stream temperatures (Figure 2). Re-established and stable streamside vegetation provides shading to further lower stream temperatures (Figure 7). Temperatures for water near the surface of post-project ponds are usually elevated due to solar exposure but deeper water in ponds can provide quality trout habitat year-round.

Apart from solar radiation effects, the raised water table that results from the pond-and-plug treatment may provide benefits to stream temperature by enhancing surface and ground water interaction. During warm periods, groundwater input to streams lowers stream temperature and buffers diurnal stream temperature variations. During the coldest winter months, groundwater input would mollify extremely cold surface water temperatures. The change in magnitude of groundwater flow to a surface stream resulting from a pond-and-plug treatment would vary both seasonally, as stored runoff is either released to the stream or to the air via evapotranspiration, as well as spatially from reach to reach. Stanford University professors used high-resolution infrared imagery and instream temperature measurements to quantify detailed spatial patterns of groundwater recharge to the restored reach at Big Flat (Loheide 2006). Their investigations led to an estimate that maximum stream temperatures could be reduced by more than 3 degrees C through pond-and-plug restoration.

Quantifying stream temperature effects for pond-and-plug projects via empirical data is difficult due to the array of variables that affect stream temperature and the spatial, annual, and seasonal variations of these elements. Most prominent of these confounding variables are flow rate and ambient air temperature, both of which vary profoundly from year-to-year while air temperature can vary substantially from day-to-day.

Recent results from CRM monitoring and informal citizen monitoring on the Smith Creek project, constructed in 2007, indicate that shallow ponds connected to the base flow channel can result in increased stream temperatures. While the ponded areas used to obliterate the gully typically are connected to surface water flow only during flood events, pond-and-plug designs oftentimes use the ponds as a stable and convenient location to cross the low flow channel from one side of the valley to the other, thus following the natural flow path of the valley. At Smith Creek, monitoring data indicates water temperature increases several degrees F as it flows through a single, shallow pond. This effect may also stem in part from less deep groundwater interaction at this project site than at other projects. CRM designers are currently adapting design methods to consider a cold-flow channel from the inlet to the outlet for ponds that are less than roughly 3 feet deep.

Heritage Resource Effects

The majority of the pond and plug projects constructed to date are in areas that are considered prehistorically and historically significant. Consequently, since 2001, over 80 heritage sites have been recorded for the first time as a result of these projects. Additionally, at least 41 heritage sites have been re-recorded or re-visited.

A Programmatic Agreement exists between the Forest Service, Region 5, the California State Historic Preservation Officer, and the Advisory Council on Historic Preservation. When Forest activities are implemented in accordance with the stipulations of this agreement, the Forest's responsibilities for compliance with Section 106 of the National Historic Preservation Act are satisfied. Section 106 requirements have generally been met on pond-and-plug projects by using the “flag-and-avoid” technique to protect identified heritage resources.

All archaeological sites within the Area of Potential Effect (APE) must be taken into account. If a no effect determination cannot be reached, Section 106 evaluations are required for heritage sites located within the APE for the pond-and-plug project. The APE includes areas of restored groundwater levels, even if no physical impact will occur. To date, the CRM projects have resulted in the evaluations of portions of two large railroad systems which are located on both public and private lands: the Clover Valley Lumber Company Railroad and the California Fruit Exchange Railroad, both of which were recommended as eligible to the National Register of Historic Places. In addition, 12 prehistoric sites have been evaluated in the Last Chance Creek meadow system, Red Clover Valley, and Humbug Valley. Site excavations have contributed geochemical data and, at times, Carbon-14 dating data, which further contribute to our archaeological understanding by providing relative dates to the occupation of the site.

A unique archaeological benefit of the meadow projects is restoration of much of the natural environment of the heritage sites. This provides archaeologists with a clearer picture of the site's natural setting during prehistoric times, and aids our understanding of the site's function and interpretation. Before restoration, the sites appear to be located in exposed, sagebrush zones. Following restoration, the sites are more functionally situated in or near a lush meadow system with access to waterfowl, fish, and cultural material. In several cases, restoration has halted artifact loss and site erosion of prehistoric sites located along degraded stream channels.

The CRM has consistently designated Supplemental Survey Areas (non-APE) in high sensitivity areas (Last Chance Creek, Red Clover Valley, and Humbug Valley) in order to gather a greater understanding of the resource. This is in keeping with its stated mission statement of Coordinated Resource Management. The use of Supplemental Survey Areas has resulted in the recording of heritage sites which otherwise would have been unrecorded.

The pond-and-plug projects have the written support of Native American groups and Tribes, who have been active participants in consultation, review, and in some cases, survey. Restoring the natural environment is a stated tribal priority. Most of the CRM archaeology has taken place on private land, in locations where heritage sites would otherwise have remained unrecorded and therefore potentially unprotected. These projects have been requested by the private landowners due to their concern about meadow degradation. The landowners have actively expressed support for the archaeological component and some have taken steps to protect identified resources on a long-term basis.

Wildlife Effects

Restoration of the hydrologic function of a montane meadow system should result in significant benefits to aquatic and terrestrial wildlife. Riparian areas are known to be highly productive habitats and ecotones for both aquatic and terrestrial wildlife (Thomas, et al 1978). More than 225 species of birds, mammals, reptiles, and amphibians depend on California's riparian habitats (RHJV 2004). Specifically, healthy meadows are biodiversity hotspots in the Sierra Nevada, providing forage and critical habitat for a wide range of plant and animal species, including many listed species such as the willow flycatcher, great gray owl, and the Yosemite toad (NFWF 2010).

As described earlier, degraded meadow streams have wide, shallow channels that capture higher amounts of solar radiation, and therefore have higher temperatures than streams that are narrower and deeper. Additionally, degraded streams typically lack stream vegetation and shade, so temperatures are further increased. Pond-and-plug designs result in stream channels where vegetation and shade are at or near historic conditions, and this, in combination with channel morphology improvement and increased interaction with ground water, results in lower stream temperatures. While the restored water table will result in higher evapo-transpiration rates that may reduce stream flows within the project reach late in the season, this change represents restoration of meadow and riparian vegetation communities that are similar to historic conditions and a more natural flow regime to which native species are adapted. Restoration of flow and temperature regimes most likely improves habitat connectivity for native species at times for which they are adapted to move.

Meadow restoration likely benefits a wide variety of wildlife species. Meadows are biodiversity hotspots for the animal species of California, particularly birds and amphibians, of which approximately two-thirds depend upon Sierra Nevada habitats (NFWF 2010). Eighty-two terrestrial vertebrate species are considered dependent on riparian and meadow habitat, 24% of which are at risk (Graber 1996). Mountain meadows are key habitats for many animal species because they provide water and shade availability during the three to six month dry season, promote lower summer stream temperatures, higher plant productivity, increased insect prey availability, and special vegetation structures such as willow thickets (Ibid). Examples of species that occur in wet meadows include mule deer, elk, mallard ducks and other waterfowl, yellow-headed and red-winged blackbirds, striped racer, and various frog species (Mayer and Laudenslayer 1988).

Montane meadow habitat is extremely important for birds in the Sierra Nevada; numerous bird species, such as willow flycatcher, depend on montane meadows for breeding habitat and other species, such as great gray owl and red-breasted sapsucker, use meadows as important foraging habitat (Siegel and DeSante 1999). Additionally, montane meadows provide critical molting and pre-migration staging areas for juveniles and adults of a broad array of Sierra landbird species, such as orange-crowned and Nashville warblers, many of which also do not actually use meadow habitat for breeding (Ibid).

Meadow restoration likely benefits native fish populations. The changes to hydrology, channel morphology and water quality described earlier all reflect positive changes to fish habitat. Typically, channels in degraded meadow systems are relatively wider and shallower than non-degraded streams. Additionally, these streams typically lack deep pool and riffle habitat, or stable, undercut banks that are important habitat attributes. Pond-and-plug designs typically restore these features to the channel components of the meadow. The restoration of stable banks to these streams also eliminates a major source of sediment. Fine sediment delivered to streams can impact spawning and incubation (typically early spring for rainbow trout) and increase mortality of eggs and fry. Reduction of sediment from these sources should increase survival.

Fisheries monitoring conducted by the CRM at Big Flat in May 2000 found 60 rainbow trout in a 100-foot reach of Cottonwood Creek; that reach was typically dry and devoid of fish at that time of year (May) in the pre-project condition (Wilcox 2005). The Little Schneider project resulted in restoration of year-long flow during non-drought years so that trout were not stranded in dried-up reaches during those years. Macroinvertebrate monitoring at a 2001 floodplain re-connection project in the Carson River watershed (using a technique similar to pond-and-plug) demonstrated statistically significant improvements in the macroinvertebrate community during the first two years after construction (Herbst 2009). The macroinvertebrate community shifted from being dominated by pollution- (i.e., sediment) and disturbance-tolerant taxa to one comprising more sensitive taxa and more closely resembling the composition found at two nearby, healthy reference streams. Recent, not yet published studies on Trout Creek in the Lake Tahoe Basin indicated improved macroinvertebrate communities in the initial period after restoration but also that the response was not sustained after a period of 5 years (Herbst 2010). This study also points to a need to monitor ecological response to stream restoration over the long term.

Meadows and riparian areas are the single most important habitat for birds in the west; meadow restoration and management should be among the highest priorities for avian managers in the Sierra Nevada (PRBO and USDA). Recent restoration efforts, primarily in the form of removing grazing, have resulted in increases in numerous meadow bird species. Dense patches of willow or alder are a critical habitat feature for meadow dependent birds and tall, lush herbaceous meadow vegetation is important for concealing nests and supporting invertebrates that birds prey upon. Preliminary results of avian monitoring conducted by the CA Department of Water Resources (DWR) at Red Clover – McReynolds (constructed in 2006) indicated 16 additional bird species observed post-project, a 20% increase over the pre-project survey. These additional species include riparian and wetland species such as marsh wren, pied-billed grebe, and Wilson’s phalarope (CA DWR 2007). The DWR surveys also indicated a 64% increase in waterfowl young produced between 2004 and 2007. Many of the species which occurred only post-project are State or federal special status species, including but not limited to bald eagle, black-crowned night heron, and double-crested cormorant. Statistically significant increases in total avian density and species richness were found for a DWR study at the Clarks Creek project (CA DWR 2005).

