TECHNICAL REPORT
Quantification of Carbon Sequestration Benefits of Restoring Degraded Montane Meadows
Feather River Coordinated Resource Management

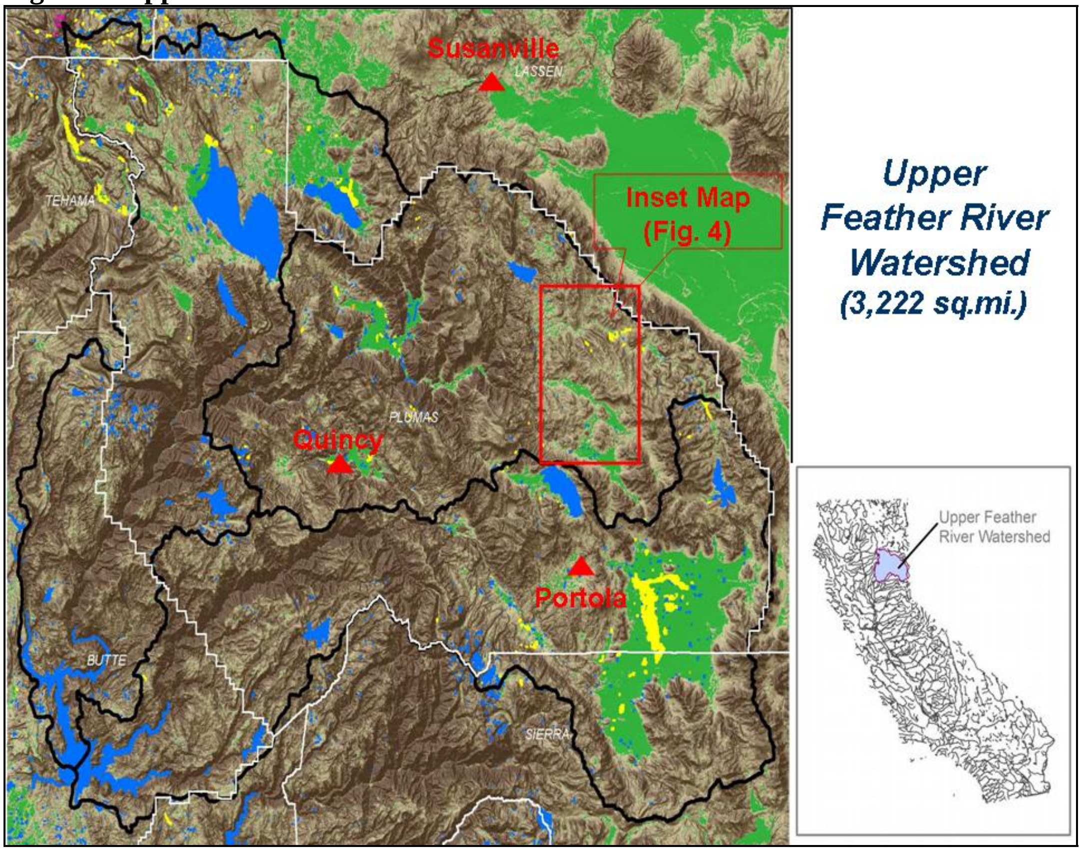
Abstract
The Feather River Coordinated Resource Management Group (FR-CRM) has been restoring channel/ meadow/ floodplain systems in the Feather River watershed since 1985. Project and watershed-wide monitoring has shown multiple benefits of this type of work. With the concern over global climate change, the group wanted to measure the carbon sequestered in project areas. No protocol was found to measure carbon stores in native Sierra Nevada meadows. Plumas County funded the FR-CRM to conduct a pilot study to develop such a protocol. The sampling protocol included discrete sampling at consistent soil depths to determine the vertical distribution of carbon. A Technical Advisory Committee developed and refined a multi-project sampling protocol for three restored meadows and three un-restored meadows. Data from the un-restored meadows will also provide base-line data for before and after restoration comparisons. Initial data analysis indicates that restored meadows contain twice as much total carbon as degraded meadows; on average approximately 40 tonnes more carbon per acre. Virtually all of the additional carbon in restored meadows occurs in the soil, and is thus protected from loss via grazing, haying, wildfire, etc.

Introduction
In 1994 the Feather River Coordinated Resource Management (FR-CRM) group shifted its stream restoration approach from bank stabilization to landscape function. Called meadow re-watering, this approach entails returning the incised stream channel to the remnant channel(s) on the historic floodplain and eliminating the incised channel as a feature in the landscape. Historic channel incision resulted in significant land degradation as the adjacent groundwater levels dropped commensurate with the incising stream bed. Vegetation conversion rapidly follows as deep, densely rooted meadow plant communities convert to xeric shrubs and other plants. After a decade of meadow restoration, the FR-CRM recognized the possibility of a significant change in carbon stocks in these restored meadows and valleys. Plumas County has been a leader in advocating for investment in watershed ecosystem services such as water storage and filtering, and now, carbon sequestration. The county provided funding for the FR-CRM to conduct a pilot study of carbon in biomass and soils.

Watershed Location and Characteristics
The upper Feather River watershed is located in northeastern California encompassing 3,222 square miles that drains west from east of the Sierra crest into Oroville Reservoir and thence to the Sacramento River. Annual runoff produced from this watershed provides over 1,400 MW of hydroelectric power, and represents a significant component of the California State Water Project, annually providing 2.3 million-acre feet of water for urban, industrial and agricultural consumers downstream.

The Feather River watershed is primarily comprised of two distinct geologies: the Sierra Nevada granitic batholith of the western third of the watershed; and Basin and Range fault-block meta-volcanics, meta-sedimentary and recent basalts in the eastern two-thirds. It is the Basin and Range zone (Diamond Mtns.) of the watershed that has been the primary area of restoration. This geologic mélange of faulted and weathered rock has resulted in over 390 square miles of expansive meadows and valleys comprised of deep fine grained alluvium, shown as green and yellow in Figure 1.

