Severy Creek Basin Analysis

Pikes Peak, El Paso County, Colorado

Report prepared by:

Eric Billmeyer, Research Director

Rocky Mountain Field Institute

For the USDA Forest Service, Pike and San Isabel National Forest

3310 W. Colorado Avenue   Colorado Springs, Colorado 80904

719.471.7736 rmfi@rmfi.org

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Executive Summary

The Severy Creek Basin, located on the northeastern flank of Pikes Peak, CO, has been classified by the Colorado Natural Heritage Program as being within an area of outstanding biodiversity significance with many rare or imperiled plants, animals, and/or plant communities represented. Indeed, within the Severy Creek Basin resides a population of the federal and state threatened Colorado greenback cutthroat trout (*Oncorhynchus clarki stomias*) as well as the largest fen on the North Slope of Pikes Peak.

This study has found that the basin has been impacted over the last 10,000 years by multiple landslide and fire events, however the most immediate impact on the basin's biological diversity is from the erosion and transport of sediments that have occurred in the basin due to anthropogenic activities since the early 20th century. Past practices of directing stormwater runoff from the Pikes Peak Highway into the basin resulted in the formation of several large gullies up to 1100 meters in length with an average depth and width of 8 meters and 11 meters, respectively. These gullies have contributed to the erosion and transport of approximately 32,500 m^3 of alluvium into the valley and wetland below. Since the late 1930's, the alluvial fan has encroached upon approximately 2.5 ha of the western most portion of the Severy Creek wetland.

The erosion and sediment deposition was one of the driving factors behind a 1998 lawsuit the Pikes Peak Group of the Sierra Club filed in US District Court against the City of Colorado Springs and the USDA Forest Service (USFS) alleging violations of the Clean Water Act. A settlement agreement was reached in 2000 that instructed the City of Colorado Springs and the USFS to address the erosion and sedimentation problems of the Pikes Peak Highway and bring the road into compliance with the Clean Water Act within a timeline of 10 years. Paving of the entire highway and placement of all erosion control structures is scheduled to be completed by the end of 2012. Under the settlement, $600,000 dollars was awarded to the Sierra Club for remediation and restoration work outside the 300 ' wide highway corridor. With the award, the Sierra Club established the Pikes Peak Fund. In 2003, the Rocky Mountain Field Institute (RMFI) was contracted by the Pikes Peak Fund to assess the environmental damage outside the highway corridor and begin prioritizing basins within the watershed for erosion control and restoration projects. Since 2005, RMFI has spearheaded the *Pikes Peak Watershed Restoration*

Project, a large-scale, multi-year collaborative restoration effort being undertaken by the Pikes Peak Group of the Sierra Club, the City of Colorado Springs, the USDA Forest Service Pikes Peak Ranger District, and the Rocky Mountain Field Institute. One of the primary goals of the project is the restoration of the impacted areas within the Severy Creek wetland.

Restoring the area of the Severy Creek wetland affected by the alluvial fan and mitigating the potential threat of additional sedimentation into unimpacted areas is the ultimate goal of any effort to protect this invaluable ecological resource. Several past studies have examined the feasibility of achieving this goal and this report presents new data regarding the basin's sediment transport and accumulation, precipitation, and groundwater and surficial hydrology to further ascertain the feasibility of restoration or mitigation efforts in the basin. The following is a synopsis of the key findings:

- The alluvial fan remains the greatest and most immediate threat to the ecological well being of the Severy Creek wetland.
- Total sediment deposition within the fan is estimated to be 32,478 m^3.
- As of 2010, surficial deposition within the impacted area of the wetland covers 2.46 ha and since 2005 has been increasing at a rate of approximately 2% per year.
- Sediment deposition associated with the main channel through the alluvial fan is currently occurring in the northern most area of the fan, well away from the fan's dominate toe and undisturbed areas of the wetland.
- Significant sediment deposition that is encroaching into previously unimpacted areas of the wetland is associated with a natural spring system that is not linked to the gully system off the Pikes Peak Highway; it is likely the surface flow of this stream will join with the established channel within the next couple years with a corresponding increase of sediment being transported into the wetland if not mitigated.
- The lead-off ditch from the Pikes Peak Highway, left in place after paving and erosion control was completed within the basin, continues to convey stormwater runoff and associated sediment into the northern section of the wetland.
- The main stream channel through the alluvial fan has began to move from its current location at the northern edge of the fan back to the south where the channel was located in 1993. Allowing the channel to migrate will dramatically increase the potential for a massive relocation of sediment to areas closer to unimpacted areas of the wetland as the stream cuts through sediment deposits up to 2.5 m thick.

- Reactivation of old channels that run along the southern edge of the alluvial fan is a distinct possibility. This also has the potential to dramatically increase sediment transport into previously unimpacted areas of the wetland by combining the flow of the channel through the alluvial fan with that of the natural spring system currently carrying sediment deep into the southernmost area of the wetland.

This study has found that the remoteness of the basin, the lack of access, and the massive volume of sediment that has formed the alluvial fan and encroached upon the western portion of the wetland preclude implementing a full restoration plan. However, the findings of the study make it clear that action is needed to mitigate the threat of additional sedimentation into the wetland. Several prescriptions can be realistically implemented to achieve a high level of protection for the wetland and maintain the biological diversity of those areas currently unimpacted. These include:

- Hardening the existing channel so that its current location within the alluvial fan can be maintained and the transport and location of sediment deposition controlled.
- Within the main channel, constructing cross-vanes to provide grade control and using felled trees and boulders to protect banks.
- Stabilizing the upper portion of the alluvial fan with additional plantings of Engelmann and Blue spruce where appropriate.
- Stabilizing the middle and lower portions of the fan with native vegetation harvested on site.
- Developing additional sediment storage capacity at the fan's toe through the use of native willow cuttings to create natural dams along areas found to be suitable.

Overall, this study provides a detailed examination and overview of the multitude of processes affecting the health of the Severy Creek wetland. It is clear from the data presented that the processes acting on the basin are quite dynamic and the entire system is still adjusting and trying to reach a state of geomorphic equilibrium. Given enough time, perhaps 1,000's of years and a continued respite from major mass wasting or fire events, the gullies and alluvial fan will eventually stabilize on their own. However, the biological importance of the wetland and the looming threat of additional loss of wetland due to sediment encroachment from the alluvial fan precludes taking no action. Therefore, it is recommended that the prescriptions suggested in this study be put forward for implementation.

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A. Introduction

Background and Study Area

The Severy Creek Basin encompasses 2,200 ha located on the northeastern flank of Pikes Peak (4302 m) within the Pike National Forest, Colorado. The basin's namesake, Severy Creek, flows from the southwest to the northeast for 5.1 km before its confluence with Cascade Creek, approximately 2 km above the town of Cascade (Figure 1). The basin is within the headwaters of the Fountain Creek Watershed (US Geological Service Hydrologic Unit # 1102000301). Elevations within the basin range from a high of 3900 m to a low of 2500 m. Several life zones are found within these elevations including the alpine, subalpine, and montane.