Human eradication of beaver from PNF meadows is believed to be a key element in the loss of available meadow ecosystems. Beavers naturally perform the same type of work and results that are desired of the pond-and-plug treatment. That is, beavers spread flood flows and can re-water dried meadow systems. The CRM’s pond-and-plug projects are usually designed with the assumption that beaver will occupy and thrive within the restored project reach. During the project planning phase, designers need to assess whether project objectives can be achieved without extensive intervention and construction by encouraging the proliferation or introduction of area beaver populations. Installation of some small raises at channel riffles using rock or large wood may be enough to encourage substantial meadow improvement via beaver.

The presence of ponds in meadows as a result of the pond-and-plug treatment represents both benefits and potential negative effects. Ponds may provide improved habitat for adult trout during seasons of extremely cool or warm temperature and, if located within the floodplain, would be accessible to the rest of the stream system. However, ponds may serve as habitat for non-native species, and, in some cases, may result in temperature increases. The creation of ponds may introduce or increase populations of non-native bullfrogs and bass in these meadows, negatively affecting amphibians. Increased trout populations, though potentially desirable for recreationists or fisheries specialists, are also known to impact amphibian populations. Amphibians of specific concern are the Mountain Yellow Legged Frog (MYLF), which the US Fish and Wildlife Service (USFWS) is expected to imminently list as a Threatened species, the Foothill Yellow-Legged Frog (designated as a Forest Service “sensitive” species), Northwestern Pond Turtle (sensitive), California Red-Legged Frog (Threatened), and Pacific Tree Frog (Management Indicator Species). Therefore, the potential for increases in bass and bullfrog should be assessed and the presence of amphibian species of concern should be considered during project design, balancing the benefits and potential negative effects, including defining mitigation measures.

Ponds created by pond-and-plug efforts typically provide high-quality potential breeding habitat for bass or bullfrogs. Dramatic increases in bullfrog populations have been observed post-project at the Little Schneider Creek, Clarks Creek (PNF) and Carman Creek (Tahoe NF) projects. Bullfrogs existed at Carman Creek pre-project, although no pre-project survey data for bullfrogs are available. Bullfrogs were not known to exist pre-project within the Little Schneider and Clarks project areas, although a population did exist upstream of the Clarks project in a roadside watering pond. A large population of bass currently exists in the ponds at Little Schneider; bass were not known to occupy that area pre-project. These are the only known cases of aquatic invasive introduction or proliferation from pond-and-plug projects in the Upper Feather River watershed. However, little formal monitoring and documentation for invasive aquatic species has been performed to date on pond-and-plug projects. Pre- and post-project monitoring of bass and bullfrogs should occur.

Substantial increases in bullfrog or bass populations would likely present a severe adverse effect to sensitive frog species like the MYLF. Bullfrogs are native to the eastern United States but introduced in the west; both natural and man-made habitats pose a risk for bullfrog invasions. Established populations of bullfrogs are extremely difficult to eradicate, as are fish species such as bass. Bullfrogs are extremely prolific; a single bullfrog may lay in a single clutch, thousands of eggs (Schwalbe in Roach, D. 2004). Adult bullfrogs are voracious, opportunistic predators (Schwalbe and Rosen 1988) that will readily attack any live animal smaller than themselves, including conspecifics and other frogs (Bury and Whelan 1984). Introduced bullfrogs have been implicated in the decline or displacement of many amphibians including foothill yellow-legged frogs (*Rana boylii*; California, Kupferberg 1997) and northern red-legged frogs (*Rana aurora*; Oregon, Kiesecker and Blaustein 1997, 1998). Fisher and Shaffer (1996) found a negative correlation between the presence of introduced exotics (bullfrogs and fishes) and native amphibians in California. However, they did not discriminate between fishes and bullfrogs in their analyses. Because bullfrogs are likely to co-occur with mountain yellow-legged frogs only at lower elevations, the potential for impact is restricted to these portions of the mountain yellow-legged frog's range. In addition to predation, bullfrogs could potentially affect desirable aquatic wildlife species by hosting and supporting proliferation of disease in the aquatic environment, such as the chytrid fungus.

MYLF concerns are usually minimal for pond-and-plug projects proposed at the drier, flatter stream systems typically found on the east side of PNF. However, invasive species are still a policy issue that needs to be addressed, regardless of MYLF presence. For areas that are suitable for MYLF, more pre-project monitoring and investigation is needed to assess the potential for bullfrogs to migrate to or proliferate within a completed pond-and-plug project. Early conferencing with USFWS is necessary for proposed projects in areas suitable for MYLF. Human introduction to the constructed ponds of bullfrog and bass species is more likely for some project sites than others. A recent conference with USFWS regarding proposed restoration for Boulder Creek (Mt Hough RD) indicated that the USFWS felt the potential human introduction of invasives was an unacceptable risk because Boulder Creek has a known population of MYLF. USFWS informally supported the hypothetical notion of implementing a project in an unoccupied drainage parallel to Boulder Creek.

Theoretically, restoration of the historic hydrologic function of a meadow should result in benefits to wildlife populations that naturally reside in that ecosystem. In the case of the MYLF, more investigation is needed to determine which physical features can be incorporated in the pond-and-plug design to improve habitat. Instream habitat for MYLF could potentially be improved but the introduction of ponds would likely not benefit MYLF and may result in indirect impacts. It should also be considered that restoring hydrologic function may increase populations of potentially undesirable non-native fish species, such as largemouth bass or brown trout. Further studies should be completed on how these pond/plug projects affect native fisheries, including water quality (temperature and potential disease), downstream sediment budgets, aquatic connectivity, development of invasive species breeding and rearing habitat, and general habitat requirements. In general, stream restoration projects on PNF lands need to protect and encourage native species while not introducing or causing proliferation of invasive species, as directed in current Forest planning documents (USDA 2004).

Botanical Effects: Invasive Plant Species

The pond-and-plug restoration technique typically involves significant ground disturbance, particularly in the excavation of pond areas and repeated traffic in hauling material from the pond area to the plug area (hauling is typically performed with a front-end loader). Large quarry rock needed for construction of the project grade control structure (described in section IV below) is usually imported and hauled to the structure site in dump trucks. These activities can result in the introduction of non-native plant and noxious weed species, which can severely impact the area ecology. The disturbed areas provide habitat where invasive plant species can thrive and out-compete native species. Further, any existing infestations of invasive plant species on the project site can be dispersed and exacerbated by construction activities. Particular noxious weed species of concern for riparian restoration projects are Canada Thistle (*Cirsium arvense*) and Tall Whitetop (*Lepidium latifolium*) because these species thrive in wet areas. If introduced, these species are difficult to eradicate because mechanical treatments may prevent seed set but typically do not kill all of a plant’s rhizomes. In most cases, eradication would require chemical treatment (i.e. herbicides).

Typical PNF measures to prevent the introduction of invasive plant species must be implemented on all pond-and-plug projects. These measures include thorough washing of construction equipment prior to bringing equipment on site; the use of native seed mixes for revegetation; and when imported materials, such as quarry rock, mulch and hay/straw, are needed, using only materials that are certified weed-free. Control areas are typically established for areas with known noxious weed occurrences. Traffic and disturbance is excluded from these areas. To establish vegetation on disturbed sites (particularly constructed plugs) CRM projects typically utilize native grass seed that is gathered the previous season from within the project site. Results for these seeded areas have been positive. The native grasses sown in the Upper Last Chance project yielded high rates of germination. No noxious weeds were found in the seeded areas during visits to the site one year after project implementation.

Carbon Sequestration

Qualitatively, restored meadows appeared to significantly increase organic carbon stocks through the much increased root mass and surface growth associated with conversion of dryland vegetation species to meadow herbs. In 2008, the CRM undertook a project 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. Initial data analysis indicates that restored meadows contain twice as much total carbon per acre (an additional 40 metric tons per acre) as degraded meadows (Wilcox 2010a).

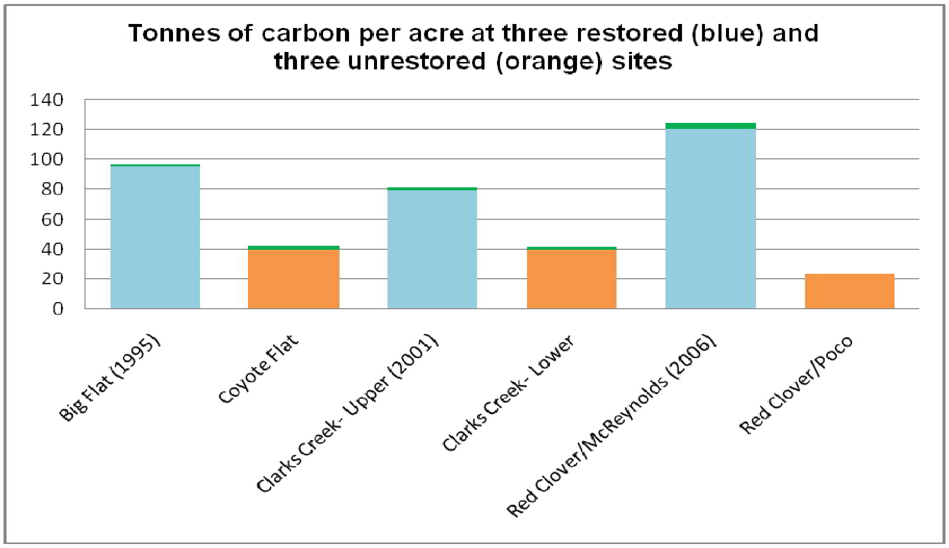

Figure 8. Metric tons of carbon per acre in each sample meadow. Green at the top of each column represents aboveground biomass carbon.

The columns in Figure 8 are arranged so that loosely comparable sites are next to each other, with the construction date given for the site treated with pond-and-plug. 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. Figure 9 demonstrates that the largest difference for carbon occurred below ground within 12 inches of the meadow surface, where most of the carbon is present for both restored and unrestored meadows.

