol. 35 (2008): 1-5. Print.

Acknowledgements

Dr. Chris Surfleet, Natural Resources Management and Environmental Sciences Department. College of Agriculture, Food and Environmental Sciences. California Polytechnic State University, San Luis Obispo.

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Appendix

I. Email communication:

Feb 26th, 2014: Confirm with Dr. Surfleet regarding article on Electrical Resistivity Imaging in preparation for the Spring 2014 project

April 23rd, 2014: Communication with Dr. Surfleet, Dr. Jasbinsek, Mr. Van Oosbree and myself regarding May2nd-4th work weekend in Chester California

April 23rd, 2014: Introduction to Mr. Stubler regarding creation of laboratory space for analysis and necessary equipment for the testing

April 24th, 2014: First submission to Dr. Surfleet regarding senior project proposal and timeline

April 25th, 2014: Communication with Dr. Surfleet regarding travel authorization for the work weekend in Chester California

April 27th: Finalization with Dr. Jasbinsek and Mr. Van Oosbree regarding departure for the work weekend and meeting point for travel

April 28th: Confirmation with Mr. Stubler regarding available lab space and meeting time to go over lab safety and equipment training

April 29th: Confirmation with Dr. Jasbinsek and Mr. Van Oosbree regarding Chester trip

May 13th, 2014: Communication with Sponsored Programs Department regarding completion of travel claim re-imbursement

May 14th, 2014: Dr. Surfleet and Dr. Jasbinsek share work weekend photos for submission