Figure 1. Upper Feather River Watershed



Upper watershed meadows and valleys (shown as green/yellow in Figure 1), often dozens of miles in length, once supported a rich ecosystem of meadow and riparian habitats, for coldwater-loving trout, a diversity of wildlife, and indigenous peoples during the dry summers of California's Mediterranean climate. The densely rooted vegetation, cohesive soils and expansive floodplains all contributed to the sustainability of these meso-scale floodplain meadows, with associated alluvial fans. River system segments are often characterized simplistically as transport and depositional reaches. Depositional reaches feature lower gradients and a more expansive fluvial setting. These landscape attributes, in conjunction with the type and quantity of sediment, debris and nutrients, are what provide for the development and evolution of meso-scale "sinks" or "warehouses", for the hydrologic products of the basin. Viewed as a macro-hyporheic corridor (Harvey and Wagner, 2000; Boulton, et.al., 1998; Stanford and Ward, 1993) these features are crucial as a landscape zone of active mass and energy transfer as well as an active storage reservoir for water, sediment and nutrients. The long-term recruitment and evolution of these features involve physical, biological and chemical synthesis within the natural variability of fluvial processes.

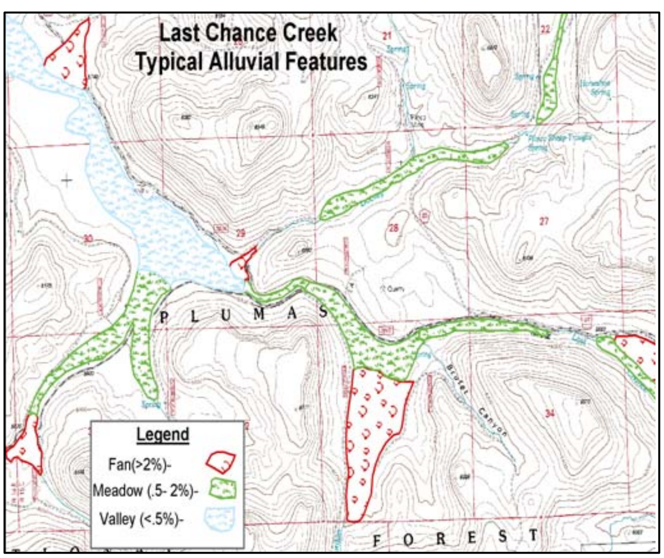


Figure 2. Typical Alluvial Features

Euro-American settlement of the watershed began in 1850 with gold mining in the western portions of the watershed and, soon thereafter, agricultural production in meadows to support the mining communities. Dairy farming, horses (for cavalry mounts), sheep and beef cattle were some of the early intensive disturbances that led to localized channel incision. The resultant lowering of shallow groundwater elevations began to alter and weaken the vegetative structure of the system. Soon, near the burgeoning communities in the mid-elevation valleys, a permanent road system was established with frequent channel manipulation and relocation efforts to simplify drainage and minimize bridge construction, again leading to localized incision. In the early 1900's both an intercontinental, and numerous local, railroad systems were constructed throughout the watershed. The local railroad networks, for the purpose of both mining and logging, were routed through the long low-gradient valleys for ease of construction. These valleys were still relatively wet at that time so elevated grades were constructed using adjacent borrow ditches. By 1940, the severe morphological changes imposed by the railroad grades, in conjunction with the above referenced land use impacts resulted in rapid, severe systemic incision of many upper watershed meadow systems.

In the mid 1980's numerous watershed stakeholders adopted a statutory authority that allowed for Coordinated Resource Management and Planning (CRMP). Twenty-four federal, state and local, public and private entities now form the Feather River Coordinated Resource Management (FRCRM) group to adopt, support and implement a watershed-wide restoration program.

FR-CRM Restoration Approach & Background

The FRCRM began an ongoing implementation program to address these watershed issues in 1990. Initially, these projects focused on geomorphic restoration techniques (Rosgen, 1996) to stabilize incised stream channels. While overall success was encouraging, the projects illustrated the concept that any restoration work in the incised channels was subject to elevated stresses even in moderate flood events (5-10 year return interval). Concurrently, the benefits from this approach were localized and limited to reduced erosion, and incremental improvement of aquatic habitats and water quality. Little overall improvement of watershed conditions was being realized (Wilcox, et al 2001). This led to re-evaluating restoration approach to encompass the entire historic fluvially-evolved valley bottom.

Called meadow re-watering, this approach entails returning the incised stream channel to the remnant channel(s) on the historic floodplain and eliminating the incised channel as a water conveyance feature in the landscape (Figures 3 & 4 and photos 1a, 1b, 2a & 2b). Simultaneously, the FRCRM had received a project assistance request from the United States Forest Service, Plumas National Forest (PNF) to develop restoration alternatives for Cottonwood Creek in the Big Flat Meadow (Photos 2a & 2b). FRCRM staff, led by Jim Wilcox, began conducting surveys and data collection that included the entire relic meadow from hillslope to hillslope. This data collection effort quickly pointed to the nascent meadow re-watering technology as a likely restoration alternative.