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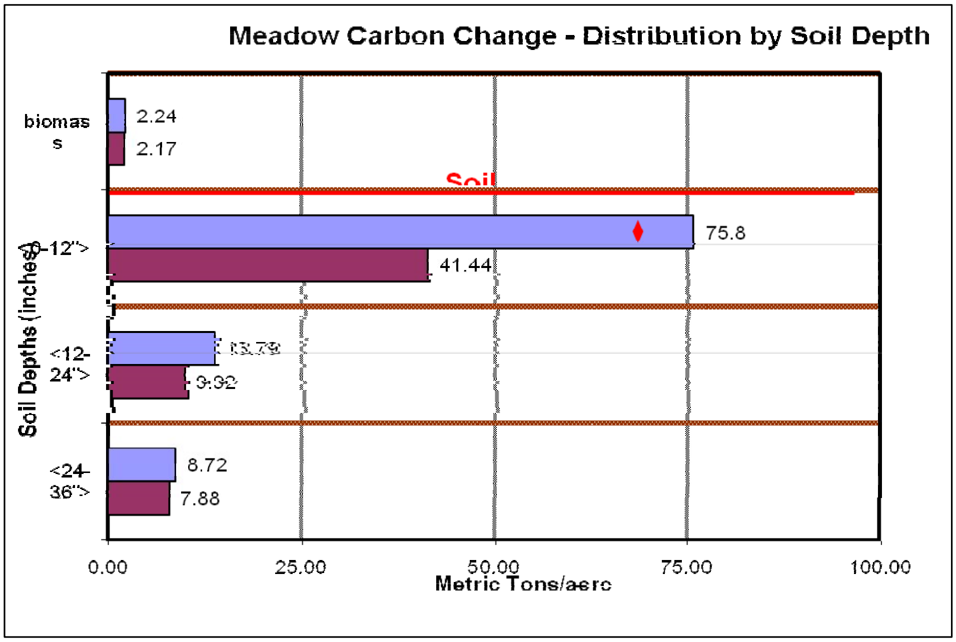

Figure 9. Total metric tons per acre of carbon in restored (blue) and unrestored (maroon) meadows displayed by depth. The soil surface is shown as a red line.

Hydrologic Risks and Design Considerations

Ever since the first pond-and-plug project was proposed on PNF lands, and continually since then, concerns have been raised by PNF specialists and CRM signatories from all disciplines regarding the long-term viability of these projects and the risk of hydrologic "failure." Certainly, such concerns are well-founded for any stream restoration technique because of the challenging expectations that the restored system will remain stable and provide improved habitat under the full range of flow and sediment loading conditions. For example, a design for Red Clover Creek - McReynolds would need to be stable throughout roughly 80% of the calendar year when flows are less than 1 cubic foot per second and also at the instances when the creek is experiencing a 100-year flood of approximately 6000 cfs.

As stated above, pond-and-plug is a relatively new technique within the relatively new field of bio-engineered stream restoration. The CRM and PNF have been among the leaders nationally in pioneering this treatment and we have learned a great deal from the implementation of more than two dozen different pond-and-plug projects.

Excessive erosion and gullying of the pioneered, new channel for the 1995 Big Flat project demonstrated the need to "under-design" rather than "over-design" the new channel so that higher flows will readily access the floodplain and not be confined to the channel to the point where downcutting occurs and is deeper than rooting depths. The Big Flat project also reinforced the approach that new channels should be cut into the meadow only when absolutely necessary and that working with existing meadow features such as remnant channels, or leaving flow to sheet over the meadow where a channel does not exist and is not needed, is preferable to constructing a new channel. Failure of the Willow Creek project demonstrated the importance of constructing an anchoring, grade control structure at a location that is assured of having large flood flows funneled over the structure. Extenuating circumstances limited the CRM to locating the grade control for that project, toward the middle of the meadow reach where flood flows could circumvent the structure. Additionally, the structure for Willow Creek was a version of a step-pool design that is no longer used. Constructed in 1996 less than three months prior to the 1997 flood of record, the step-pool structure failed and re-initiated headcutting. CRM designers have consistently applied adaptive management to pond-and-plug projects, improving design and construction techniques and resulting in recent projects that are much more stable than the two projects discussed in this paragraph, which were constructed nearly 15 years ago.

Most recently, hydrologic concerns voiced have emphasized the viability of grade control structures, risks associated with flow over the plugs, risks associated with steeper meadow systems, and viability of projects during large floods like a 100-year event. These concerns, and design considerations to address such concerns, are briefly described below.

As stated in the introduction, design considerations are presented here in very basic terms, with the intention that readers who are resource professionals but not hydrologists or engineers can gain a better understanding of how the treatment works. This paper is not intended to be a technical guide for how to design pond-and-plug projects. Detailed case studies of the design for one or two specific pond-and-plug projects would provide stream restoration practitioners with better, more comprehensive insight to the design details of this treatment.

Within the stream restoration field, different design philosophies and approaches currently exist so a brief characterization of the approach used to date for pond-and-plug projects may be helpful. In fluvial geomorphology parlance, use of existing remnant channels on the meadow surface would likely be considered an "analog" approach to channel restoration. The designer starts with the assumption that the remnant channel was once stable and will be stable with respect to erosion and sedimentation in the future. Other restoration practitioners may take a more "analytical" approach to design in which hydraulic and sediment transport modeling are used to determine the dimensions of a stable channel system rather than ascertaining those dimensions from a presumed stable, reference channel on or near the project area. Intensive analytical designs can take more time and money to develop, primarily due to extensive sampling and surveying necessary to perform sediment transport modeling or advanced hydraulic modeling. Most stream restoration designs combine these two approaches. A "combination" design approach might include the assumption that the remnant channel will be stable, but that assumption would be verified with hydraulic and sediment transport modeling and field investigations.

To date, the CRM's "combination" design method could be characterized as closer to an analog approach, with the stability of remnant channels identified within the project area being verified by analytical assessment using basic, industry-standard hydraulic models and qualitative field investigations of sediment transport competence and capacity. These remnant channels are expected to adjust over time to the sediment size and load delivered. More intensive quantitative sediment modeling and advanced hydraulic modeling may be helpful for improving designs and predicting performance, particularly on steeper pond-and-plug projects, as discussed briefly below.

Grade Control Structure

As described above, by restoring streams to regain connectivity to a broad floodplain, the likelihood of project success is far greater than a restoration treatment that is undertaken within the incised gully of the existing stream system. This position is plainly supported by comparing calculated shear stresses for large flood flows that are spread out over a floodplain versus the much higher stresses developed when those flows are confined to a gully.

When the base level of the stream system is raised to meadow elevation at the first upstream plug, it is common for the stream level to be lowered back to the incised, gullied elevation at the downstream end of the project reach. At that terminus, flows typically need to be dropped 3-10 vertical feet over a structure constructed of rock and soil. This is the point at which the pond-and-plug treatment is most vulnerable. The typical mechanism for potential failure is called an "end run" of the structure, in which a portion of a flood flow finds a soft location off of the armored structure. Once a small nick is formed at this soft location, flow can be concentrated there, eroding the nick deeper. Given enough flow power and duration, the nick can deepen, widen, and lengthen, developing into a gully that diverts the majority of flow around the hardened structure.

To avoid an end-run of the grade control structure, it must be placed at a location in which the landscape naturally funnels all flows, including large floods, over the structure and into the downstream gully. This is the chief design consideration for these structures. Also, the grade control structure needs to be keyed into the gully or funnel walls so that the seam between the hardened structure and the softer wall material does not become a nick point where an end run can start.

Other design considerations include structure slope and shape. For example, the grade control structure for the Three-Corner Meadow project (Tahoe NF) was damaged during the 2006-07 floods due to excessive concentration of flow in the middle of the structure, which was built at a relatively steep slope of 7%-8%. The Three-Corner Meadow grade control structure was subsequently repaired and reconstructed to spread flows better and the slope of the structure was reduced to approximately 5%.

The CRM's design for these structures has changed considerably since earlier projects such as the Willow Creek project. Current grade control structures are built to be long spillways with no more than a 5% slope. The low flow channel is constructed within the spillway to confine base flows to a narrow channel that is fish-passable. The low flow channel meanders over the spillway so that its effective slope is less than 3%-4%. Riffle-pool sequences are built within this channel to dissipate flow energy and to aid fish passage. The structure is built with a soil core that is mixed and armored with a 3-4 ft thick layer of soil and small rock intermingled with large rock (typically 2-3 feet in diameter). Willow and sod transplants are installed on the soil and rock mixture to improve shading and habitat on the structure and to further resist flow erosion. The dense root system of these plants further binds and strengthens the structure.

Figure 10: Alkali grade control structure on Last Chance Creek demonstrates the stability of the current design method during a flood in spring 2006. First photo is February 23, 2006, second photo taken on February 28, and third photo in May 2006. Note in the first and third photos that low flows remain in the constructed riffle-pool base flow channel after the flood. (Photos: Jim Wilcox)

Concerns have been raised because these structures have not been tested by a large, 100-year flood. In the Upper Feather River watershed, the largest test flood to date occurred in

2005 – 2006. The floods of that runoff season peaked at calculated return intervals that range from less than 5 years to as much as 15 years, depending upon location in the watershed, and several flood events greater than bankfull occurred that season in the Last Chance Creek watershed. Apart from the Three-Corner Meadow structure, none of the dozen or more pond-and-plug grade control structures that existed at that time received significant flood damage (see Figure 10). During design phase, conventional engineering charts and models for shear stress and channel rip rap sizing can be used to specify large rock of sufficient size to maintain the structure (USACE 1991 and USDoT 1989).

Piping of flow, in which the structure erodes from within due to material being pushed through the face of the grade control structure by pressure from the water surface upstream of the structure, is not a practical concern because the length of these structures, relative to the length of earthen dams, is much greater. Conventional engineering flow net calculations can be used to verify that the length of the spillway is sufficient to prevent piping.

Flow over the Plugs

A common concern for the long-term stability and integrity of a pond-and-plug project is whether or not the earthen plugs that obliterate the gully are stable. For a typical application of the treatment, the earthen plugs are not considered to be dams because the "head," i.e. the static water pressure exerted on the plug as measured by the difference in water elevations of the pond immediately upstream and downstream of the plug, is small, ideally less than 0.5 ft to 1.0 ft. Unlike a grade control structure, the downstream face of a plug may not be long and shallow-sloped but is typically abruptly sloped at approximately 30%-70%. However, piping is usually not a concern for these plugs because the head (water pressure) is not large enough to force material through the plug and because most plugs are relatively longer than typical earth dams. Piping could be an issue for plugs on steeper projects (see below).

The integrity of a plug can also be threatened by excessive flows over the plug. As described above, the remnant channel typically conveys low flows over the meadow at a location that is separate from the obliterated gully. However, during flood stages, flow is spread across the entire meadow, including over plugs designed to be part of the floodplain. If a headcut develops on a plug, flow could be concentrated for a long enough duration to divert more flow over the plug and eventually cut through the entire length of the plug (Figure 11).

If flow over a plug were to cause a nick point, that nick would usually occur at the downstream edge of the plug because the flow elevation drops abruptly at this edge, from the elevation of the pond upstream of the plug to the elevation of the downstream pond, potentially resulting in turbulent, erosive force at this edge of the plug during a large flood. The downstream edge of a plug with a small change in flow elevation (less than 0.5 ft to 1.0 ft) will be subjected to less erosive force than a plug with a larger change in base elevation and will thus be less likely to form a headcut. If a plug were to have concentrated flow that eventually cut through the entire plug, the plug immediately upstream would now have its head essentially doubled, placing further stress on that plug.