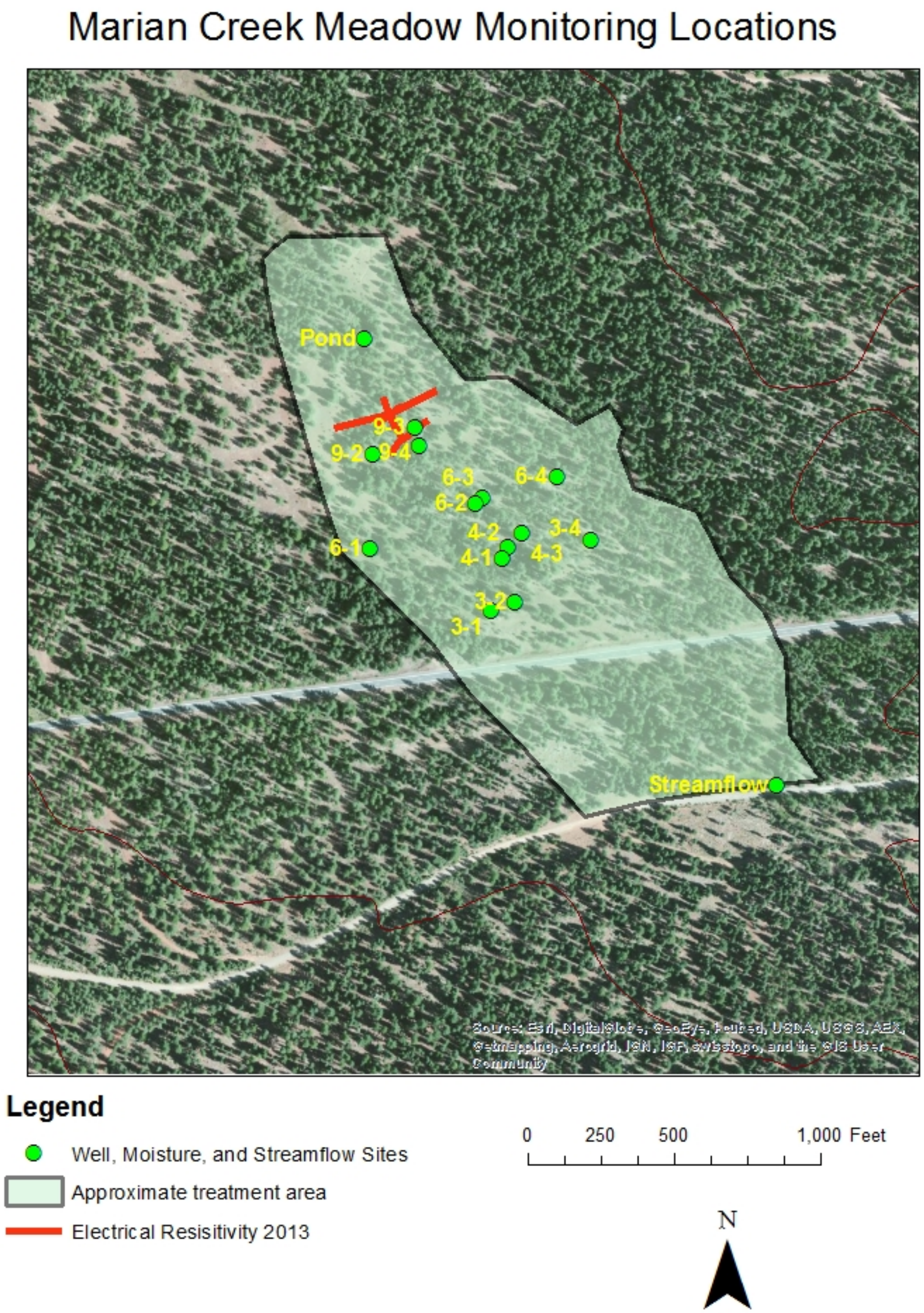

Figure 1. Historic Marian Creek Meadow with encroaching conifer and instrument site locations. The approximate area of conifer tree removal is shown (Map by C Surfleet, 2014).

