Restoration of Hydrologic and Ecological Connectivity of Long Meadow

Final Report for Long Meadow Project

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Cover photo: Long Meadow during June 2016 by Nina Hemphill

PREFACE

This report is the result of a grant from the Army Corp of Engineers which was administered by the National Fish and Wildlife Foundation (NFWF). The NFWF Agreement #40659 with the Sequoia National Forest, Porterville, Ca. funded the restoration of Long Meadow, a headwater Meadow for Dry Meadow Creek, a tributary of the North Fork Kern River.

EXECUTIVE SUMMARY

The focus of the Long Meadow Restoration Project was to regain wetland ecosystem functions that were lost through the effects legacy grazing, or other unknown legacy land use in the Kern River watershed. The Project is located on Long Meadow Creek which flows into Dry Meadow Creek and into the Kern River. Long Meadow Creek encompasses approximately 3.5 linear miles of stream before reaching its confluence with Bone Creek. The restoration returned about 325 feet of Long Meadow Creek back to the level of the meadow and to a swale where possible. The restoration activities encompassed 3 acres; however 35 acres were preserved, enhanced, and protected from degradation and loss of Pleistocene soils. The Long Meadow sub-watershed 8H-D encompasses 2,400 acres and will benefit by improved connectivity of habitats for amphibians, reptiles, aquatic invertebrates, small mammal, and birds. Anticipated reduction in excessive sediment will enhance the function of Dry Meadow Creek a tributary of the Kern River. The watershed is contained within the Giant Sequoia National Monument and the Sequoia National Forest. The Kern River flows into Lake Isabella. The restoration restored hydrologic connectivity to the meadow as evidenced by wetland vegetation growing well in the portion of the meadow that was dried by the headcuts. Willows are still very small and are surviving at the same height as the robust wetland *Carex* species which are growing well again and should begin to enhance carbon sequestration. Erosion has been halted. The remaining meadow had been protected.

INTRODUCTION

Unrestricted grazing by sheep from 1860's to 1890's denuded vegetation and altered the functioning of many meadows in the Sierra Nevada. Roads for logging or other purposes further disrupted the hydrology of many wet meadows. These legacy effects were prior to the US Forest Service acquiring management of these lands. Since the legacy degradation, stochastic events such as fire in conjunction with rain on snow events have further degraded the meadows. The Sequoia National Forest has many meadows that have lost part of their wetland ecosystem functions through the effects legacy grazing, or other unknown legacy land use.

Restoring, protecting and enhancing headwater meadow ecosystem functions and connectivity is important for downstream amphibians, birds, and fish that use stream and riparian corridors. Kern River Rainbow trout, a California native inland golden trout were once supported in Long Meadow Creek and Bone Creek. Bone Creek is a possible location for reintroduction of these native trout. The restoration of hydrologic connectivity and an increase in storage capacity of the soils in Long Meadow is an important part of the restoration of Bone Creek for native trout. By protecting the meadow from further erosion downstream fish were protected from scouring by fine sediments and destruction of deep pool habitat. Fishing for inland trout is a prized recreational activity.

The entire meadow was at risk over the long term to further upstream migration of multiple headcuts. Has the headcuts move upstream they could have reached several other meadows and the deep soils of the Long Meadow Grove upstream. Prior to the return of hydrologic connectivity, vegetation composition at the base of the meadow was shifting from traditional moist meadow species to dryer upland meadow vegetation types, allowing for conifer encroachment into the meadow. This process has slowly been reversing. Some conifers still appear healthy and we will continue to track their survival and more importantly any new incursions. The meadow experience a fire in the late fall of 2016, and we have not had a chance to evaluate the effects on native endemic plants.

PROJECT LOCATION

The Sequoia National Forest (Forest) is in the southern end of the Sierra Nevada. The Kern River drains from north to south unlike many other rivers in the Sierra Nevada. This restoration site is within the Upper Kern River (8 Digit HUC # = 18030001), the which is in the Tulare- Buena Vista Lakes HUC. Dry Meadow’s 6 Digit HUC # = 180300, includes Long Meadow sub-watershed; these tributaries contribute hydrologic benefits to the Kern River. The Long Meadow Restoration Project (Figures 1) is located is located in Township 22 South, Range 31 East, Sections 25 and 36, MDBM close to the mountain ommunity of Johnsondale, California. The site is located in the Western Divide Ranger District of Giant Sequoia National Monument, and Sequoia National Forest.