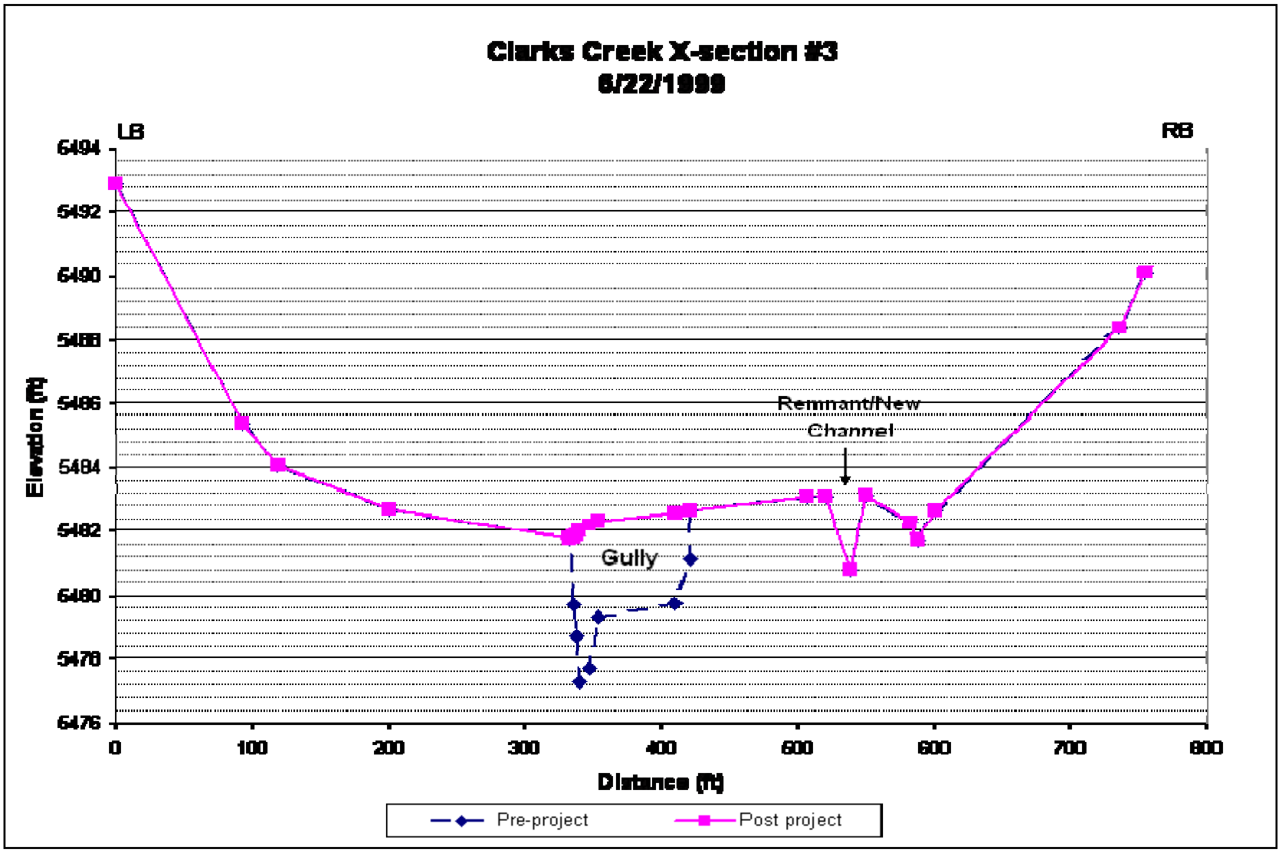


Figure 3. Typical cross-section, showing pre-project incision, post-project plug elevation, and the new channel. Photos 1a and 1b below show this same cross-section, however, the entire gully is not shown in the pre-project photo.

Photo 1a- Clarks Creek Pre-project, July, 2001

Photo 1b- Clarks Creek Post project, July, 2006

The rocks in the background of photos 1a and 1b can be used for reference. Because the new channel is in a different location, the photo point also moved in order to show the channel in the pre- and post-project conditions.

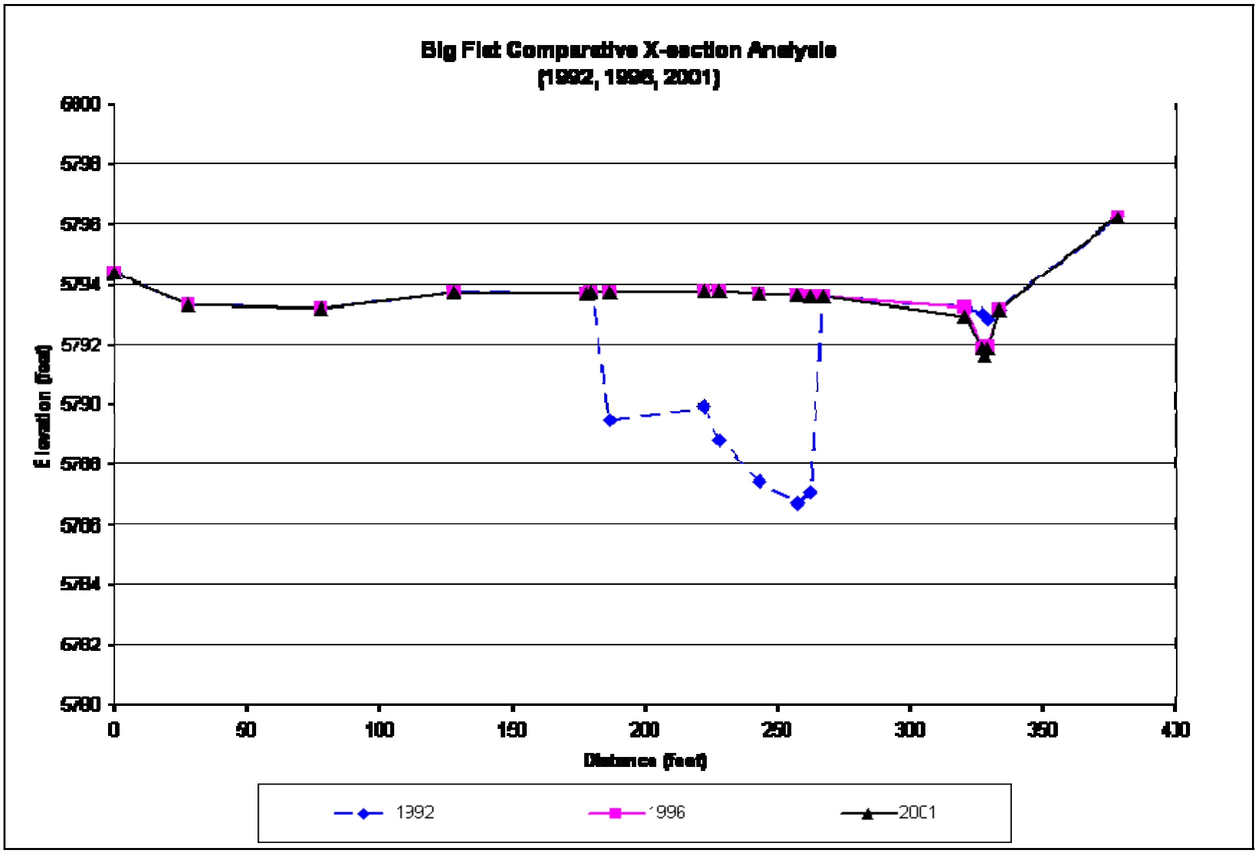


Figure 4. Typical cross-section, showing pre-project incision, post-project plug elevation, and the new channel.