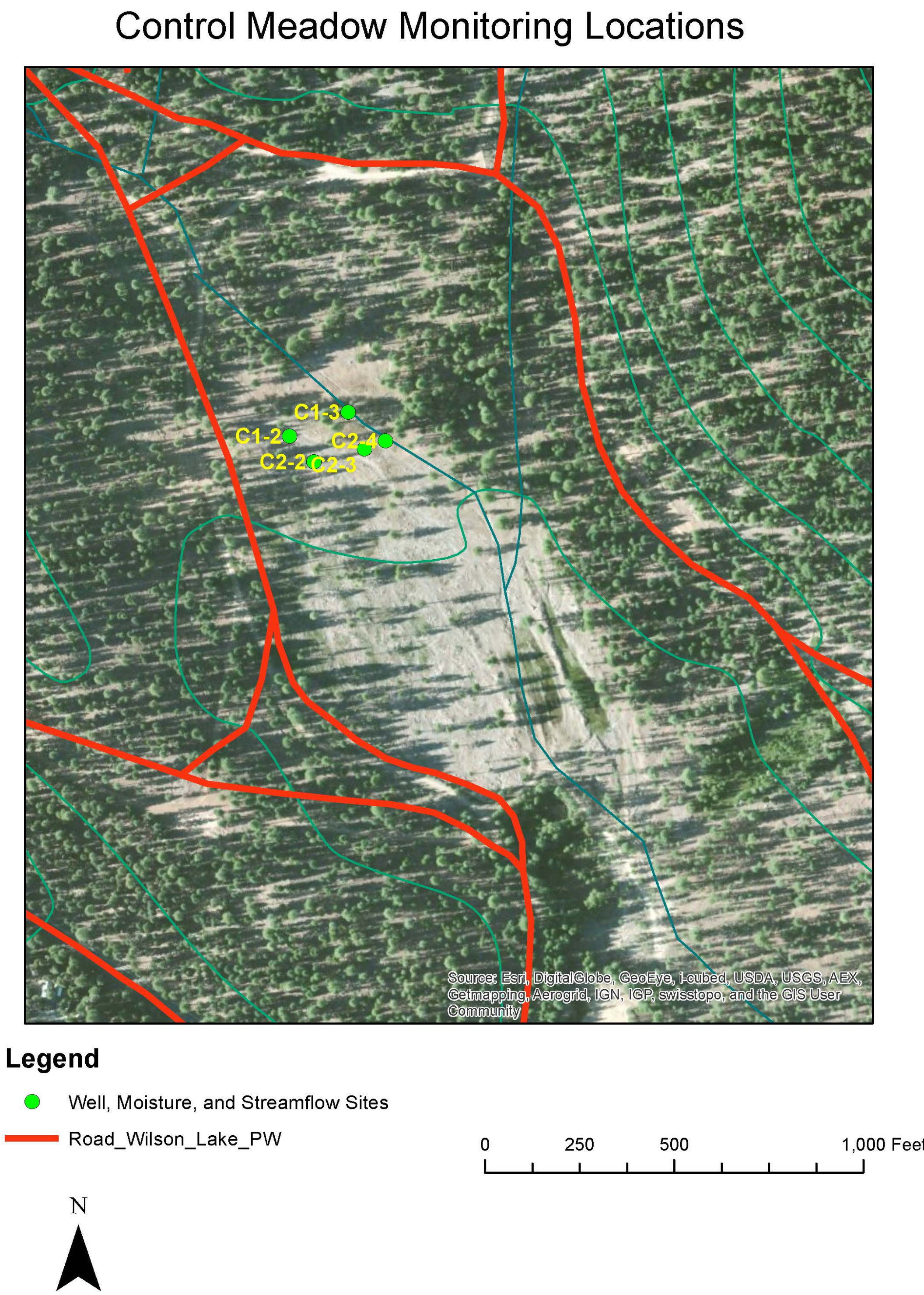

Figure 2. Control Meadow and instrument site locations (Map by C. Surfleet, 2014).

II. Photo documentation from the work weekend May 2nd- May 4th, 2014 in Chester California

Figure 3. Dr. Jasbinsek, Greg VanOosbree, and Todd Davis installing Electrical Resistivity equipment in preparation of a transect measurement in Chester California.

Figure 4. Dr. Surfleet, Greg VanOosbree, and Todd Davis kneel behind an installed soil moisture probe to measure soil saturation in Chester California.

Figure 5. Greg VanOosbree and Todd Davis prepare soil samples from the field for lab analysis in Chester California.

III. Data

Table 1- Laboratory results of the soils collected at sites: C1-3, 9-3SM, C2-3, 6-3, and 4-1 at the treatment and control sites in Chester California.

Run 1			C1_3			9_3SM			C2_3			6_3			4_3		
R Value			R Value	Soil Moisture		R Value	Soil Moisture		R Value	Soil Moisture		R Value	Soil Moisture		R Value	Soil Moisture	
393.12	100%	210 mL Wate	0	0%	Oven Dry	94065.49	0%	Oven Dry	381.11	0%	Oven Dry	3939.05	0%	Oven Dry	218.76	0%	Oven Dry
			13,347.30	9.52%	20 mL Water	20,438.80	9.52%	20 mL Water	9,854.29	9.52%	20 mL Water	11,415.37	9.52%	20 mL Water	6,651.65	9.52%	20 mL Water
			6,182.05	19.05%	40 mL Water	3,493.79	19.05%	40 mL Water	3,888.54	19.05%	40 mL Water	3,642.82	19.05%	40 mL Water	3,024.80	19.05%	40 mL Water
			3697.33	28.57%	60 mL Water	2,337.07	28.57%	60 mL Water	2,385.42	28.57%	60 mL Water	2,202.39	28.57%	60 mL Water	1,946.82	28.57%	60 mL Water
			2369.08	38.10%	80 mL Water	1,685.60	38.10%	80 mL Water	1,484.49	38.10%	80 mL Water	1,646.29	38.10%	80 mL Water	1,471.23	38.10%	80 mL Water
			1547.71	47.62%	100 mL Water	1255.48	47.62%	100 mL Water	1,116.12	47.62%	100 mL Water	1,164.79	47.62%	100 mL Water	1,093.71	47.62%	100 mL Water
			1250.26	57.14%	120 mL Water	1,032.03	57.14%	120 mL Water	858.81	57.14%	120 mL Water	910.46	57.14%	120 mL Water	889.85	57.14%	120 mL Water
			1061.65	66.67%	140 mL Water	879.56	66.67%	140 mL Water	745.6	66.67%	140 mL Water	761.53	66.67%	140 mL Water	761.86	66.67%	140 mL Water
Run 2																	
210 ml			C1_3			9_3SM			C2_3			6_3			4_3		
R Value			R Value	Soil Moisture		R Value	Soil Moisture		R Value	Soil Moisture		R Value	Soil Moisture		R Value	Soil Moisture	
393.12	100%	210 mL Wate	8622.70	0%	Oven Dry	137.59	0%	Oven Dry	204.70	0%	Oven Dry	560.02	0%	Oven Dry	239.55	0%	Oven Dry
			10,691.98	9.52%	20 mL Water	26.62	9.52%	20 mL Water	143.64	9.52%	20 mL Water	6447.64	9.52%	20 mL Water	371.70	9.52%	20 mL Water
			4,370.00	19.05%	40 mL Water	2,150.36	19.05%	40 mL Water	2894.44	19.05%	40 mL Water	2294.43	19.05%	40 mL Water	2224.34	19.05%	40 mL Water
			2,760.46	28.57%	60 mL Water	2,337.07	28.57%	60 mL Water	1670.54	28.57%	60 mL Water	1463.76	28.57%	60 mL Water	1521.04	28.57%	60 mL Water
			1,716.13	38.10%	80 mL Water	1,484.49	38.10%	80 mL Water	1324.47	38.10%	80 mL Water	1164.08	38.10%	80 mL Water	1184.74	38.10%	80 mL Water
			1,202.45	47.62%	100 mL Water	826.49	47.62%	100 mL Water	912.63	47.62%	100 mL Water	859.13	47.62%	100 mL Water	883.14	47.62%	100 mL Water
			959.19	57.14%	120 mL Water	671.3	57.14%	120 mL Water	701.59	57.14%	120 mL Water	637.99	57.14%	120 mL Water	663.32	57.14%	120 mL Water
			832.36	66.67%	140 mL Water	581.66	66.67%	140 mL Water	583.77	66.67%	140 mL Water	536.88	66.67%	140 mL Water	566.70	66.67%	140 mL Water