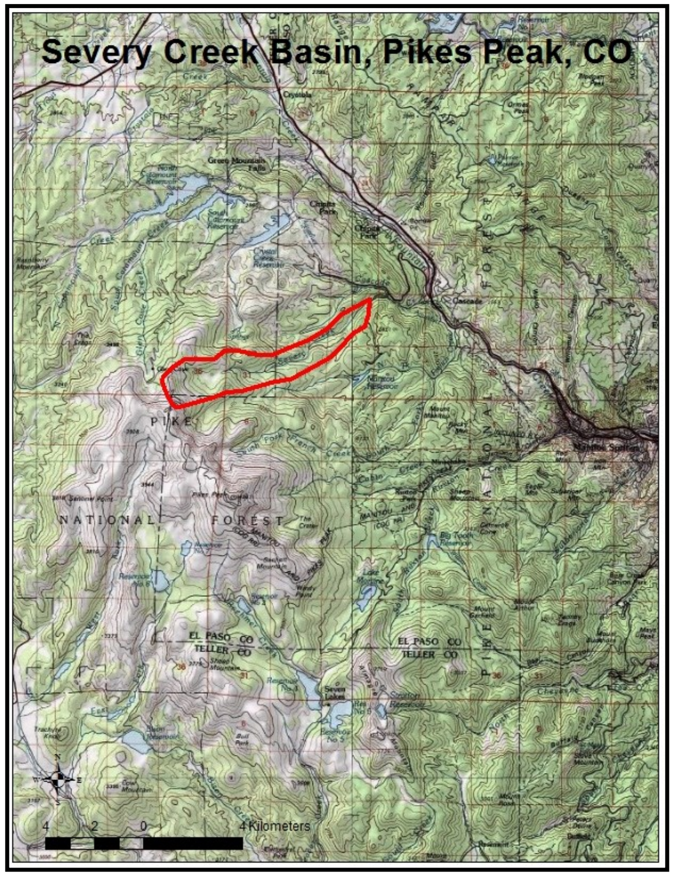


Figure 1. Overview map showing the location of the Severy Creek Basin on Pikes Peak.

The Severy Creek Basin has been classified as part of the Pikes Peak Potential Conservation Area, a region of outstanding biodiversity significance, by the Colorado Natural Heritage Program (Fayette, 1999). Within the lower portion of the basin resides a population of the federal and state threatened Colorado greenback cutthroat trout (*Oncorhynchus clarki stomias*). Other species of special concern have suitable habitat within the basin and are either known or are suspected to occur (Table 1). Conifer forests of Engelmann Spruce (*Picea engelmannii*) and Douglas Fir (*Pseudotsuga menziesii*) are dominate in the lower basin's montane zone. The upper section of the basin, within the alpine and subalpine, is defined by extremely steep slopes greater than 45 degrees composed primarily of decomposed Pikes Peak Granite. Krummholtz and stands of dwarf Engelmann Spruce are widely interspersed throughout the subalpine. Alpine tundra is sporadic throughout the upper reaches of the basin with isolated pockets of flowering alpine plants found in protected areas.