An abrupt drop at the downstream edge of plugs is susceptible to cutting during flood flows and can be ameliorated by sloping the surface of the plug. Again, this mitigation would be more difficult to achieve on plugs subjected to a larger difference in elevation of adjacent ponds because the slope of the plug surface would be steeper and shear stress due to flow on that steeper slope could be too high. Willow or sedge mat transplants can be added to armor the downstream edge or slope of plugs that are identified to be at risk of cutting due to flood flows.

Figure 11: Excessive flow over this plug on Last Chance Creek at Jordan Flat during the 2006 floods caused the base flow to be diverted over the plug. Excessive flow was due to unforeseen dynamics between Last Chance Creek and a tributary stream. A berm was constructed and the problem corrected in 2007. Excessive flow over plugs could headcut through the entire plug, lowering the upstream pond elevation to the elevation of the downstream pond and essentially doubling the head on the next upstream plug. (Photo: Joe Hoffman)

A significant test of the integrity of plugs located within the floodplain during large flows occurred on the Big Meadows project on the Sequoia NF (Wilcox 2010b). Several of the design elements discussed above to reduce risks associated with flood flows on plugs were incorporated in the Big Meadows project (constructed in 2007, Figure 12). In October 2009, the project area was subjected to a high volume, high intensity precipitation event with over 8 inches of rain falling in less than 20 hours. Post-event field observations and stream gage records from the Kings River watershed indicated that flow through the project peaked at approximately 1200 cfs, estimated to be the flood with a 50- to 100-year return interval (i.e. a 1% - 2% chance of occurring in any given year). Post-flood observations indicated that all project plugs sustained some overland flow. Despite flood depths on the plugs of up to 2 feet and estimated flow velocities of up to 3.5 feet per second, no headcut was observed on any plug and very little mobilization of surface soil particles was observed.

Nearly all pond-and-plug designs assume that, due to natural processes, the channel that carries base flow could, and likely will, leave the designed low flow channel and flow somewhere else on the floodplain, potentially over plugs that have been designed to be part of the floodplain. Only in the case where plug surfaces are substantially higher than the restored floodplain is this assumption not made. For example, flow could occur over a plug throughout the year, not only during larger floods, because a beaver dam on the designed base flow channel could divert the base flow. Since base flow location is likely to shift in response to natural processes, stable, well vegetated plug surfaces, particularly at the downstream edge of the plug, are critical for the success of pond-and-plug projects.

Figure 12: Big Meadows Pond-and-Plug Project, Sequoia NF. Project was constructed in fall 2007. Photo taken in spring, 2008 during the first runoff season. (Photo: Wayne Luallen)

Beaver may also help to maintain the surface of plugs and the base level of pond-and-plug projects. As an example, the CRM recognized during the design phase for Red Clover - McReynolds (on Goodwin Ranch) that beaver would likely move into the project area, which in fact they did shortly after construction began. The beaver constructed a dam on the low flow, remnant channel, diverting the low flow back toward the obliterated gully and over one of the plugs. In anticipation of this, the CRM designed the difference between all ponds on the project to be less than 6 inches, so that when the low flow was diverted, stresses on the plug would be lower and plug vegetation would eventually keep the new, diverted channel stable. Since the beaver dam described above occurred before the plug was vegetated, flow did cut through the entire plug. However, the beaver apparently were not satisfied with a lower baseflow elevation at this point and fixed the elevation change by damming the new baseflow channel at the cut plug (see Figure 13).

Figure 13: At the Red Clover – McReynolds Project, flow had cut through a plug shortly after construction due to damming of the designed base flow channel. Beaver subsequently dammed the cut at the plug so that base flow elevation is maintained upstream of the plug. (Photo: Joe Hoffman)

Vegetation established on plugs is key to keeping the plug surface stable and capable of resisting shear stresses associated with flood flows. To facilitate quicker establishment of vegetation on the newly constructed earthen plugs, mats of native sedges and topsoil excavated from the pond borrow sites have been stockpiled and spread over the surface of the completed plug. CRM monitoring from the past 10 years indicates that seeding of plugs is integral to establishment of vegetation on the plug. In most cases a matted grass surface on a plug would not develop within the first two to three years, and could take up to 5 years to provide coverage that is dense enough to fully resist shear stresses associated with larger flood flows. Transplant or import of sod mats during project implementation can provide a highly-resistant, matted vegetative surface on the plug within the first year after construction.

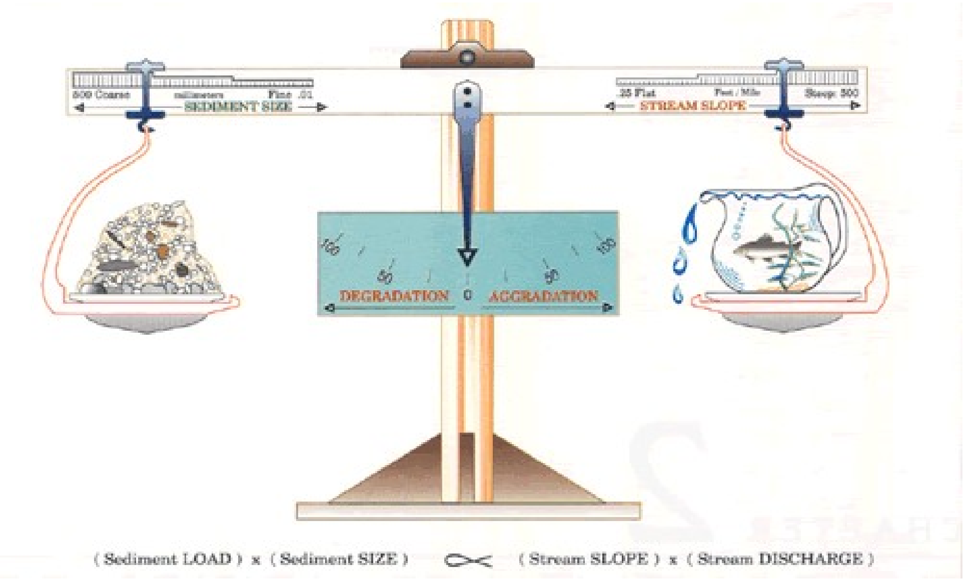

Figure 14: Lane's classic diagram illustrates that the size and volume of sediment transported in a stream channel is proportional to the channel slope and the stream discharge.

The size and volume of sediment transported throughout the range of a watershed's flood events, not merely the volume of water transported, is critical to any stream or meadow restoration design. Lane's classic diagram demonstrates that the size and volume of sediment transported is proportional to the flow rate and channel slope (Figure 14). Steeper stream systems are often associated with bedload that is coarser (gravels and even cobbles) than the bedload typically associated with meadow streams. Plugging of the designed, post-project base flow channel with this coarse bedload, initiated by sediment deposition in the channel or a tree falling across the channel, can result in a diversion of the base flow channel much like that accomplished by beaver. Flatter meadow systems may need to transport sediment and that sediment would likely be finer than for steeper systems. However, the volume of sediment transported to the project reach may be large and could result in sediment deposition in the meadow reach, causing a rise in the channel bed elevation that may divert flow out of the designed base flow channel. Some meadow stream systems may not need to be designed to transport sediment. Analysis of the designed channel's ability to transport the predicted size and volume of sediment delivered to the channel is critical to the long-term success of any stream restoration project. Project design also needs to consider that capture of a stream's sediment load within the pond-and-plug reach could affect the sediment / water balance such that erosion processes downstream of the project are accelerated.

Low differences in pond elevations at each plug are clearly desirable. However, such low differences are physically difficult to achieve in meadow systems that are steeper. Figure 15 depicts a simple representation of example pond elevation differences for a flatter and a steeper meadow (the figure is meant only to demonstrate elevation differences; actual constructed plug shapes are more complex). For a 0.5% meadow, plugs can be spaced 100 feet apart and a pond elevation difference of 6 inches will exist. For a 2.0% meadow, plugs that are spaced just 63 feet apart result in a pond elevation difference of over 1 foot. To reduce that difference, plugs would have to be spaced closer together, approaching the point where the gully is nearly filled with plug material, which becomes economically infeasible for larger incisions.

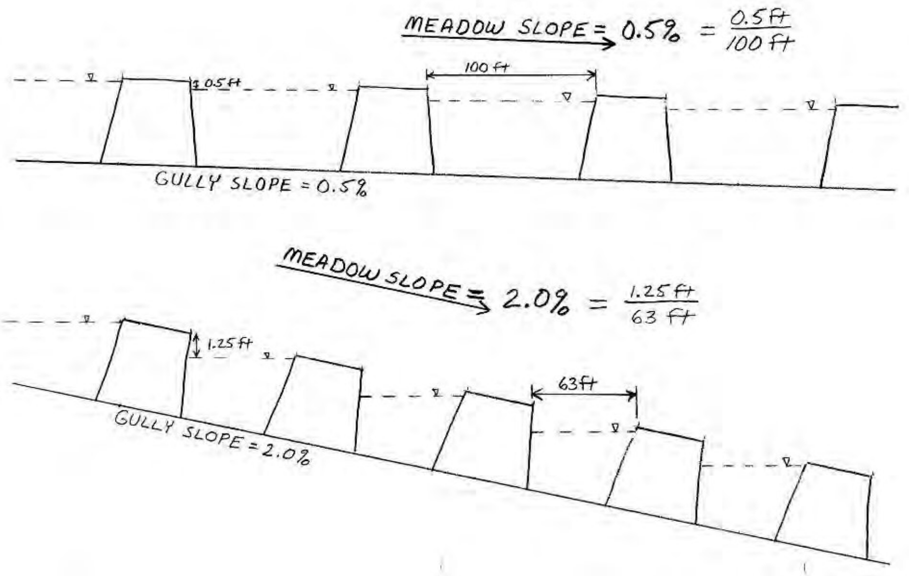

Figure 15: Example valley profiles for a flatter and a steeper meadow demonstrate the higher pond elevation differences inherent with steeper meadows.