Figure 6.Log Soil Resistivity V. Log Soil Moisture for soil samples collected in Chester, Ca.

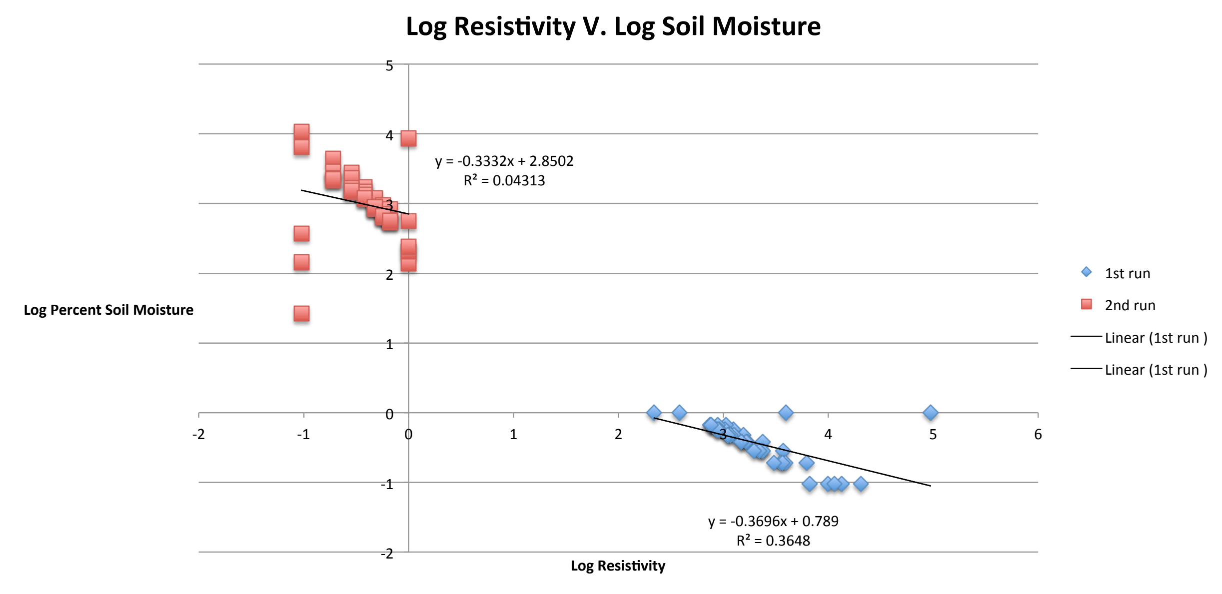

Figure 7. Log Soil Resistivity V. Log Soil Moisture for all soil samples collected in Chester, Ca.