Common Name	Scientific Name	Status	Known or Suspected to be Present	Suitable Habitat Present?
Federally-Listed Threatened and Endangered Fuana				
Canada lynx	*Lynx canadensis*	Threatened	Yes	Yes
Mexican spotted owl	*Strix occidentalis lucida*	Threatened	Yes	Yes
greenback cutthroat trout	*Oncorhynchus clarki stomias*	Threatened	Yes	Yes
Forest Service R2 Sensitive Species: Fauna				
Wolverine	*Gulo gulo*	Sensitive	No	Yes
American marten	*Martes americana*	Sensitive	Yes	Yes
water vole	*Microtus richardsoni*	Sensitive	No	Yes
Rocky Mountain bighorn sheep	*Ovis canadensis canadensis*	Sensitive	Yes	Yes
Townsend's big-eared bat	*Plecotus townsendii*	Sensitive	Yes	Yes
northern goshawk	*Accipiter gentilis*	Sensitive	Yes	Yes
boreal owl	*Aegolius funereus*	Sensitive	Yes	Yes
olive-sided flycatcher	*Contopus cooperi*	Sensitive	Yes	Yes
white-tailed ptarmigan	*Lagopus leucurus*	Sensitive	Yes	Yes
loggerhead shrike	*Lanius ludovicianus*	Sensitive	No	No
American three-toed woodpecker	*Picoides dorsalis*	Sensitive	Yes	Yes
boreal toad	*Bufo boreas boreas*	Sensitive	Yes	Yes
northern leopard frog	*Rana pipiens*	Sensitive	Yes	Yes
Forest Service R2 Sensitive Specis: Flora				
slender moonwort	*Botrychium lineare*	Candidate	Yes	Yes
lesser yellow lady's slipper orchid	*Cypripedium parviflorum*	Sensitive	No	Yes
Altai / whitebristle cottongrass	*Eriophorum altaicum* var. *neogaeum*	Sensitive	No	Yes
russet / Chamisso's cottongrass	*Eriophorum chamissonis*	Sensitive	No	Yes
slender cottongrass	*Eriophorum gracile*	Sensitive	Yes	Yes
clawless draba / Garys Peak draba	*Draba exunguiculata*	Sensitive	No	Yes
Gray's Peak whitlow grass / Gray's draba	*Draba grayana*	Sensitive	No	Yes
Smith whitlow grass / Smith's draba	*Draba smithii*	Sensitive	No	Yes
English sundew	*Drosera anglica*	Sensitive	No	Yes
round leaf sundew	*Drosera rotundifolia*	Sensitive	No	Yes
rock-loving neoparrya / Bill's neoparrya	*Neoparrya lithophila*	Sensitive	No	Yes
Rocky Mountain alpineparsley	*Oreoxis humilis*	Sensitive	No	Yes
Kotzebue's grass-of-Parnassus	*Parnassia kotzebuei*	Sensitive	No	Yes
Rocky Mountain cinquefoil / rock cinquefoil	*Potentilla rupincola*	Sensitive	No	Yes
Ice cold buttercup/tundra buttercup	*Ranunculus karelinii*	Sensitive	No	Yes
Barratt's willow	*Salix barrattiana*	Sensitive	No	Yes
hoary willow / sageleaf willow	*Salix candida*	Sensitive	No	Yes
blueberry willow	*Salix myrtillifolia*	Sensitive	No	Yes
autumn willow	*Salix serissima*	Sensitive	No	Yes

Table 1: Federally Listed Threatened and Endangered Species and Forest Service R2 Regional Sensitive Species known or suspected to be present in the Severy Creek Basin (Weaver, 2008).

One of the more interesting physical features found in the basin and of particular importance to this study is the Severy Creek Wetland. The wetland covers 5.89 ha of a relatively flat bench area at an elevation of 3300 m and is the largest found on the north flank of the Pikes Peak massif. The eastern most portion of the wetland (1.26 ha) is a fen supported by upward seepage from mineral soil, groundwater throughflow from spring fed streams, and groundwater recharge from adjacent slopes. In this area, vegetation is diverse and resides on up to 147 cm of peat deposits. Species include bog birch (*Betula glandulosa*), white marsh marigold (*Psychrophila leptosepala*), and queen's crown (*Rhodiola rhodantha*) among others (Cooper & Gage, 2008). The western section of the wetland has been highly impacted by recent and historic alluvial deposition that has inhibited peat development and resulted in the vegetation being dominated by water sedge (*Carex aquatilis)* and plain leaf willow (*Salix planifolia)*. Canada bluejoint grass (*Calamagrostis canadensis*) and shrubby cinquefoil (*Pentaphylloides floribunda*) are found on the margins and where alluvial deposition is greatest. Overall, 2.5 ha of the western most area of the wetland has been inundated by sediments that are part of a large alluvial fan covering 3.87 ha in total (Figure 2).