Pond-and-plug treatments on steeper meadows are much more challenging and require more careful design. Flood modeling needs to be performed to calculate the depth and duration of flow that may run over the plugs. Generally, plugs with a head of 1.0 feet or more should be subjected to very infrequent flood flows of shallow depths so that the plug vegetation can resist the erosive shear stress. Conventional engineering charts for vegetated channels can be used to predict whether the vegetation will withstand the shear stress (USDoT 2005). Installation of imported rock across a plug surface, while expensive, is a potential mitigation for plugs that will be subjected to erosive flood flows. Willow and sedge mat transplants can also be used to armor plug surfaces.

Design consideration should be given to the notion that the modeled floodplain width could be restricted if flood flows occur when deep snow depths exist on the floodplain. Such snow depths could confine the flood flow, resulting in deeper, more erosive flows, both within the low flow channel and on the floodplain (potentially including plug surfaces). While investigating mortality effects of winter floods on fisheries, Erman, et al reported that large flows occurred with snow on the ground during six separate floods between 1953 and 1988 at the UC-Berkeley field station on Sagehen Creek near Truckee, CA (Erman 1988). These researchers surmise that increased shear stress due to snow confining flow to the channel would increase the sediment transport rate by approximately an order of magnitude for the winter flood measured in 1982, when dead Paiute sculpin were collected during bedload sampling. Much of the study reach is located in a forested riparian area and these researchers assert that the effect of snow confining flood flows would be more prevalent in meadow systems. The Sagehen Creek station is located at an elevation of 6300 feet in a basin that averages 37 inches of precipitation per year. The frequency of snow-confining flows, and the depths of snow experienced, would likely be reduced for lower elevation sites and for drier sites.

For steeper reaches approaching 3% - 4%, the difference between pond elevations at plugs can reach 3 – 6 feet. Clearly, flood flow over these plugs should not be considered a stable design unless the plugs are constructed more like grade control structures with hardened surfaces and spillways. Additionally, for plugs that approach this head, engineering design elements for conventional earthen dams should be evaluated or employed to prevent piping through the plug. Such elements may include controlled compaction of suitable, low permeability plug material and / or installation of a plug core consisting of clay or similar material of very low permeability. If a plug looks like a dam and acts like a dam, it should be designed, constructed and monitored as a dam.

Finally, assessment of the hydrologic success of any restoration project, including pond-and-plug projects, should include a definition of what "failure" and "success" mean. Flow that cuts across a plug is not likely a failure if the new path is stable or if the flow can be easily diverted back to a location that is stable in the long-term. A minor amount of repair to a grade control structure as a result of a large flood is not likely a failure if the integrity of the project upstream and the meadow base level were maintained. A project which loses a number of plugs in a flood and is left in an unstable condition that can not be repaired without essentially re-doing the treatment is likely a failure. Consideration should also be given to the consequences of not doing any treatment. Leaving the system to continually degrade, widen, and erode vast amounts of meadow could also be considered a "failure."

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Appendix A: List of Pond-and-Plug Projects Implemented in Upper Feather Watershed

Project Name	HUC-5 Watershed	Date	Private Land	USFS Land
Big Flat (Cottonwood Cr)	Last Chance Creek	1995		Plumas
Willow Creek	Upper Indian Creek	1996		Plumas
Bagley Creek II	Red Clover Creek	1996		Plumas
Ward Creek	Lower Indian Creek	1999	X	
Little Schneider Creek	Spanish Creek	1999		Plumas
Clarks Creek	Last Chance Creek	2001		Plumas
Stone Dairy	Last Chance Creek	2001		Plumas
Carman Creek (Knuthson Mdw)	Sierra Valley	2001		Tahoe
Hosselkus Creek	Lower Indian Creek	2002	X	Plumas
Last Chance Phase I - Pvt	Last Chance Creek	2002	X	
Carman Creek (3-Corner Mdw)	Sierra Valley	2002		Tahoe
Greenhorn Cr (New Eng Ranch)	Spanish Creek	2002	X	
Last Chance Phase I - USFS	Last Chance Creek	2003		Plumas
Poplar Creek	Lake Davis – Long Valley	2003	X	Plumas
Humbug - Charles	Lake Davis – Long Valley	2004	X	
Last Chance - Charles	Last Chance Creek	2004	X	
Ross Meadow	Lake Davis – Long Valley	2004		Plumas
Dooley Creek – Downing Mdw	Last Chance Creek	2005	X	Plumas
Jordan Flat	Last Chance Creek	2005		Plumas
Humbug – Charles II	Lake Davis – Long Valley	2006	X	
Hosselkus Creek II	Lower Indian Creek	2006	X	
Red Clover – McReynolds Creeks	Red Clover Creek	2006	X	Plumas
Sulphur Creek KV	Lake Davis – Long Valley	2007		Plumas
Rapp – Guidici (Sulphur Cr trib)	Lake Davis – Long Valley	2007	X	
Dixie Creek	Red Clover Creek	2007	X	
Last Chance – Ferris Fields	Last Chance Creek	2007		Plumas
Smith Creek	Lake Davis – Long Valley	2008	X	
Boulder Creek (Sulphur Cr trib)	Lake Davis – Long Valley	2008	X	
Long Valley Creek	Lake Davis – Long Valley	2008	X	

Sage Grouse Initiative

Science to Solutions

Private Lands Vital to Conserving Wet Areas

for Sage Grouse Summer Habitat

In Brief: In the arid West, life follows water. Habitats near water – streamsides, wet meadows and wetlands — support the greatest variety of animal and plant life, and attract wildlife during their daily and seasonal movements. In a water-scarce landscape, these lush habitats are also where people have naturally settled. A recent groundbreaking study reveals a strong link between wet sites, which are essential summer habitat for sage grouse to raise their broods, and the distribution of sage grouse breeding areas or leks. The authors found 85% of leks were clustered within 6 miles of these wet summer habitats. Moreover, although wet habitats cover less than 2% of the western landscape, more than 80% are located on private lands. This study makes it clear that successful sage grouse conservation will greatly depend on cooperative ventures with private landowners, ranchers and farmers to help sustain vital summer habitats.

Green Magnets for Grouse

The sage grouse's life history is intimately linked to sagebrush shrubsteppe uplands. Yet in late summer, as the uplands dry out, hens seek out emerald islands in the sagebrush sea: riparian edges, wet meadows, seasonal wetlands, and irrigated fields – remaining spots of green where they can still find moist forbs and plenty of insects for their growing chicks. These scattered wet habitat sites are critical for brood survival and recruitment.

Do these islands of late summer green somehow influence where sage grouse choose to breed in spring? And how does summer habitat fit into the conservation picture for sage grouse?

To answer these questions, Patrick Donnelly with the Intermountain West Joint Venture/U.S. Fish and Wildlife Service (IWJV/USFWS) and his co-authors Dave Naugle and Jeremy Maestas with the Sage Grouse Initiative (SGI), and Christian Hagen with Oregon State University (OSU), mapped sage grouse breeding sites in relation to wet habitats across a large landscape, and analyzed the land ownership of wet habitat sites.

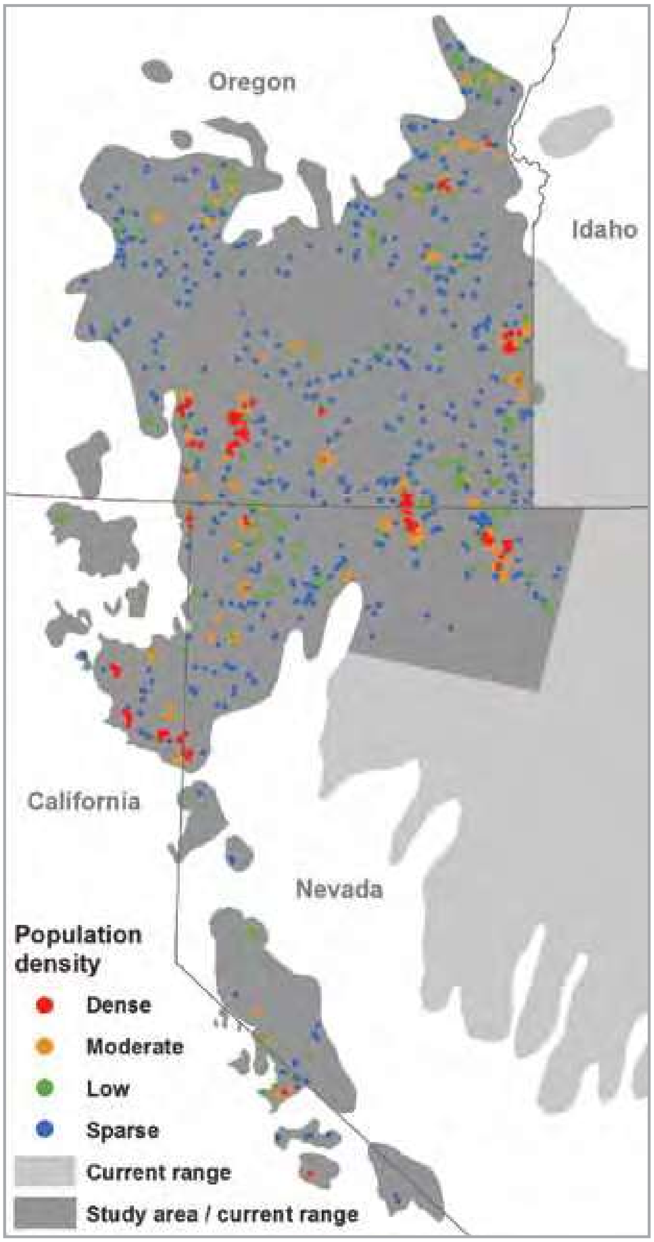
In late summer, wet meadows, riparian edges, and irrigated fields become islands of green in the sagebrush sea – vital foraging habitat for growing sage grouse broods. Photo credits: top - Dan Taylor; bottom left - Conservation Media; bottom right - Ken Miracle.

Lek Counts and Landsat

The authors studied patterns in the distribution of sage grouse breeding sites (leks) and summer habitats over a 28-year period (1984-2011) by taking advantage of two existing long-term datasets: annual lek survey data collected by the states and Landsat satellite imagery. The study area covered more than 32 million acres of current sage grouse range, encompassing populations in California, Oregon and northwestern Nevada. The scientists examined location and count data for 1,277 active lek sites in relation to habitat cover interpreted from Landsat satellite imagery. Using lek survey data they could categorize breeding areas by sparse, moderate or dense populations.

Landsat images used to map wet habitats were acquired for each year in late summer (August and September) during a time when sage grouse rely heavily on these resources for food. This allowed the authors to account for annual variations in climate and determine how changes altered summer habitat distribution during wet and dry periods. Summer habitats were classified as natural or agricultural areas. Natural sites included riparian areas, seasonal and temporary wetlands, as well as reservoirs, lakes, and playas with moist vegetation. Agricultural sites included wet meadows and alfalfa fields. Although wet meadows form naturally in basins, more than 92% of wet meadows in the study area were irrigated.