Implemented in 1995, this project quickly validated the fundamental soundness of this approach. The one mile long, 47 acre project produced elevated shallow groundwater levels, eliminated gully wall erosion, filtered sediments delivered from the upper watershed, extended and increased summer baseflows, and reversed the xeric vegetation trends resulting in improved terrestrial, avian and aquatic habitats. These benefits persisted despite withstanding a 100-year RI (return interval) flood in 1997.

Photo 2a- Big Flat Pre-project, Dec.,1993

Photo 2b- Big Flat Post project, May, 2006

The success of this initial project led to the implementation of an additional 18 projects utilizing this technology (Table 1.). Varying in scale and watershed characteristics, these projects have restored another 20 miles of channel and 5,000 acres of meadow/floodplain.

Carbon Sequestration

Qualitatively, these projects appeared to significantly increase organic carbon stocks through the much increased root mass as well as increased surface growth, and, possibly, through the more effective hyporheic exchange throughout the meadow. The purpose of the following protocol is to quantitatively establish the effective carbon sequestration potential of this watershed restoration technology. Causative mechanisms, other than meadow re-watering restoration, were not investigated in this study. The protocol evaluated three restored meadow projects, ranging from two to thirteen years in age, and three un-restored, but planned, project areas. Data from the un-restored meadows will also serve as pre-project data for a before and after comparison over time.

The goal of this effort was to: 1) establish an acceptable scientific protocol to quantify carbon sequestration in restored versus un-restored meadows; 2) quantify carbon stocks in three restored meadows; and 3) quantify carbon stocks in three un-restored meadows to provide baseline data for future restoration. The FR-CRM is committed to developing a cost-effective, defensible and replicable protocol for quantifying carbon sequestration opportunities with this growing restoration technology. It is hoped that the value of the sequestered carbon can provide an income stream for landowners or land management agencies, and/or provide funding to continue these management/restoration strategies for degraded lands.

Methodology

The project had three basic components. The first component concerned identification of the meadows to be sampled. Restored project areas were chosen in order to sample different project ages. Un-restored meadows were chosen based on their suitability for meadow re-watering restoration. The meadow component included an analysis of the meadow's soils, slope, watershed area, land use, etc. The potential restoration options also needed to meet criteria that would likely lead to increased carbon stocks, such as a potentially raised water table that could support more vigorous plants, and/or controlled grazing, etc.

The second component was the development of field sampling and lab testing methodologies that could be used by a wide range of resource professionals, landowners and groups. The intent was to develop a methodology that may require training and quality control measures, but would not be overly technical or financially burdensome. The budget for this study was $2,000 per meadow per sample period.

The third component of this project was to determine appropriate temporal and spatial scales for long-term monitoring and management of a market-eligible sequestration project to ensure sustainability and continuing benefits. This component of the project is only partially complete. This protocol was designed to ultimately compare pre- and post-restoration carbon stores (i.e. a comparison of the same meadow over time). However, this initial effort used projects of three different ages as a surrogate for temporal change, until the un-restored study meadows undergo restoration and can be re-sampled for carbon storage.

A Technical Advisory Committee (TAC) was formed to implement this pilot project. The TAC was comprised of: Jim Battagin of Butterfly Botanical Consulting; Denny Churchill, consulting soil scientist; Dale Johnson and Sherm Swanson of University of Nevada in Reno; and FR-CRM staff (Jim Wilcox, Jessica Albietz, Gia Martynn, and Kara Rockett). Ken Cawley assisted with statistical analysis after data collection, and comments on future statistical design.

Meadow Analysis and Geomorphic Restoration Design

The identification of an appropriate meadow requires a geomorphically-based survey and analysis approach that documents the landscape degradation and the channel, floodplain, and watershed impacts that initiated the degradation. The restoration design should clearly show the hydrologic changes that would manifest from the project and what structural and/or management measures would be taken to prevent future degradation.

For this pilot study, three un-restored and three restored meadows were chosen. The choice of the un-restored meadows in this project was based upon completed initial studies by the FR-CRM. Each of these meadows has been targeted for meadow re-watering restoration in the near future, with detailed cross-sectional surveys already completed. The three restored meadows were chosen to achieve a sampling of carbon stores in restoration projects in varying stages of maturation. Because restoration probably prevents continued loss of carbon from oxidation of historic soil stocks, a post-incision temporal sequence may also show restoration benefits through time.

Table 1. Sampled meadow statistics.

HUC 5 Watershed	Estimated incision decade	Meadow	Year project constructed	Years since restoration work	Acreage of project area (hydrologic effects)
Red Clover	1950’s	Poco	un-restored		178
Last Chance	1950’s	Lower Clarks Cr	un-restored		65
Last Chance	1940’s	Coyote Flat	un-restored		100
Red Clover	1950’s	McReynolds	2006	2	375
Last Chance	1950’s	Upper Clarks Cr	2001	7	56
Last Chance	1920’s	Big Flat	1995	13	47

Sampling and Analysis Methodology:

Many of the degraded meadows in the Feather River watershed are comprised of a variety of soil types, due to complex geology and influence from tributary channels. Similarly, the vegetation communities reflect not only the soil, but also the duration and severity of flooding, or de-watering from the incised channel. It was hypothesized that vegetation, soil types and water table elevation might affect the carbon sequestration rate or potential in any given meadow. Each meadow was surveyed to delineate Level 1 soil types and existing vegetation communities.