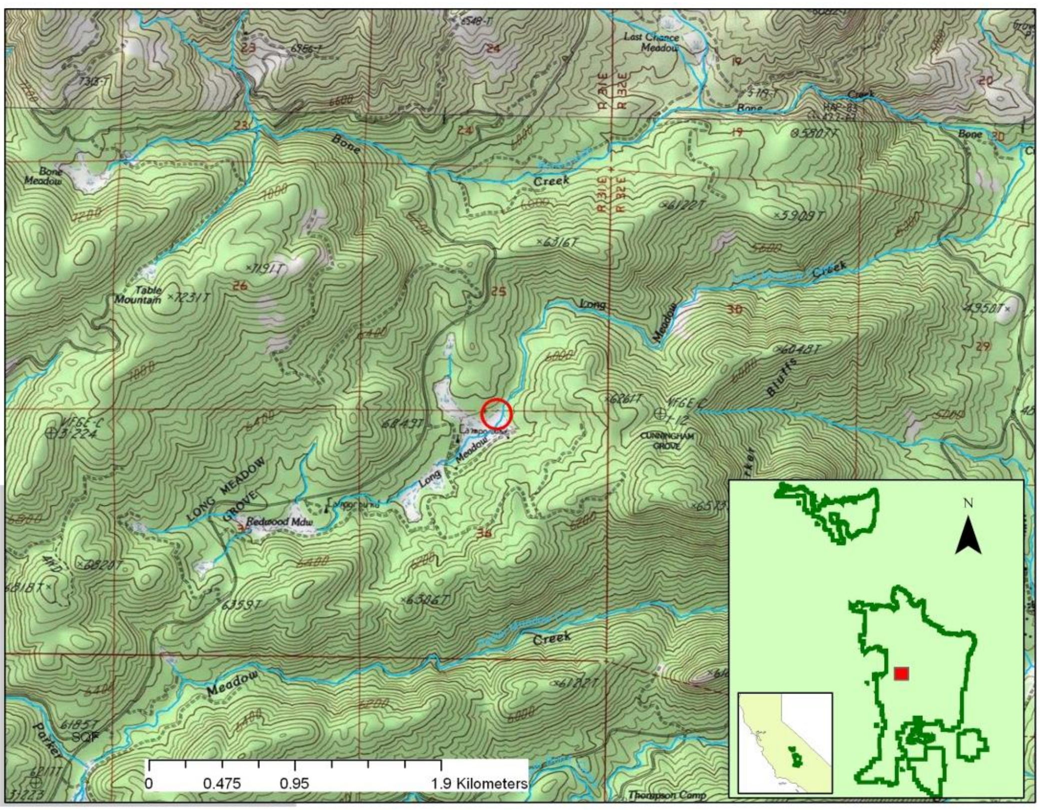

Figure 1. The Long Meadow restoration site on Long Meadow Creek is circled in red. Map inset shows location of site on Sequoia National Forest (red square); while the additional inset shows location of the Forest (dark green) in California.

ENVIRONMENTAL CONDITIONS

The Greenhorn Mountains at the Southern end of the Sierra Nevada are characterized by cold winters where precipitation falls mainly as snow. The elevations of mountains in the watershed range from

6,500 to 7,200 ft. Long Meadow Creek sub-watershed 8C_H encompasses 2,400 acres and flows through a complex of moderately high elevation meadows (5800-6000 ft.) and eventually flows into Dry Meadow Creek and the Kern River. Long Meadow Grove is in the headwaters of Long Meadow Creek, and the creek flows into several meadows before flowing into Long Meadow, Bone, Nobe Young and Dry Meadow Creeks. Redwood Meadow and Long Meadow are two of the headwater meadow for Bone Creek. The stream is fed by snowmelt in spring, rainfall in the fall, and springs.

Long Meadow Creek is a perennial stream within the Long Meadow sub-watershed (8HD). Stream surveys have been completed from Long Meadow upstream to the headwaters of the sub-watershed. The steeper headwaters of Long Meadow Creek are naturally-stable, moderate gradient, boulder/bedrock channel types. Where Long Meadow Creek shifts to a lower gradient and flows through Redwood and Long Meadows, the stream channel changes to stable-sensitive, low gradient, gravel/sand dominated channel. Just below the restoration site and outside the meadow, the channel becomes more confined and is bedrock controlled. Below the bedrock control; based on aerial photos and topography, the channel is expected to be a low gradient stream with sandy pools and low gradient riffles. IN 2017 we will document depth of sediment in pools to see if good spring flows will mobilize sediment slowly or quickly downstream.