Once mapping was complete, the team could examine the spatial relationship between summer habitat locations, the likelihood of a habitat site being wet from year to year, and the distribution and abundance of sage grouse based on lek surveys. In addition, the researchers overlaid land ownership maps with wet habitat locations to establish whether late summer sage grouse habitat is more likely to be on pubic or private land.



The study area encompassed sage grouse range in Oregon, California and northwest Nevada. Colored dots represent leks. Grouse leks and populations cluster in the landscape: red and yellow indicate higher breeding densities; blue and green are more sparse. Map courtesy of Patrick Donnelly, IWJV/USFWS.

In late summer, sage grouse seek out productive wet habitats in both natural and agricultural areas. In this study, natural sites included riparian habitats, seasonal and temporal wetlands, and the edges of reservoirs, lakes, and playas with moist vegetation. Agricultural sites included alfalfa fields and wet meadows, which were most often associated with irrigation.

Summer Habitats Connect Sage Grouse with Private Lands

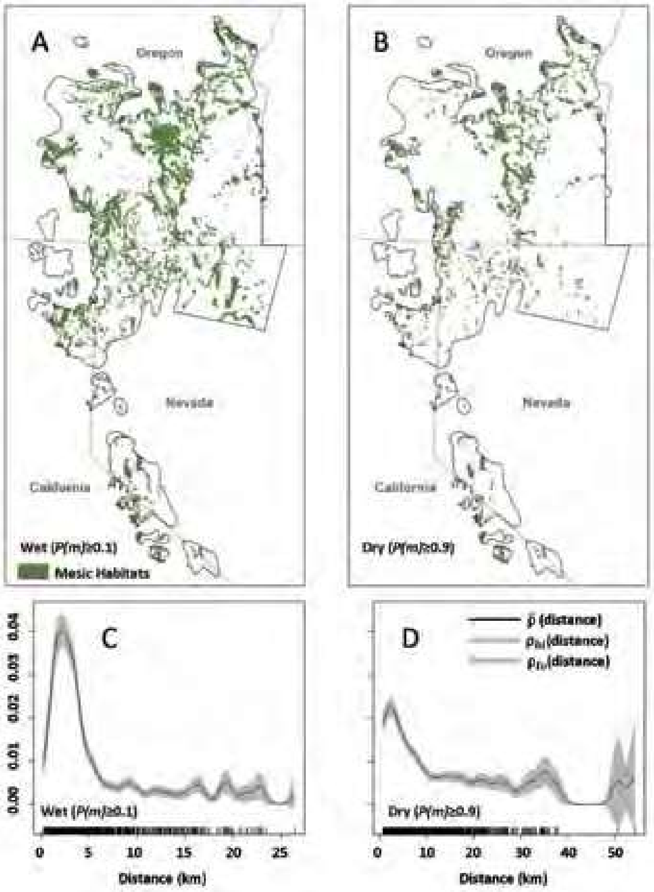
Several patterns quickly became clear. Not only were leks clumped in the landscape, but the distribution of those clusters were strongly linked to the location of wet habitats: 85% of leks were within 6.2 miles of wet sites. The breeding areas with the highest densities of birds were even closer — within only 1.8 miles of wet habitats. In other words, the scarcity of wet habitats in sagebrush ecosystems drive the location of grouse breeding sites on uplands: hens choose to mate and nest within a reasonable walk of where they can find late summer foraging for their broods.

While sagebrush uplands are characteristically more stable environments, the study found the extent of wet summer habitats varied greatly from year to year with shifting climate patterns. In dry years, grouse broods must walk farther to find adequate summer foraging sites — the distance can double, increasing nutritional stress and making hens and chicks more vulnerable to predation.

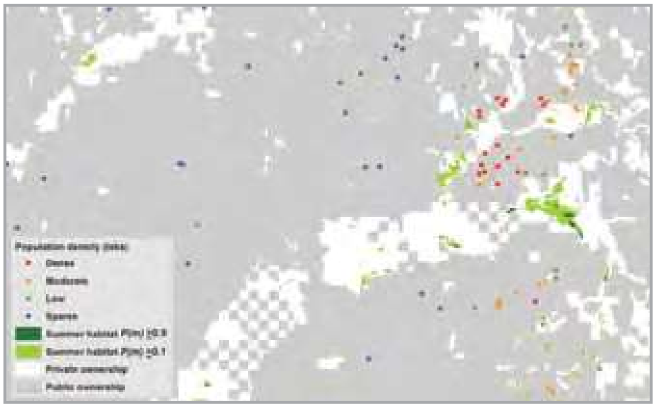
Grouse breeding sites with larger populations were also linked to the best natural summer habitats, and in wet years these sites may drive population recruitment: more chicks survive. On the other hand, sparsely populated breeding areas were farther from summer habitats and often associated with irrigated agriculture. During drought, grouse find fewer options for late summer foraging and may rely more on irrigated fields and wet meadows, when natural sites dry out.

European settlers to the Great Basin well understood the best sites for farms and pastures, and settled stream bottoms and basins that collect snowmelt and remain productive late into summer. Donnelly and his team overlaid current land ownership with 1887 maps of topographic basins and with Landsat imagery of current wet habitat condition. The natural basins that support both temporary and persistent wet habitats were magnets for settlers, and virtually all are in private ownership today. The authors found that while wet habitats make up only 1 to 2% of the land area, 81% are in private hands.

> *"I don't think it was so much a surprise that grouse rely on these wet areas and that wet habitats are limited; it was how much of this was private, and how much wet summer habitat controlled the distribution of grouse across the landscape."*
> ~Patrick Donnelly, IWJV/USFWS



In wet years, the extent of wet (mesic) habitats can nearly double (maps at top). Hence leks are much closer to summer habitat (bottom graphs) – an easier trek from nesting areas for hens with broods. Chart courtesy of Patrick Donnelly, IWJV/USFWS.



Mapping leks, wet summer habitats and land ownership revealed a startling pattern: although >80% of upland breeding habitat is on public lands, >80% of critical summer brood habitat is located on private lands. Chart courtesy of Patrick Donnelly, IWJV/USFWS.

An Essential Piece of the Conservation Puzzle

Conventionally, sage grouse conservation has focused on management of sagebrush uplands, yet this study reveals that wet summer habitats and private land partnerships are vital for sustaining sage grouse. "How do you conserve grouse that split their time between private and public lands?" asks Donnelly. "With 81% of sparse summer habitat in private ownership, sage grouse success is inextricably linked to ranching and farming in the West."

Conservation must consider the connection between seasonal habitats on public and private lands and involve cooperative efforts with private landowners. By understanding the importance of privately-owned summer habitats to sage grouse, conservation pracitioners can use existing volunteer and incentive-based programs to target conservation easements, and focus investment in cooperative programs to reduce threats to, restore, and enhance these habitats.

How Can I Access this Data?

IWJV and SGI have created a map-based "Decision Support Tool" for land managers to help identify summer grouse habitat and coordinate conservation. The tool can be used to target summer habitat areas for conservation, and to evaluate the outcomes of conservation efforts. The tool is available on the SGI website as an ArcGIS data package and must be downloaded to an ArcGIS platform. If you are a private landowner interested in using this decision tool, or have no ArcGIS capability, contact your NRCS field office for assistance.

The tool can help practitioners:

- Target protection, enhancement and restoration of summer habitats in priority landscapes.
- Maintain or expand available summer habitat to sustain grouse distribution and abundance.
- Coordinate conservation efforts across public and private lands.

Currently, the decision tool only covers sage grouse range in Oregon, California and northwest Nevada. Work is underway to expand the study and provide a tool for the entire sage grouse range across 145 million acres within the next two years.

To view the science webinar, "Rangewide Mapping of Scarce Wetland Resources", presented by Patrick Donnelly, visit http://www.sagegrouseinitiative.com/private-lands-harbor-scarce-wetlands-ideal-sage-grouse-view-science-webinar/

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Patrick Donnelly with the IWJV/USFWS in Missoula, Montana, lead this ground-breaking study that revealed a tight link between sage grouse upland breeding sites and nearby wet summer habitats. Photo courtesy of Patrick Donnelly.

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Additional Resources

To learn more about sage grouse conservation and the Sage Grouse Initiative, visit the SGI website at **http://www.sagegrouseinitiative.com/.**

To find your local NRCS Service Center, visit the NRCS website at **http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/contact/local/.**

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September 2014.

Red Clover/McReynolds Creek Restoration Project Monitoring Report 2010

Ryan Nupen fly fishing in project area June 2010. (Photo G. Martynn)

Feather River Coordinated Resource Management
Plumas Corporation
Spring 2011

Background

This Annual Monitoring Report, for the Red Clover/McReynolds Creek Restoration Project, covers monitoring and results from 2010 for a few select metrics. This report tiers to the 2007 – 2009 Monitoring Reports. Past monitoring reports, which display data from all metrics, are available at the Plumas Corporation office and at www.feather-river-crm.org on the Red Clover McReynolds project page.

Due to a lack of on-going funding for project monitoring, the Feather River Coordinated Resource Management group (FRCRM) was only able to continue monitoring water temperature, stream flow, turbidity, and fish for this project in the 2010 water year. In 2010 avian monitoring was conducted by PRBO Conservation Science, Plumas National Forest, and Plumas Audubon and is included in this report. Monitoring from on-going watershed monitoring efforts by the FRCRM, helped to answer some of the monitoring questions as discussed below.