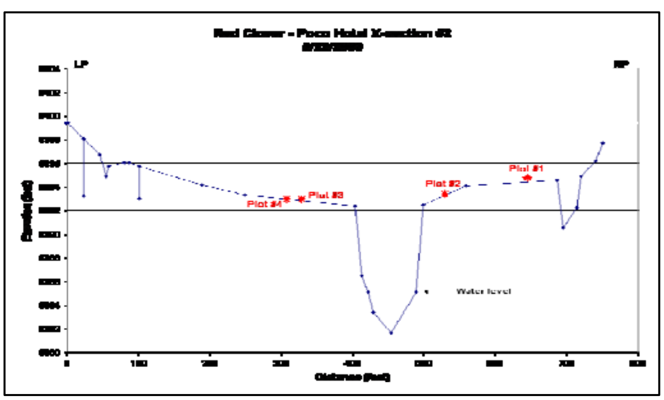


Fig. 5 Typical cross-section w/sample plots.

Based on the soil and vegetation types, an existing surveyed cross-section was chosen that provided the best characterization of each meadow’s vegetation/soil types. Location of the plots along a cross-section allows integration of carbon data with topographical data (see Figure 5). (The FR-CRM monitors resource attributes along cross-sections. It is hoped that such integration may allow future identification of surrogate metrics for some monitoring parameters.) Four one-foot square plots were chosen along the cross-section, each plot representing a soil/vegetation type. In the un-restored meadows, it was also necessary to make sure that plot locations would not interfere with potential design features, such as a pond location. Within these parameters, sample plot locations were randomly selected. Randomness of the square foot at each sampling station was achieved by tossing the square behind the back.

Table 2. Vegetation and soils types of the sampled plots.

Sampled Meadow	Plot Number	Soil Type	Vegetation
Big Flat restored in 1995	1	9	Poa secunda
	2	9	Carex angustata/ Trifolium beckwithii
	3	9	Carex angustata
	4	9	Carex angustata/ Juncus balticus
Upper Clarks restored in 2001	1	13	Carex angustata/ Juncus balticus
	2	13	Carex angustata
	3	13	Carex angustata
	4	13	Muhlenbergia richardsonis
RC McReynolds restored in 2006	1	34a	Juncus balticus
	2	34s	Poa secunda
	3	34s	Carex angustata
	4	9w	Carex angustata
Lower Clarks un-restored	1	15	Carex angustata/ Juncus balticus
	2	23	Artemisia tridentata
	3	23	bare soil
	4	23*	Artemisia tridentata
Coyote Flat un-restored	1	34c	Artemisia tridentata
	2	34c	Artemisia tridentata/ Poa secunda
	3	34c	Poa secunda
	4	34c	Bare soil/ Poa secunda
RC Poco un-restored	1	14*	Chrysothamnus viscidiflorus
	2	14*	Elymus trachycaulus trachucaulus
	3	9*	Poa secunda
	4	9*	Artemisia cana c./Poa secunda

* soil types were extrapolated

Not all vegetation/soil types were sampled in each meadow, and some types were sampled more than once. No attempt was made to duplicate soil/vegetation types among meadows. As mentioned above, this protocol is not proposed for future use in between-meadow comparisons. The protocol is proposed for pre- versus post-restoration comparisons in the same meadow.