Long Meadow is situated on Cretaceous age granitic rock. The soil samples derived from the material in the project area were dominated by the Chaix and Dome soil series. Both soil series are weakly developed soils formed in granitic residuum. Because of the young age of these soils and the mineralogy of the parent rock, little clay accumulates within the soil matrix and the soils have a characteristic coarse-texture (sand dominated) with little soil strength and water-holding capacity. Perhaps the most significant character of the soils in the project area is a very recent deposition of coarse grained material overlying an older, more stable meadow surface. This recent deposit is likely due to a historical disturbance (historic grazing and road building) that allowed for excessive erosion and sedimentation in the watersheds above the meadow such as an atmospheric river. The textures change from loamy sands and loams in the upper horizons to silt loams in the buried horizons. Other soil horizons evident at multiple intervals in the headcut included charcoal from fires in the watershed. This successive deposition is part of the natural process of soil formation in the meadow.

Historically, Long Meadow consisted of 3 pastures used to gather and hold livestock during entry and exit, and for horses used for management of the grazing allotment. Managed cattle and horse stock grazing continues in the meadow under current USFS guidelines, and are at lower levels than those noted historically. The restoration site within Long Meadow has been used annually as a pasture for horses for more than 50 years. A cabin along with other structures lies immediately adjacent to the meadow which is used for management of a grazing permit (Summit Allotment). There are remnants of a partial dam structure at the northeastern end of the meadow (downstream of proposed project). The age of the dam is currently unknown. The Long Meadow and Redwood Campgrounds are upstream from the meadow.

Long Meadow Creek, within the northern portion of Long Meadow, was eroding the meadow as a result of a large headcut (See Figures 2, 3, and 4.). Rather than a swale gently sloping down, this headcut had eroded upstream approximately 375 feet; creating approximately a seventy foot wide and seven foot deep gully. The total estimated sediment lost from within the gully is approximately 3,400 cubic yards. This erosion process has created five additional smaller headcuts along the sides of the gully. Prior to restoration, the main headcut eroded at an average rate of five cubic yards per year.

Figure 2. Photograph of Long Meadow headcut looking towards right bank. The stream has sediment in it despite low flows. Exposure of relic soils occurs at this interface.

Figure 3. Looking upstream from the lower end of the gully towards the headcut. The banks with the large conifers to the right and left are the old meadow surface. A person is standing at the headcut.

Figure 4. Close up of the location of the conifer on right showing young conifer encroachment.

The northern portion of the meadow no longer functioned hydrologically; inhibiting floodwaters from connecting with its natural floodplain. As a result, meadow vegetation composition shifted from traditional moist meadow species to dryer upland meadow vegetation types allowing for conifers to grow (or encroach) into the meadow. Conifers still occur in the meadow. Some are obviously dying from wet roots. Small pines on higher surfaces are doing better. Sedges and wildflowers are in the lower wetter part of the meadow. Conifers will be monitored until 2018, and if they do not have wet roots and are within the meadow, we will cut them down.

In the riparian area surrounding the meadow and in the watershed, tree mortality is high. Post restoration, the Meadow Fire burned through the area in November, 2016, we were not able to get in to assess due to the closure of the area for the fire and then closure due to winter storms. We will assess benefits of the low intensity fire on meadow plants. The soils burn severity was very low and the fire was patchy. We anticipate native vegetation will germinate in the light burn areas.

Figure 5. Firing fuels and small conifers along edge of meadow. Patchy light fire which burned the grasses seen in foreground in meadow.

Figure 6. Low intensity fire burning grasses in upper end of meadow.

PROJECT OBJECTIVES

The erosion of meadow sediments affected downstream water quality (non-point source pollution), and impacted meadow hydrology, such as storage capacity and connectivity. As a result of loss of ground water, vegetation composition at the base of the meadow shifted to dryer upland meadow vegetation types, allowing for conifer encroachment into the meadow. Goals for restoration of the site included returning natural historic functions to the degraded portion of the meadow. Benefits from this project included: reducing the loss of valuable meadow habitat, reducing nonpoint source pollution by decreasing sediment transport, increasing water storage by raising the water table, and providing for long term hydrologic connectivity for the meadow. Ancillary benefits of this project are the protection of upstream archeological resources, improvements in wildlife and aquatic habitat, retention of scenic recreation values for adjoining campgrounds, and hydrologic benefits that may promote long term stability of Long Meadow Giant Sequoia Grove, located upslope and southwest of the meadow.

The project was designed to meet the following objectives:

1. Increase water storage by raising the water table
   - Is the meadow water table higher on average for a longer hydro period?
   - Has meadow wetland vegetation responded positively?
2. Restore wetland vegetation to the damaged part of the meadow
   - Is the meadow dominated by wetland *Carex* species with rhizomatous roots?
3. Reduce lateral erosion and downstream sediment transport
   - Are signs of erosion of the channel evident below or within the restoration site?
4. Restore the hydrologic connectivity of the meadow
   - Do flows spread over the meadow rather than funneling into a deep channel?