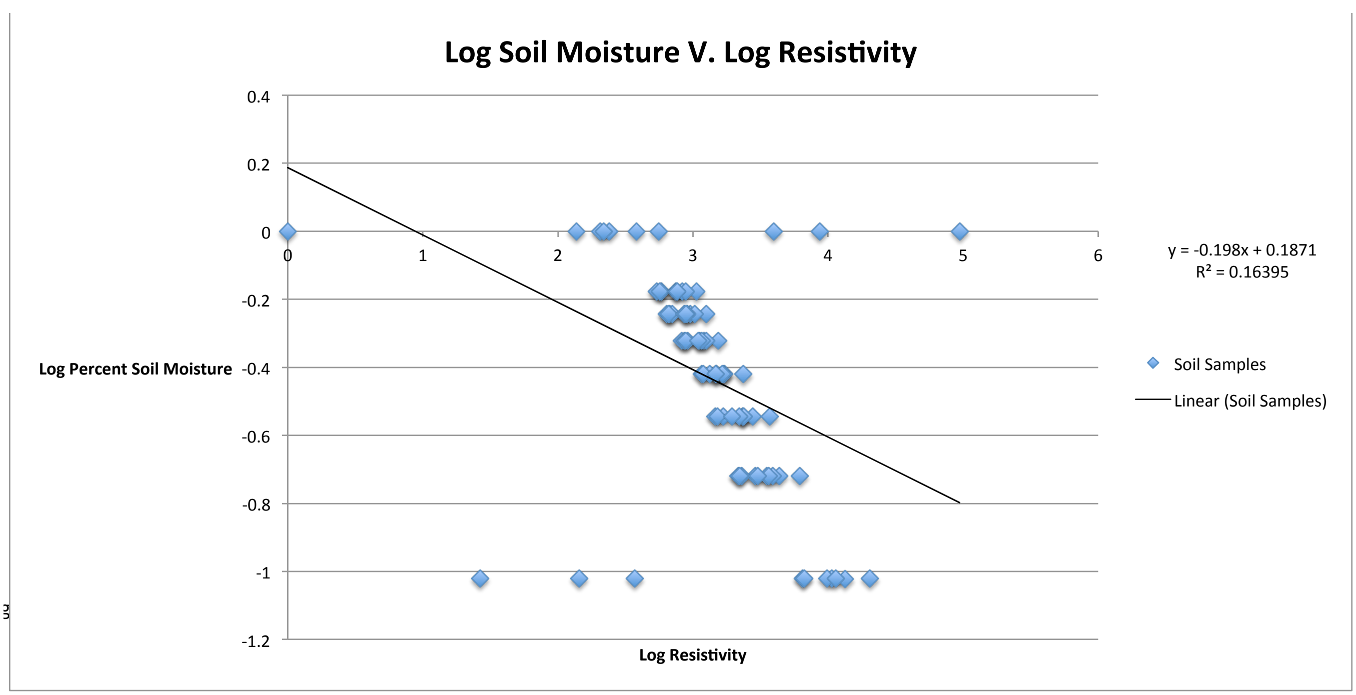

Figure 8. Control meadow soils run 1. Percent soil moisture V. Resistivity.