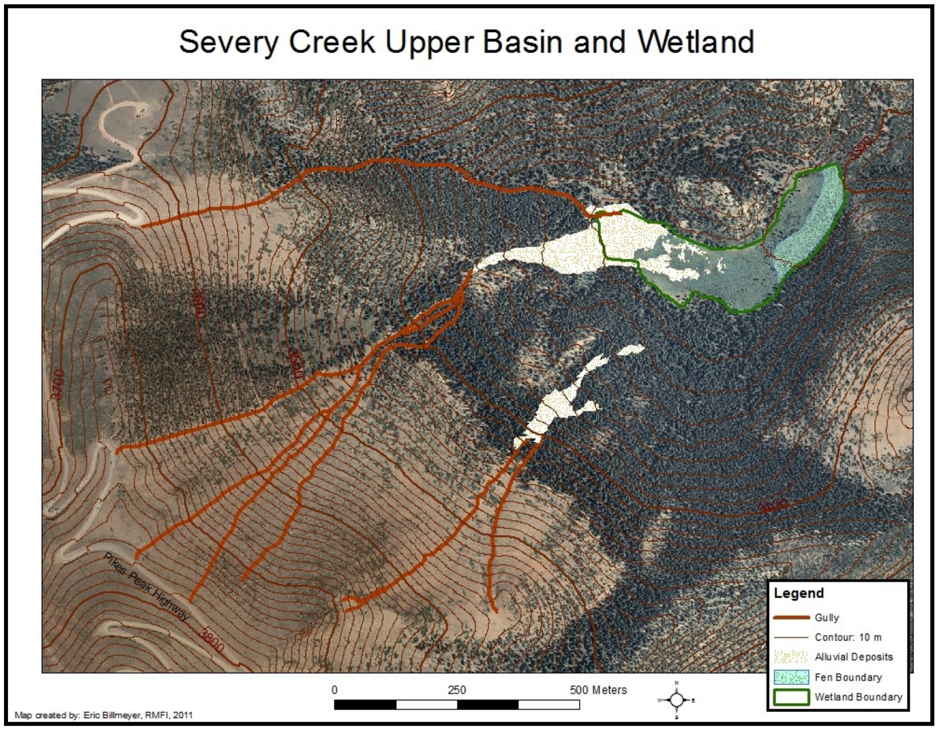


Figure 2. Overview map of the upper Severy Creek Basin and Wetland.

The source of the alluvium in the fan is from several major gullies that have formed in the upper reaches of the basin where it is bisected by the Pikes Peak Highway. Several culverts and ditches previously found along this portion of the highway augmented flows into the Severy Basin by acting as a conduit directing runoff from other basins into Severy Creek. The flows caused several large gully channels to develop off the highway (Figure 2). The gully channels are up to 1100 m in length and average 6-9 m deep and 9-12 m wide (Figure 3). The eroded material from these channels provided the sediment source for the alluvial fan and the volume of sediment is estimated to be upwards of 32,500 m^3.

Figure 3. Example of gully channel leading into the alluvial fan.

In order to understand the present geomorphic processes affecting the wetland, it is important to examine the geomorphic and cultural history of the Severy Creek Basin. The majority of the sediment inundating the wetland is derived from decomposing Pikes Peak Granite (PPG). PPG is the primary type of igneous rock that comprises the massive Pikes Peak Batholith. Estimated to be over a billion years old (1080 MA), the batholith has a surface exposure of over 3800 sq km and provides the geologic structure for Pikes Peak as well as the Front Range and Rampart Range south of Denver (Smith et al., 1999). PPG is a pink to light reddish-brown, coarse-grained, equigranular to locally porphyritic granite. The primary mineral composition is quartz, potassium feldspar, and biotite mica, with smaller quantities of hornblende, plagioclase feldspar, and fluorite present. Due to its large crystal size and the easily weathered nature of the potassium feldspar and biotite minerals, PPG decomposes readily into grus that can be meters thick. Soils that develop from this parent material are sandy or gravelly in texture and have very low clay concentrations resulting in poor binding properties for nutrient retention. Very thin A horizons can develop on top of deep C horizons of grus but are extremely susceptible to erosion with any type of disturbance (Chavez et al. 1993).