DESIRED CONDITIONS

The stream channel exhibits properly functioning condition for a meadow system and accesses the full extent of its floodplain. The water table within the meadow has returned to a level similar to pre-headcut condition. Late seral meadow vegetation (moist) species are reestablished. Conifer encroachment (seedlings and saplings) has stopped and existing conifers that have died due to saturated root systems. Natural streambank erosion and sediment delivery to downstream resources is at a natural background rate (0.1 – 0.4 cubic yards per year). Conditions that favor the existence of the active headcut are not present.

MONITORING METHODS

We surveyed for amphibians, including chorus frogs, western toads, and mountain yellow legged frogs. None of these amphibians were seen or heard at the restoration site or the meadow. Redwood meadow is a short ways upstream and we believe we should see recolonization of the meadow once the drought (2011 -2016) is no longer with us. We will keep monitoring for colonization in the spring until 2018. Fish should not be present in this headwater meadow. However, native Kern River rainbow trout will be placed just downstream in Bone Creek starting in 2018 or 2019.

We installed wells at 7 locations (see Figure 5) around the restoration site in the spring of 2014 several months to the restoration. We monitored these wells annually during the accessible months (May to October, unless drought gave us earlier access).

Vegetation was monitored visually before restoration and after. The species composition and growth of wetland vegetation and indicators were visually monitored in 2015 and 2016. Conifer survival was monitored as well.

Photo-monitoring was done in 2014 and 2015

Figure 7. Locations of wells placed around at the meadow level to judge changes in groundwater in the area of the restoration.

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RESTORATION METHODS

Rocks for the valley grade control structure were inspected for weeds and no weeds were found. The rocks were hauled and placed in an existing gap (former landing). Two ponds were dug instead of the original design of 3 ponds. The first pond was used to fill the gully at the lower end of the meadow. Care was taken to work quickly and cleanly. No spills of hydraulic fluids, oil, or other chemical spills occurred. Rock fill was laid down in the gully below the ponds first to help provide a strong anchor for the meadow. Then soils were placed on top to fill the gully to the level and slope of the old transition zone (8a and b). An old dam wall occurs below the restoration site and care was taken not to disturb this wall in the building of the valley grade control structure. Access from the old logging road was closed after use and blocked at the Western divide Highway end. The ponds and the plugs and gully fill took 4 days including mobilization into the meadow. The as built design is shown in Figure 10.