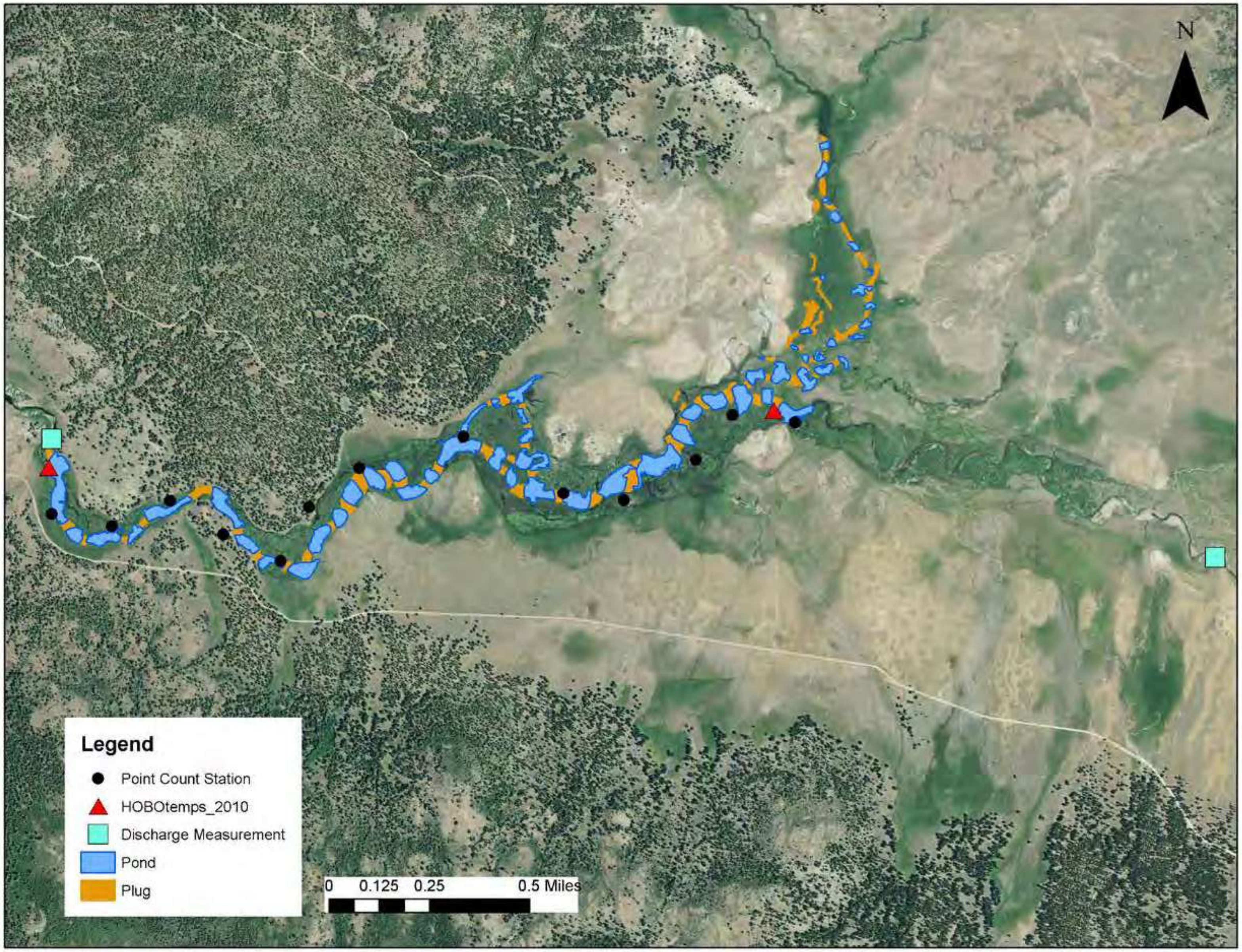
The purpose of this document is to report the results of a fourth year of project effectiveness monitoring, as implemented according to the Project Monitoring Plan. The project was constructed in 2006, from July through November. Most pre-project monitoring was completed in 2005. Post-project monitoring reported herein was conducted in 2007-2010.

The Red Clover McReynolds project area is just downstream of, and partially within, a check dam project implemented by the FRCRM in 1985. Results of the 1985 monitoring effort can be found at www.feather-river-crm.org.

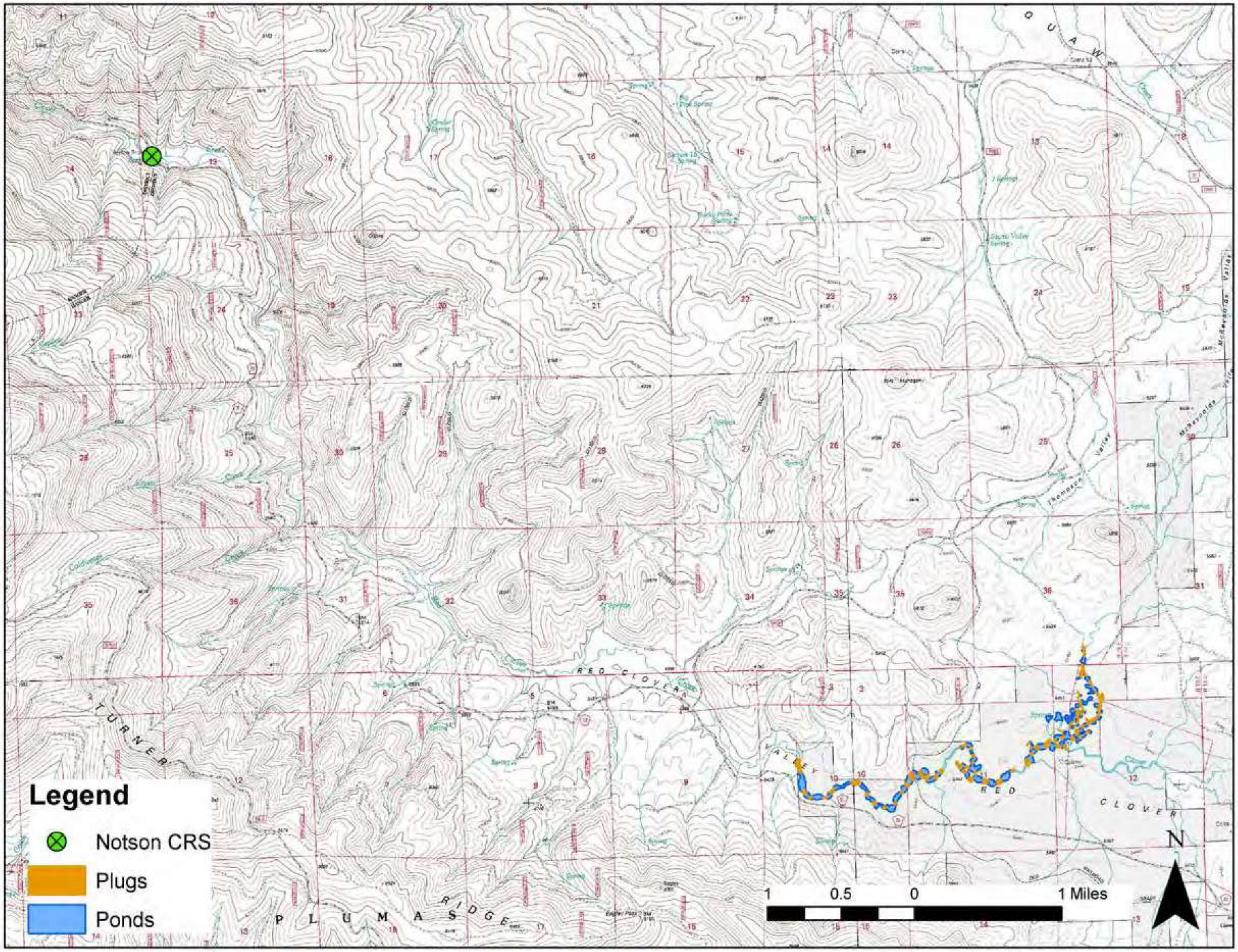
Project Overview

In 2006, 3.3 miles of gullied stream channel immediately downstream of the 1985 project was eliminated. Stream flows were returned to remnant channels at original meadow/channel elevations utilizing the "pond and plug" technique, restoring the functionality of 400 acres of floodplain within Red Clover Valley, along Red Clover and McReynolds Creeks on both private and public lands. Pond and plug is a technique that obliterates a gullied channel by replacing it with a series of earthen plugs and ponds. The excavation of the ponds provided the fill material for the plugs. The Red Clover/McReynolds Creek Restoration Project consists of 59 ponds and 66 plugs. The primary project goal was to improve the water and sediment retention functions of the watershed, with objectives focusing on reduced bank erosion, improved water quality, improved fish and wildlife habitat, reduced flood flows, and increased base flows. Primary funding ($1,101,000) was provided through the State Water Resources Control Board Proposition 13 CALFED Watershed Program, with contributions from Department of Water Resources, Natural Resources Conservation Service, U.S. Forest Service-Plumas National Forest, the landowner, and volunteers.

Map 1: Monitoring Locations in the Red Clover/McReynolds Creek Restoration Project



Map 2: Notson Bridge in relation to Red Clover/McReynolds Creek Project Area



Base Flow

Stream discharge measurements, to analyze the project's effect on base flow, are taken at two spatial scales. The watershed scale is measured at Notson Bridge, located nine miles downstream of the project area at the FR-CRM's continuous recording station, which has been operating since 1999. This station collects stream stage, air temperature, and water temperature every 15 minutes with a Campbell CR10X data logger. The stage and temperature readings are stored as hourly averages and then summarized into daily files at the end of each water year. The FR-CRM staff are responsible for capturing discharge measurements over the range of flows to maintain/update a rating table. The rating table is reviewed and updated annually by Sagraves Environmental Services.

Project scale base flows are also measured 1.5 miles above the McReynolds Creek confluence and below the project grade control structure. Flows at the Notson Bridge station also include several tributary channels, and project effects on flow may be diluted by the time flows reach this station.

Results:

Figure 1 displays pre- and post-project base flows at Notson Bridge in 2000 and 2010. 2000 and 2010 were compared because of the similarity in amount of precipitation (101% of normal precipitation) between these water years. The baseflow discharge in both years is very similar, though 2000 was the end of a wet decade and 2010 was the end of a dry decade. Data are missing from July 5 to August 10, 2000 due to problems with the equipment. The normal historic average precipitation is from the California Department of Water Resources' (DWR) California Data Exchange Center website (http://cdec.water.ca.gov/).

Figure 1. Pre-project vs. Post-project hydrograph at Notson Bridge.