With little soil development and plant growth on the upper slopes of the basin, the exposed loose grus is easily transported by fluvial processes and is a factor in exacerbating mass wasting in the area due to slope instability. Analysis of strata from boreholes hand augured along several cross-sections through the wetland indicate that large mass wasting events have probably occurred on the upper slopes of the basin with sediment transported down into the wetland in the geologic past (Cooper & Gage, 2008). In 2009, a geologic map of the upper basin was completed by the Colorado Geologic Survey and the author to determine the relative age of the bedrock and surficial geology (Figure 4). This study found that 100 ha of area above and within the wetland had been subjected to colluvium and/or debris deposits since the late Pleistocene (Morgan & Billmeyer, 2010). Included in this area is a large boulder dam that is present at the mouth of the Severy Creek Wetland. The material for the dam appears to have originated from a large rocky outcrop 177 m higher and 450 m to the southeast. A fan of boulder material, some as large as 10 m across, extends from the summit of the outcrop down to the location of the dam (Figure 5). The dam provides a significant control on the topographical relief of the upper basin. Above the dam, the average slope of the wetland is 2.3%. Immediately below the dam, the average slope increases dramatically to 31%.

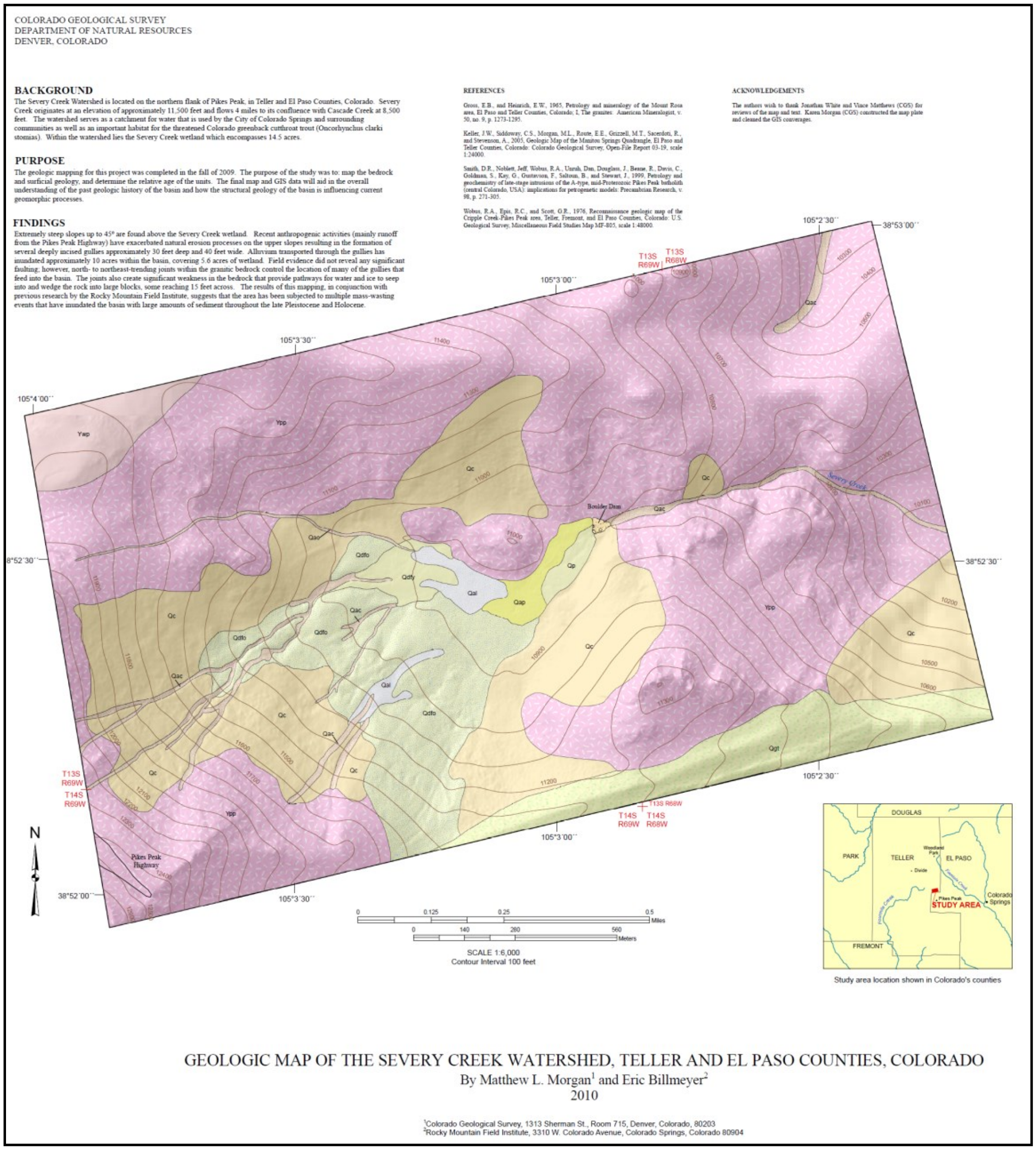


Figure 4. Geologic map of the upper Severy Creek Basin. Full map, including unit descriptions, is included in Appendix A.

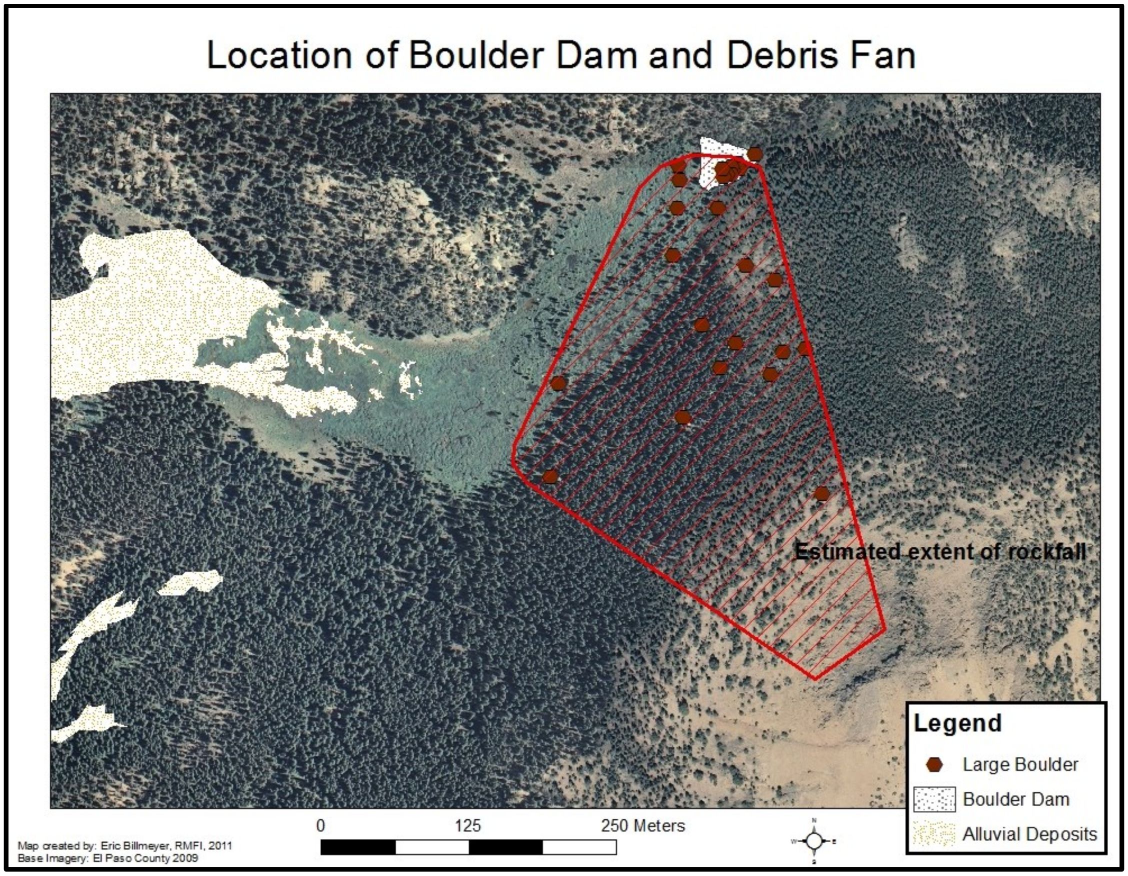


Figure 5. Map showing the estimated extent of a large rock avalanche that likely produced the boulder dam that predates the wetland (~6300 BP).