Figure 8. a. Gully beginning to be filled

8b. Gully Filled, note location of large pine to the right

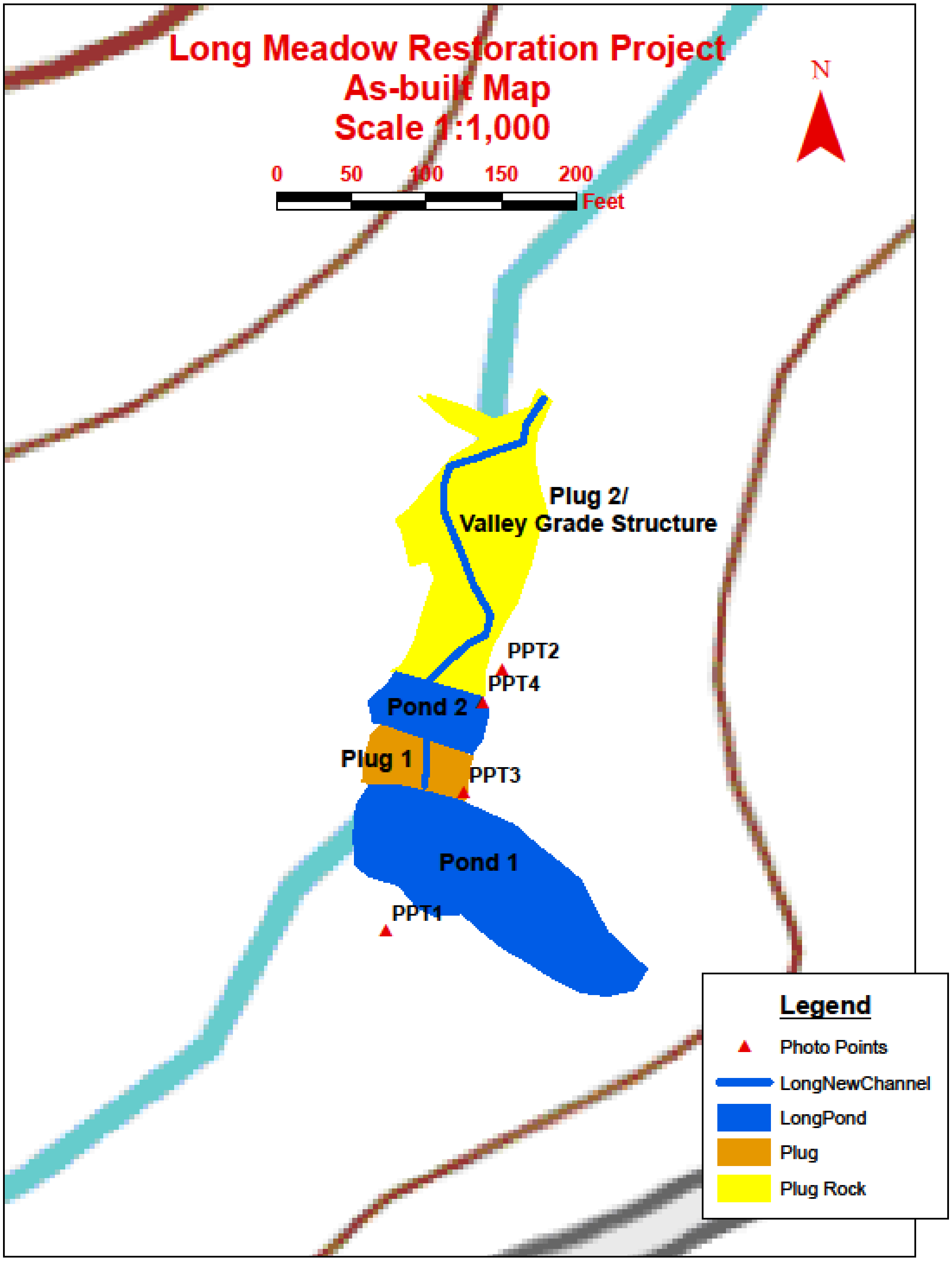

Figure 10. The as built design showing ponds, plugs and valley grade control. The stream structure was built in. This Figure also shows locations of Photo-Points.

Figure 11. Aerial View of the restoration site in 2014 showing primary headcut and the subsidiary erosion occurring.

Figure 12. Google earth 2016 imagery of the restoration site showing the two ponds that were built and the fill. A channels where water has flowed is evident in this imagery (area that are darker indicating ponding). The white areas are rocky where water also appear to have flowed.

RESULTS

We surveyed for amphibians, including chorus frogs, western toads, and mountain yellow legged frogs. None of these amphibians were seen or heard at the restoration site or the meadow. Redwood meadow is a short ways upstream and we believe we should see recolonization of the meadow once the drought (2011 -2016) is no longer with us. We will keep monitoring for colonization in the spring until 2018. Fish should not be present in this headwater meadow. However, native Kern River rainbow trout will be placed just downstream in Bone Creek starting in 2018 or 2019.

Vegetation dominant wetland species height were used as indicators of whether the hydrologic function was returning to the meadow. Prior to restoration in 2014; the vegetation was in poor shape; not all due to the drought (Figure 13). Visually the wetland Carex and other species monitored in 2015 and 2016 showed that all the areas that had been impacted by a lowered water table were doing well (Figure 14). Conifer survival has been variable and we will continue to monitor. Native wetland vegetation has responded positively to the restoration indicating that water table is sufficient to support this function.

Lateral erosion and downstream sediment movement were halted by restoration project. Figure 13 shows no channel downstream from the ponds. A small stream developed within the gully area but it is shallow. No deep channel has formed in the time since the restoration was done. We will continue to monitor erosion potential through 2018.

Figure 13. Grasses were dry in late July 2014. Wetland sedges were not doing well.

Figure 14. In late July 2016, green waves of healthy sedges can be seen on all the surfaces around the original headcut (first pond).

How has the water table changed since prior to restoration and how has it stayed the same? All of these data were collected during the years of drought here in the Southern Sierra Nevada in California. 2015 was one of the driest years on record, and 2016 was still a severe drought (see Figure 15). At well number 1 (Figure 16) at the lower end of the meadow the early summer water table level was higher post resoration. well data from well 1 late in summer showis little difference between the pre- and post resoration (Figure 17). When well locations just upstream from the headcut are examined (wells 4 and 5,Figure 17) a steady decline from early in the uyear to later in the year is seen. The lowest water table is in September in all years. 2015 had the lowest water table overall. I found no correlation between precipitation and groundwater levels using the data plotted in Figure 15 and the well data.