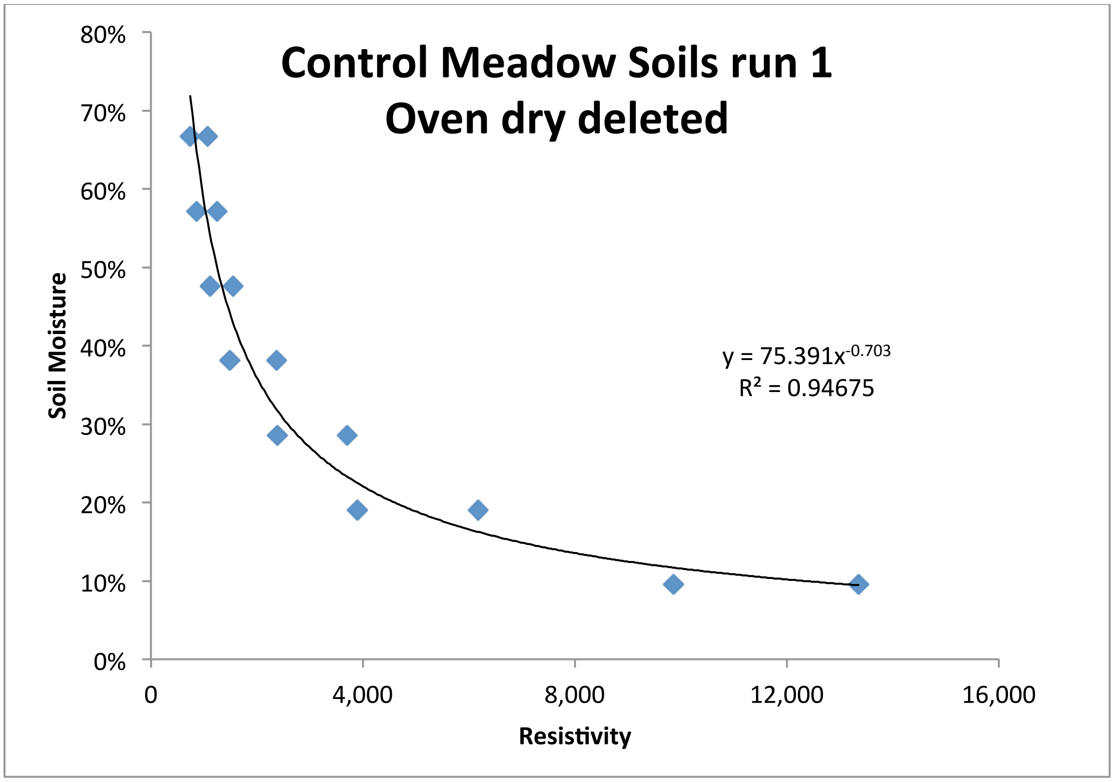

Figure 9. Marian Meadow soils run 1. Soil moisture V. soil resistivity.