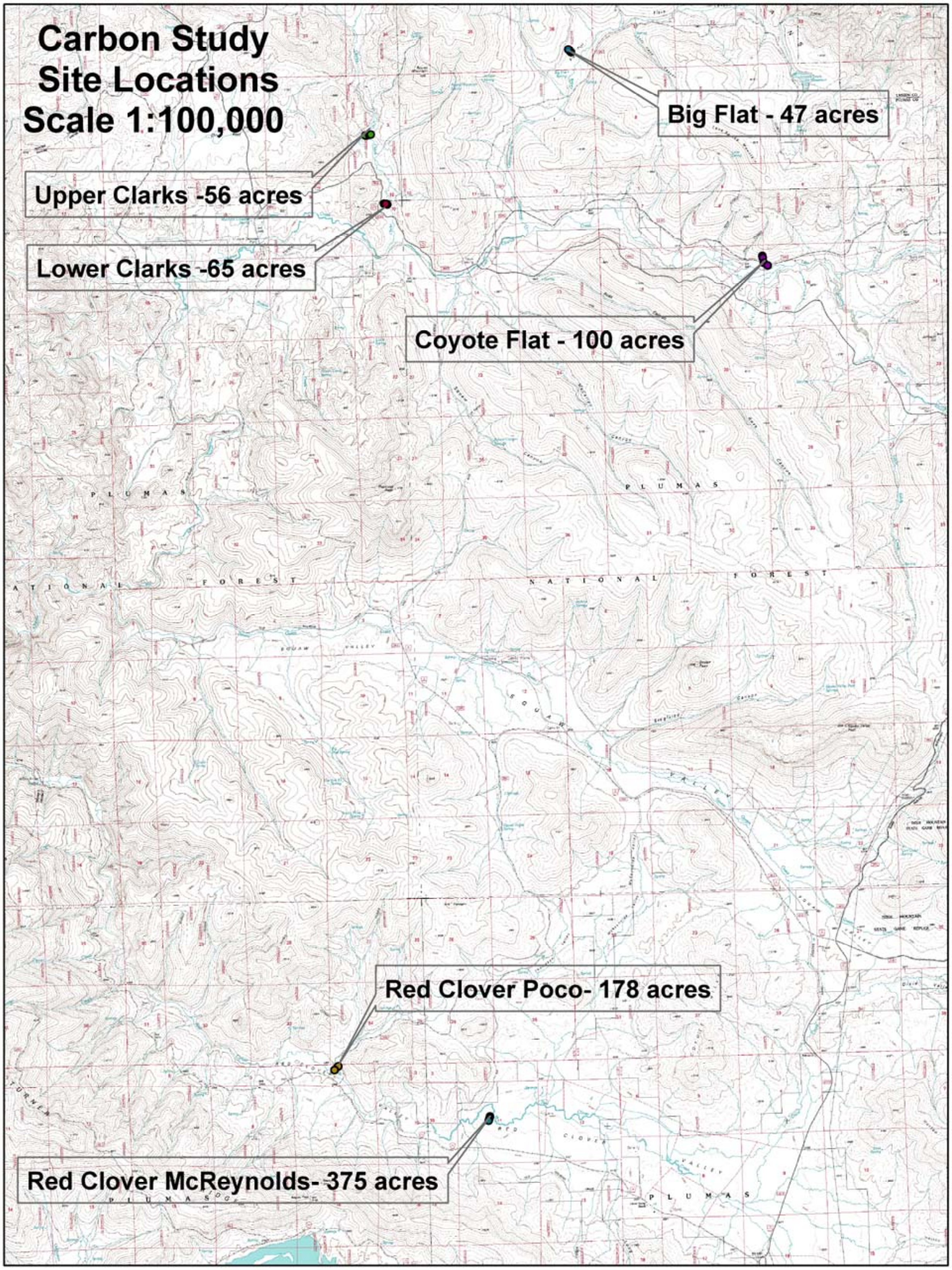


Figure 6. Relative locations of each of the sampled meadows.

Samples were collected in fall 2008. Samples were removed within the square in pre-determined, definable layers, following this protocol: 1. All above-surface biomass material within the square was clipped to ground level. Soil surface was defined as the top of the O horizon. Material was removed, bagged and labeled by plot number for the entire square foot area. (All meadows were moderately grazed (40%-60% utilization) prior to sampling, except Red Clover McReynolds.) 2. In wet sites, a 4" auger-size sample of the O horizon was taken. In dry sites, the O horizon of the entire square foot was taken. O horizon material consisted of duff, litter and residual live plant material, down to a bare, mineral soil surface. Material was removed, bagged and labeled, including a notation of whether the wet or dry site method was used. 3. In the center of the square, an auger was used to sample the top three feet of soil. Representative samples of each foot of depth were collected. Approximately 20% of the soil in the auger was removed for analysis, with an attempt made to collect material from the upper, middle and lower portion of the core. 4. During augering, a representative bulk density sample (Blake, G.R., and K.H. Hartge, 1986,) was collected for each foot of depth. Bulk density samples were collected at 9", 18" and 27". Soil cores were collected using an Oakfield 3-ft. Model B 36" Soil Sampler (mud augers worked best in wet sites). Bulk density samples were collected with a 0200 soil core sampler manufactured by Soilmoisture Equipment Corp. All samples were stored in plastic bags, and labeled with meadow, plot number, depth, and date.

Because of the correlation between depth and carbon, and improvement in sampling would include more accurate subsampling of each foot of core depth, so that an equal volume of soil is taken from the same inch within each foot of the core.

Sample Testing

Biomass testing was conducted by FR-CRM staff. All biomass material recovered from the one foot square was hot-air dried atop a woodstove. Samples were tested for 'dry' when the bagged sample was placed in a standard freezer for 30 minutes, removed, checked for condensation on the bag interior and re-dried if moisture was present. Dry weights were determined from a digital scale to a resolution of one gram. Dry weights were multiplied by 0.48 to determine total carbon of the sample (carbon makes up approximately 48%-50% of the dry weight of organic matter, Pluske, et al, 2007).

Soil samples were also dried as above and sieved using an ASTM#10 (2mm) 8" brass sieve. Large organic material (roots) were removed and tested as above (small organic particles went through the sieve and became part of the soil sample). An improvement in processing would be to use a hot air oven at a constant 105ºF to dry the samples.

Approximately one teaspoon of each sieved soil sample was sent to the Soil, Water and Forage Analytical Lab at Oklahoma State University, Stillwater, Oklahoma for soil C tests using a LECO TruSpec Carbon and Nitrogen Analyzer. Lab QA protocol is excerpted below:

> Accuracy and precision of test results are assured through daily analysis of quality control samples, a three step internal data review process, and participation in external certification and sample exchange programs. All instruments are calibrated with certified standards and maintained according to the specification.
>
> Internal quality control standards listed below are included in each sample run. The permissible ranges are set at two times the standard deviation (mean ± 2 std.). If results are outside the permissible ranges, corrective action will be taken.
>
> One check sample is included in every 9 samples for soil pH, carbon, nitrate, phosphorus and potassium analyses;

Results

All carbon results are reported in metric tons (tonnes) (2,200 lbs.) of Total Carbon (TC) per acre (the current standard unit). Table 3 and Figure 7 show the summarized results of the four samples in each meadow without stratification.

Table 3. Summarized soil, biomass and total carbon at each site.

	Restored		Unrestored		Total Carbon	
Site	**Soil**	**Biomass**	**Soil**	**Biomass**	**Restored**	**Unrestored**
Big Flat (1995)	95.2	1.1			96.3	
Coyote Flat			39.6	2.6		42.2
Clarks Creek- Upper (2001)	79.3	2.1			81.4	
Clarks Creek- Lower			39.8	1.7		41.5
Red Clover/McReynolds (2006)	120.5	3.6			124.1	
Red Clover/Poco			23.5	0.6		24.1
Averages	**98.3**	**2.3**	**34.3**	**1.6**	**100.6**	**35.9**