As a rough estimate of the change in volume of groundwater storage I made a quick estimate. This estimate indicates a doubling of storage of water in the meadow late in the season. I used the 19 acres of meadow right above the old headcut site (expressed as feet squared). I assumed a mean depth of 12 feet for the soils and used a range of porosities of soil from 10 to 30 percent. Water Table Depth from bedrock was estimated for pre-restoration and post restoration values in September for the years indicated (2014 and 2016) in the Table1. Volume of water in storage (cubic feet and acre feet) for September only was calculated using formula: Volume = Area x ST x SY

Where; Area is the lower portion of the meadow above old headcut; ST is saturated thickness or depth of groundwater; SY is the Specific yield or effective porosity or volume of water per unit volume of aquifer that can be extracted by pumping (R. W. Buddemeier, J. A. Schloss Groundwater Storage and Flow (http://www.kgs.ku.edu/HighPlains/atlas/apgengw.htm)). Under the lowest porosities, and this rough estimate, the volume increased by 19 acre feet in September 2016 compared to September 2014.

Meadow Size acres	**SY**	**Water table 2014**	**Volume 2014**	**Water table 2016**	**Volume 2016**	**Increase in storage volume snapshot**	**Acre feet increase in storage snapshot**
19	10	9	744876	11	910404	-165528	19
19	20	9	1489752	11	1820808	-331056	**38**
19	30	9	2234628	11	2731212	-496584	**57**

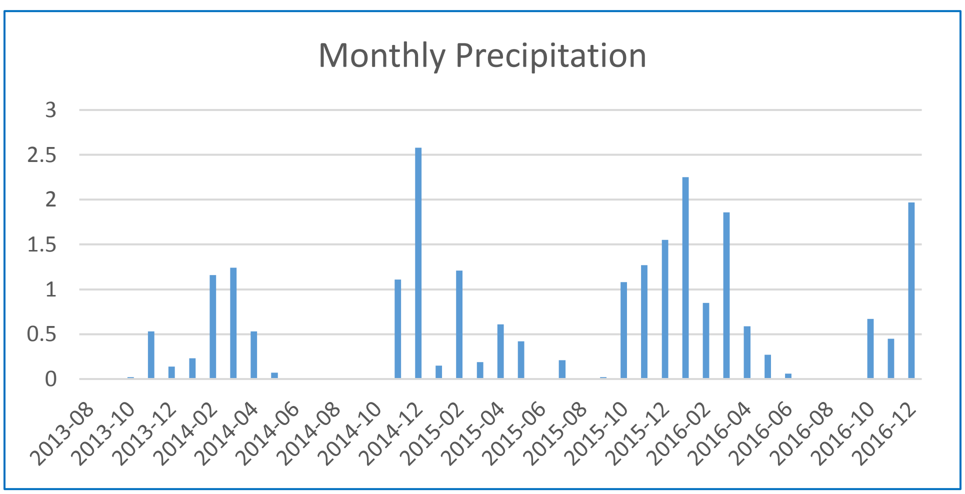

Figure 15. Precipitation patterns at Long Meadow from August 2013 to December 2016. (Data from PRISM, retrieved 3/16/2017).

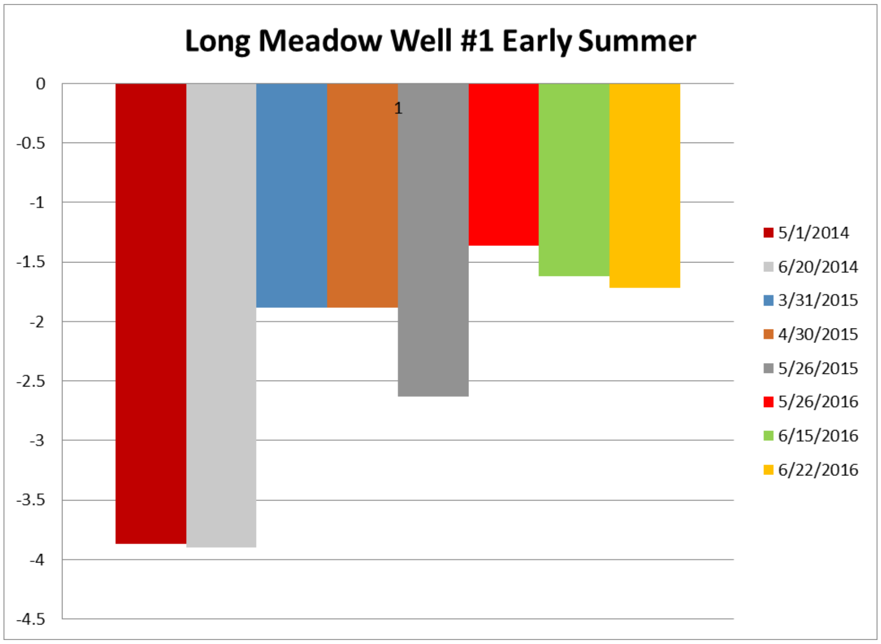

Figure 16. Early Summer well 1. Water table is higher post restoration.