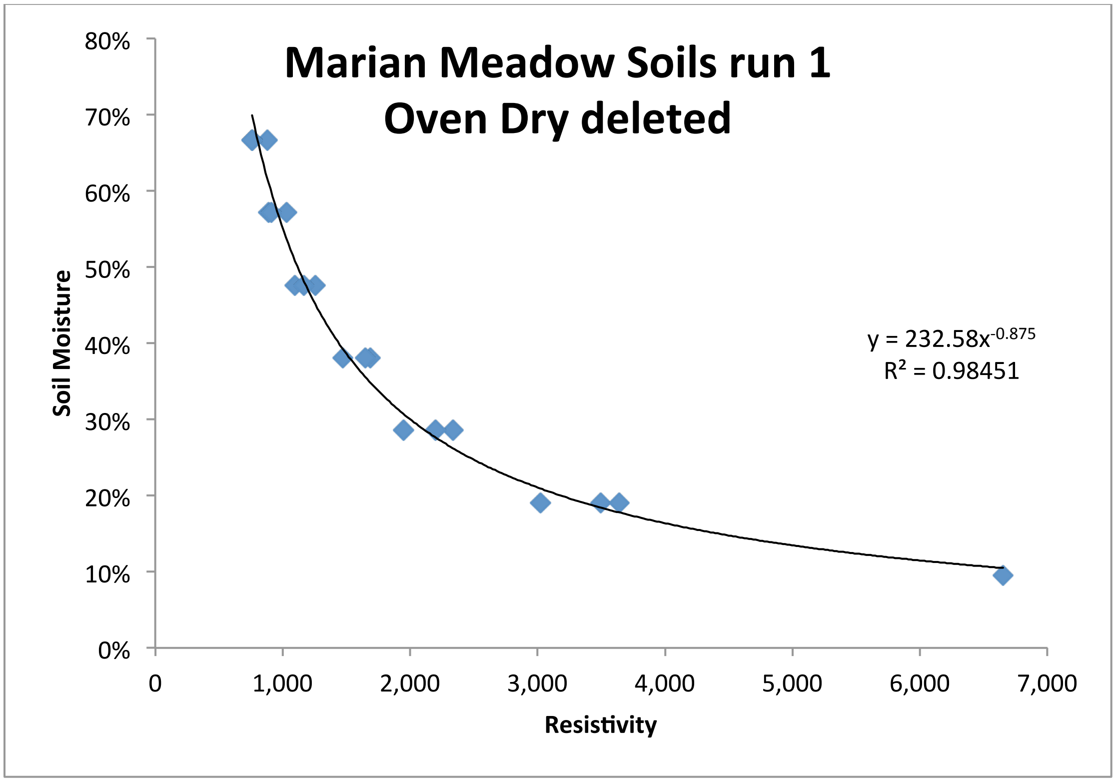

Figure. 10. Control meadow soils with combined resistivity runs. Percent soil moisture V. Resistivity .

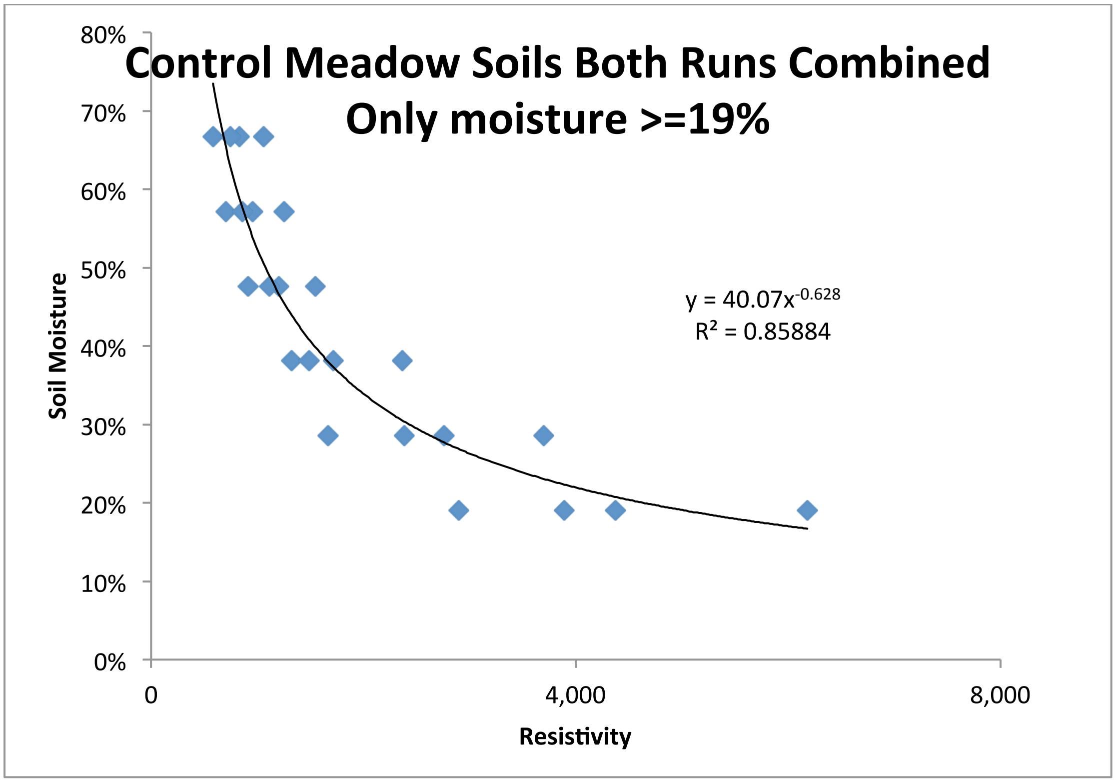

Figure 11. Marian Meadow soils with both resistivity runs. Percent soil moisture V. soil resistivity.