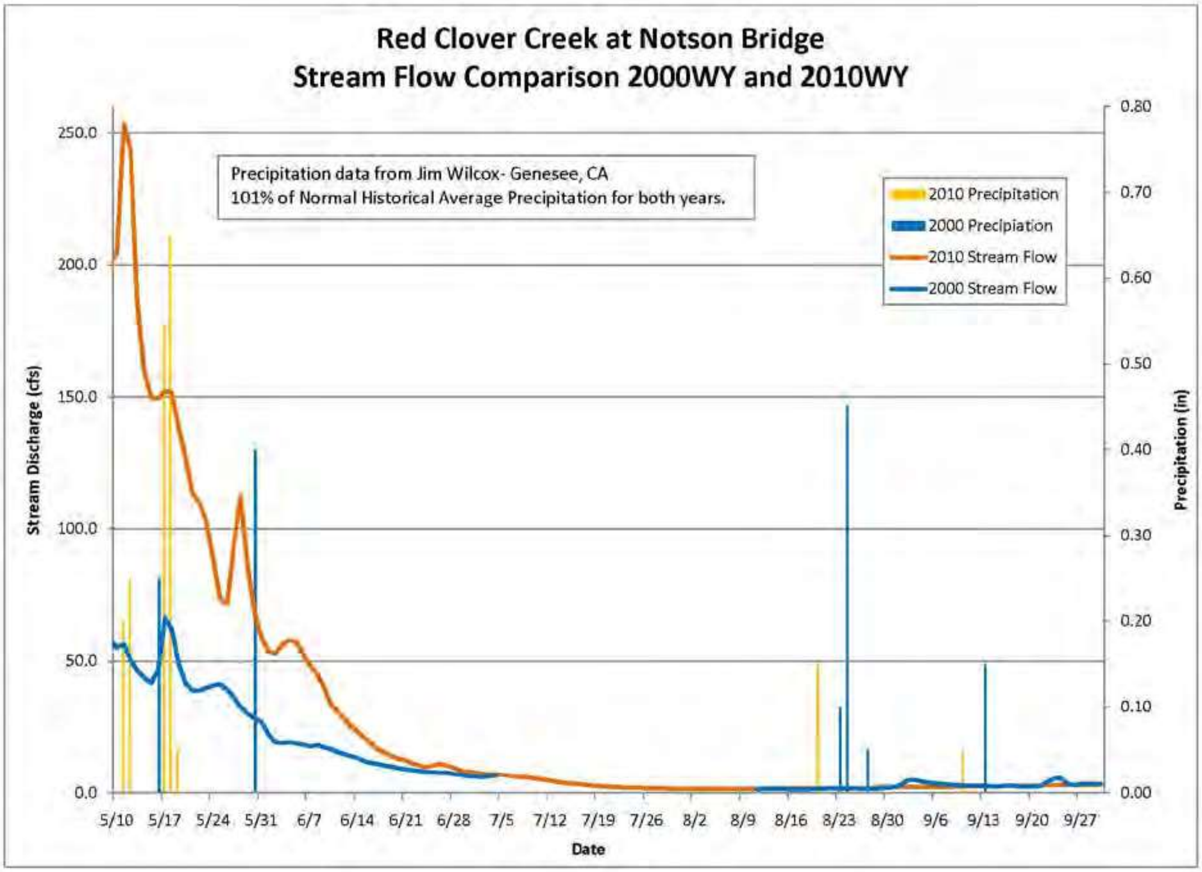


Table 1 shows precipitation totals at Doyle Crossing and Genesee Valley for water years 2001, 2002, 2006-2010 to provide context for Figure 1 and Table 2.

Table 1. Precipitation totals at Doyle Crossing and Genesee Valley

Water Year (10/1-9/30)	2000	2005	2006	2007	2008	2009	2010
Doyle X-ing Precip (in)	Not available	14.56	29.47	11.07	11.49	17.11	14.55
Genesee Precip (in)	43.3	45.50	66.25	31.05	25.40	38.05	33.85

Monthly flow measurements from June through September are taken at the top of the project above McReynolds Creek, and at the bottom of the project just below the rock grade control structure. Flows are measured with a Marsh-McBirney FLO-MATE following the USGS stream discharge measurement protocol. Table 2 on page 6 shows the results of these measurements.

Discussion:
The expectation is that the 2010 data in Figure 1 would show an increase in base flow compared to 2000 due to the project, despite the fact that 2000 was the end of a wet decade and 2010 was the end of a dry decade. However, starting in July the base flows from both years are almost identical. There are small increases in base flow as the season progresses in 2000, due to precipitation events.

In Table 2 (pg 6) the rapid decline in flows from June to July (>90% decrease) seen in pre-project conditions indicates the poor condition of the watershed, and the lack of seasonal storage and release in the project area. It is also interesting to note that there is less water at the bottom of the project area than at the top for every measurement pre- and post-project, except June 2005. The loss may be due to evapotranspiration, or it may be lost into a deep aquifer. The increase of flow in September suggests that the loss is due, at least in part, to evapotranspiration.

The major decline in flows between pre- and post-project conditions was most likely due to three years of drought after project completion. However, in 2007 through 2009, despite the lack of precipitation, there was a less dramatic decline in flows from June to July. The 2010 water year had 20-40% more precipitation than the past few water years and surface water flowed through the project area all year.

It should also be noted that there is a significant difference between the flows at the top of the project between 2007 and 2008-2010. The flow at the top of the project drops to zero during August and September of 2007, while during the same months of 2008-2010 the flows are about 1.5 cfs. It is unclear why inflow dropped to zero in 2007. The measurement cross-section at the top of the project was moved in 2008 to above the 1985 check dam project. Measurement location was moved due to changes in flow at the top of the project area caused by beaver.

Table 2. Pre- and Post- project monthly flow measurements at top of project (above (abv) McReynolds Cr) and below (blw) project area (in cubic feet per second).

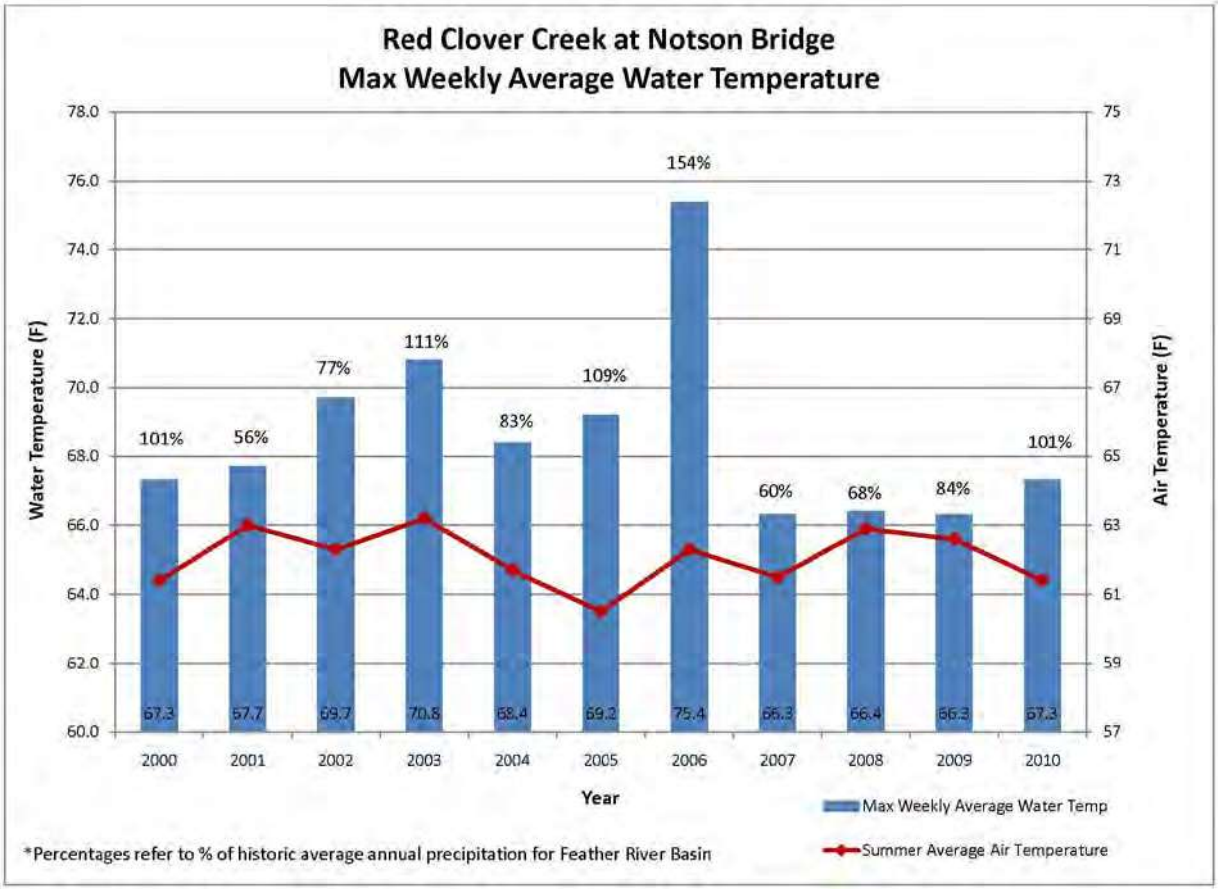
Month	June					July					August					September				
	pre 2005	post 2007	post 2008	post 2009	post 2010	pre 2005	post 2007	post 2008	post 2009	post 2010	pre 2005	post 2007	post 2008	post 2009	post 2010	pre 2005	post 2007	post 2008	post 2009	post 2010
Abv McReynolds	15.3	3.8	2.36	6.88	16.46	1.4	1.2	2.14	1.62	3.2	1.4	0	1.37	1.49	1.88	1.8	0	1.51	1.39	1.6
Blw project	17.8	2.6	1.64	6	16.14	1	0.1	0.49	0.61	1.36	1.1	0	0.002	0.01	0.04	1.6	0	0	0	0.6

Water Temperature

All stream and pond water temperatures are recorded using a HOBO Temp® water temperature logger. Water temperature at the bottom of the project area is only available through July 2010, due to loss of the temperature logger at the bottom of the project area once the Red Clover Poco project construction commenced. The HOBO will be picked up hopefully summer 2011. Until then late summer water temperature data are not available.

Figure 2 shows the maximum weekly average water temperature at Notson Bridge, compared with summer average air temperature and historic average annual precipitation for the Feather River Basin. Summer average air temperature is an average of DWR weather stations at Antelope Lake, Doyle Crossing, Quincy, and Grizzly Ridge from June 1 through September 30. This graph shows that even though 2007 through 2010 were some of the lowest water years in the past 10 years of monitoring at Notson Bridge, they had the lowest maximum weekly average water temperatures. A comparison between 2000 and 2010, both with 101% normal annual precipitation and 61.4 °F summer average air temperature, shows that both years have the same maximum weekly average water temperature (67.3°F).

Figure 2. Maximum (max) Weekly Average Water Temperature at Notson Bridge.



Fisheries

To remediate difficulties with sampling technique in the past, the FRCRM has made use of volunteer fishing days. There have been two volunteer days since project construction, one in June 2008 and one in June 2010. See Table 3 and Map 3 for data from volunteer fishing efforts. Pre-project electroshocking found very few trout. Only one trout (3.5 inches long) was found out of the three sampling areas (please reference past monitoring reports for complete