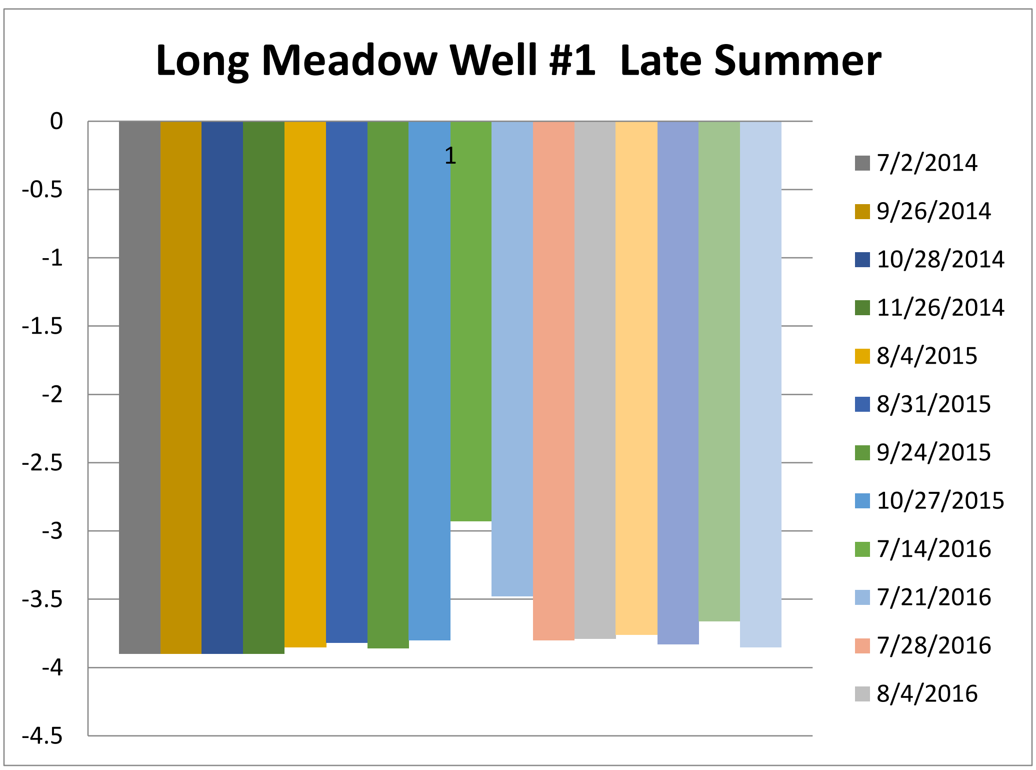

Figure 17. Late summer well 1 data indicate decline to the same level every year pre- and post-restoration.

Figure 18. Wells 4 and 5 are above where the head cut was. 2015 was the driest year and 2016 had a much higher water table even as it declined over the season.