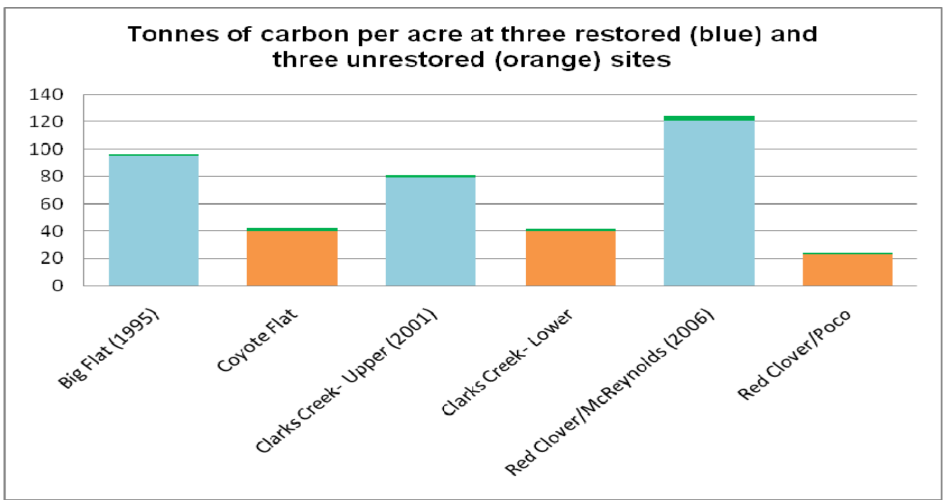


Figure 7. Tonnes of carbon per acre in each sample meadow. Green at the top of each column represents biomass carbon.

The columns in the graph are arranged so that loosely comparable sites are next to each other. Big Flat and Coyote Flat are both in the Last Chance drainage, three miles apart from each other. The two Clarks Creek sites are on the same creek, less than one mile from each other. The Red Clover Poco site is two miles downstream of the Red Clover McReynolds site. On average, the restored meadows show a 177% increase in total carbon per acre over the unrestored meadows. 97% of that additionality was soil carbon.

Stratification by Soil Depth

Stratification by soil depth was the only stratification on which a statistical analysis was performed. Figure 8 shows that most of the carbon (about 70%) is stored in the upper one foot of soil. This layer of soil also contained the highest root density.

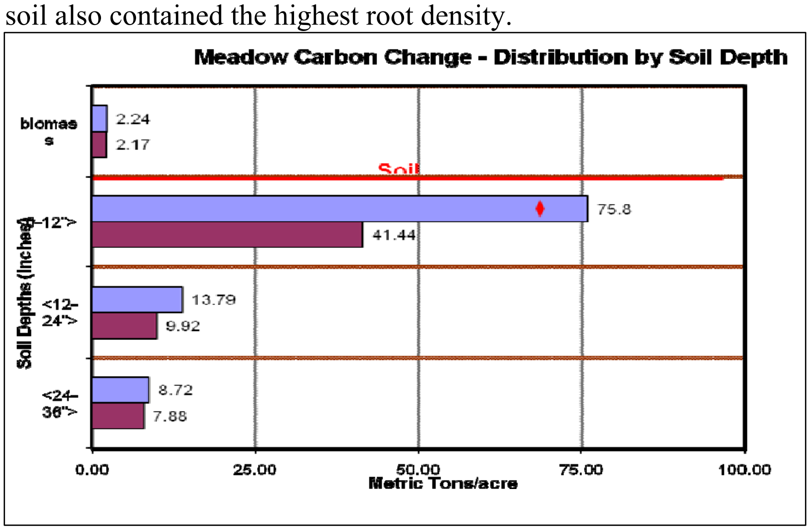


Figure 8. Total tonnes per acre of carbon in restored (blue) and unrestored (maroon) meadows displayed by depth. The soil surface is shown as a red line.

A two-factor analysis of variance (ANOVA) was conducted to test the significance of the difference in mean soil carbon levels between restored and unrestored meadows (factor 1) and soil depth (factor 2). The purpose of including soil depth was to test if differences in carbon between restored and unrestored meadows were represented throughout the soil profile. For the ANOVA, data were log transformed to better meet test assumptions of normality and equal variances. The experimental design is shown in Table 4.

The overall null hypothesis of no difference in group means was rejected at the 0.05 alpha level. The test of the Factor 1 x Factor 2 interaction was not significant indicating that differences are the result of the factors acting independently.

		FACTOR 1	
		Unrestored	Restored
FACTOR 2 - SOIL DEPTH	Biomass	1.626	2.240
	1"-12"	20.30	75.85
	12”-24”	7.363	13.79
	24”-36”	6.618	8.718

Table 4. Mean tonnes of carbon per acre at three soil depths in restored versus unrestored meadows.

The Tukey-Kramer test was employed to identify which group means were significantly different. In this study, we were primarily interested in differences between restored and unrestored sites by soil layer. A significant difference between restored and unrestored sites was only detected at the 12-24” and 24-36” depths.

The most surprising result is the finding of no significant difference for the surface soil horizon (1-12 inches). Although the difference in means between restored and unrestored sites is large, the variance was also quite large, especially due to the presence of an extremely high value (258.6 T/ac) at one site. It is most likely the high variance that resulted in a failure to show a significant difference in the 1-12” layer. This suggests that future sampling may need to include a larger number of samples at the 1-12” depth, and the same number at the lower depths.

When Factor 2 is removed, the analysis is reduced to a simple Student t test of independent samples and compares total carbon (all soil layers) between restored and unrestored sites. The results of this test show a highly significant difference in mean carbon levels ($\alpha \leq 0.01$).

Stratifications by Soil Type and by Vegetation Type

Since no attempt was made to sample the same soil or vegetation types across meadows, only two soil and two vegetation types were sampled in both restored and unrestored conditions. From these limited data, it is not possible to make a statistically valid conclusion regarding soil types or vegetation types and carbon in restored versus unrestored meadows. Table 5 and Figure 9 display data in a loose aggregate by major soil type. Table 6 and Figure 10 display tonnes of carbon per acre by loose vegetation type. These types of stratification may be interesting to pursue in future sampling efforts.

Soil Type	Restored		Unrestored	
	Tonnes C	# Plots	Tonnes C	# Plots
Soil types 9 aggregated (Coolbrith siltyloam)	34.9	5	5.8	2
Soil type 13 (Dotta sandy loam)	20.4	4		
Soil Types 14 & 15 aggregated (Fluvents)			10.8	3
Soil Type 23 (Greenhorn loam)			7.2	3
Soil types 34 aggregated (Ramelli silty-clay)	15.4	3	10.5	4

Table 5. Average total tonnes of carbon per acre in restored vs. unrestored meadows, by soil type.

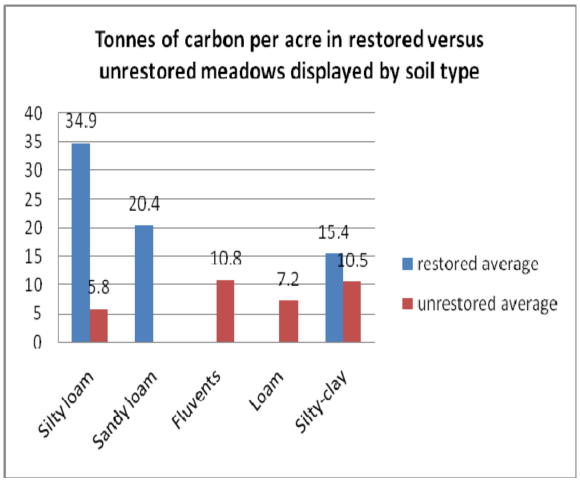


Figure 9. Average total carbon in five soil types.

Vegetation Type	Restored		Unrestored	
	Tonnes C	# Plots	Tonnes C	# Plots
Bare Soil			8.9	2
Graminoid	16.2	3	7	4
Juncus	10.2	1		0
Sage			8.4	5
Sedge	30.4	8	20	1

Table 6. Total carbon and number of plots in aggregated vegetation types.

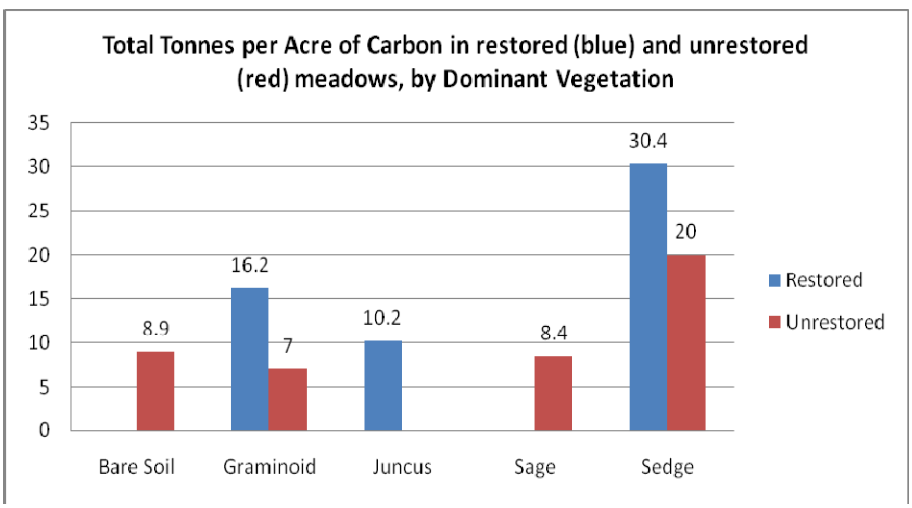


Figure 10. Total tons of carbon by vegetation type.

Discussion

As with many projects of this type, perhaps there are as many questions generated by this work as there are answers. However, two of the primary objectives of the project were met: Carbon was quantified in six project areas, and meaningful comparisons were made between unrestored and restored meadows. The data clearly show that more carbon is sequestered in restored meadows than unrestored meadows. Most of the carbon is also stored below the surface of the soil, and thus not subject to catastrophic loss due to wildfire or short term grazing management. Long term grazing management may affect root biomass, and therefore affect carbon. Sample sizes were most likely adequate for the total carbon and depth comparisons, however, adequate sample sizes were not determined by this project. High variance in the 1-12" depth suggests the need to collect samples at this depth.

In the two comparable soil types and two comparable vegetation types, the restored meadows showed a greater store of carbon. However, since this protocol is proposed for pre- versus post-restoration comparisons, the issue of similar types of vegetation and soil should not arise again. It is also not likely that soil and vegetation types will be the same in pre- versus post-restoration. The higher water table is likely to affect both. Soil and vegetation typing, however, should remain a component of the protocol to ensure that the sample plots are representative of the acreage proposed for the sequestration market.

In the future, the study design will involve *before-and–after* restoration comparisons of soil carbon in the same meadow. This should address shortcomings in the design used in this preliminary study which include:

- Uncertainty over the validity of comparing meadows
- Uncertainty about the source of soil carbon; "legacy" carbon versus carbon contributed as a result of restoration activities.
- Time required to detect a change in soil carbon, if any, following restoration (funding will hopefully allow multi-year sampling).

A two-way ANOVA study design such as that shown in Table 7 is a likely possibility. In this case, unrestored meadows would be used as control sites to test whether changes in soil carbon could be related to extrinsic factors (rain/snow/temperature) that could affect plant growth or the amount of water available to transport surface carbon to deeper soil layers. The operative hypothesis would be to expect significant differences in mean carbon value between Cells B x D and Cells C x D with no differences in Cells A x B and Cells A x C. A significant interaction between factors would suggest the presence of an extrinsic effect (as mentioned above) driving some of the change in soil carbon during the study period. It is expected that such a study could be used by a broad range of land managers, so that sequestered carbon in restored meadows could be marketed for potential income. It is also expected that marketing could bcome easier if enough sampling identifies community types that can predict carbon stores.

		FACTOR 1	
		Unrestored	**Restored**
FACTOR 2	**Before Restoration**	Cell A	Cell B
	After Restoration	Cell C	Cell D

Table 7. Proposed statistical design for future before versus after restoration carbon sampling in meadows.

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