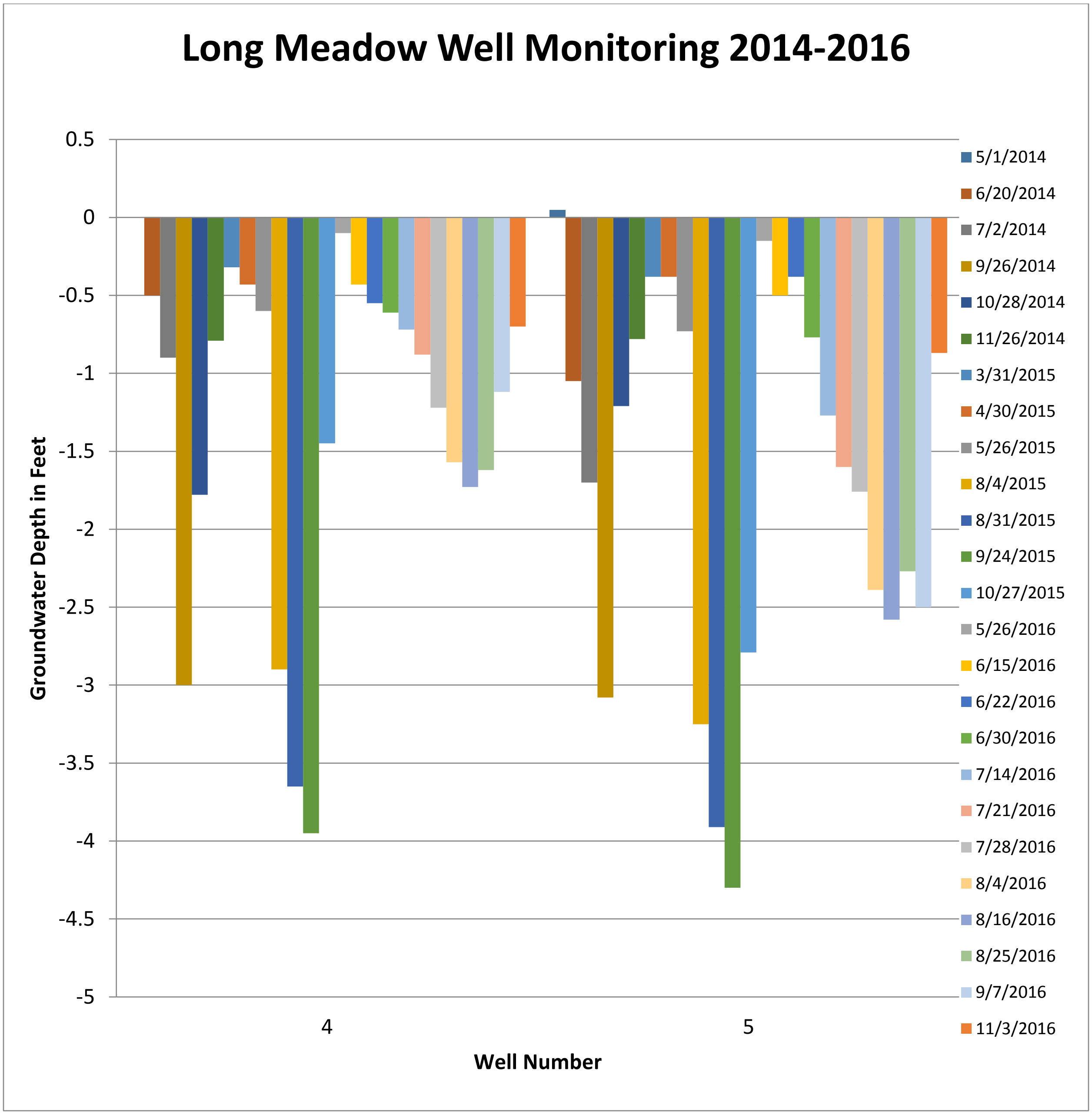

Photo-monitoring was done in 2014 and 2015

Photo-monitoring points were taken in 2014 pre- restoration and in 2015 post restoration. Some points were taken in 2016. They show the changes which occurred in the immediate area of the headcut (Figures 19 and 20). This area was grazed by horses late in the season in 2013 and no horse or cattle were supposed to use the area in 2014 due to the restoration. Note the vegetation is sparse and not growing well in Figure 19. In Figure 20, vegetation on surfaces with soil are doing well, areas denuded before or in the rocky fill *Carex aquaticus or Carex nebrascensis* was starting to grow

Figure 19. Photo point 2. Looking upstream in meadow at head cut in late summer 2014

Figure 20. Photo point 2. July 2015 looking upstream at headcut area.

Figure 21. Photo point 1. July 2014 looking downstream,

Figure 22. Photo point 1. In 2015 vegetation is starting to grow on surfaces around the restoration area.

Figure 23 Photo point 3. Looking upstream at the headcut.

Figure 24. Photo point 3. Looking upstream at the headcut in 2015.

Figure 25. Photo point 3 post-restoration in 2016. Ducks had begun to use pond.

Figure 26. Photo point 4. Pre restoration in 2014 looking downstream.

Figure 27.Photo point 4. Post restoration in 2014 looking downstream.

Figure 28. Photo point 4. Post restoration in 2015 looking downstream.

Figure 29. Detail of grade control looking upstream in July 2016. Native Carex has sprouted between rocks on the grade control structure. By July the stream is a series of small pools.

Riparian and meadow vegetation has improved, fewer conifers are present but about 15 remain. We will continue to watch these through 2018 and then remove. The connectivity for terrestrial or amphibian species has improved in downstream areas (see Figure 12). The riparian corridor downstream was in good shape in July 2016 enhancing the connectivity for species (see Figure 12) early in the season.

Conclusions

Erosion has been halted and the entire 35 acre meadow conserved. Native wildflowers and sedges are abundant in the meadow. Conifers encroached in meadow will be removed if still alive in 2018. The grade control structure is gradually being colonized by native vegetation. No amphibians have been found in the meadow yet. This includes no invasive bullfrogs. Ducks have been observed in the ponds so we anticipate other plants being brought in. While shallow groundwater appears tied to precipitation during the year a pattern of decline from early in the year to late season was observed every year. In 2016, year with more precipitation, the meadow water table stayed higher all year. Because we did not have pre-drought levels of groundwater in the meadow we cannot separate out the effects of the restoration from availability of water in the watershed. We will keep monitoring to see if we can determine the relationships between precipitations in the winter before with the shallow groundwater in the meadow. However, a function of a shallow water table; better growth and size of wetland vegetation has been achieved.