The mass wasting event that created the dam also very likely initiated the development of the Severy Creek Wetland. To determine the age of the wetland, a peat sample was collected from a depth of 138-142 cm and radiocarbon dated by labs at Beta Analytical, Inc (Cooper & Gage, 2008). The depth of the sample was limited by contact with sharp, angular decomposing granite 40-60 mm in size. The sample was acquired at a location approximately 25 m to the southwest of the rock dam in the eastern area of the wetland. Analysis of the sample returned a date of ~6,290 calendar years BP. This suggests a peat accumulation rate of approximately 20 cm per 1,000 years and corresponds well with past studies examining peat accumulation rates in the western U.S. (Chimner et al. 2002, Chimner & Cooper, 2003). Development of thick peat beds in this area of the wetland indicate a long period of stability and an absence of further mass wasting events. However, this apparent undisturbed portion of the wetland only represents 21% of the total area. The remaining wetland area has been subjected to mass wasting events such as landslides and debris flows since the late Pleistocene (Morgan & Billmeyer, 2010).

Several lines of evidence on what may have triggered these historic events has been found. In the process of creating the geologic map of the basin, it was noted that the upper slopes to the southwest of the wetland contain several north to northeast trending master joints within the granitic bedrock (Morgan & Billmeyer, 2010). These joints create significant weakness in the bedrock by allowing water to seep into the bedrock and cause weathering to occur at depth. Freezing of water allows additional weathering to take place, wedging the bedrock into large blocks up to 5 m in diameter. As these blocks and the areas along the joints continue to weather, deep C horizons of unconsolidated grus of Pikes Peak Granite develop with depths up to 9 m. The presence of deep, loose grus residing on slopes up to 45° exacerbates the risk of large mass wasting events occurring due to the low shear strength of the soil.

Another factor that appears to have played a major role in past mass wasting events within the basin is fire. High rates of sediment transport, including large debris flows, have been widely observed after major fires throughout areas that have burned within the boundaries of the Pikes Peak Batholith (Moody & Martin, 2001, Jarrett, 2001, Robichaud & Wagenbrenner, 2006). The reported observations clearly show that grus of decomposing Pikes Peak Granite is readily transported during precipitation events if left unprotected; such as when a major fire removes all forest cover. On the upper slopes of the Severy Creek Basin, between the elevations of 3475 m and 3570 m, evidence of several fires have been found in the form of multiple ash layers within the strata of the slope. Presently much of this area is unforested with only widely interspersed patches of Krummholtz and stands of dwarf Engelmann Spruce occurring.

Radiocarbon dating of charcoal fragments (4mm-15mm) found within the ash layers at two sites record a long interval fire history within the basin. The ash and charcoal deposits were exposed after a major storm event in August of 2007 caused a pre-existing channel to downcut by over 2 m creating steep walled banks that clearly showed the charcoal strata. Charcoal samples were removed from these newly exposed banks. The first sample site (Site A) is found at an elevation of 3482 m with the second site (Site B) located 75 m downslope at an elevation of 3452 m (Figure 6). A charcoal sample was obtained from Site A in October of 2007 at a depth of 100 cm. Analysis of the sample returned a date of ~9010 calendar years BP. In September of 2008, additional samples were acquired at Site B where five separate ash layers were exposed in the strata of a gully bank over 110 cm in height. The first ash layer was found at a depth of 10 cm below a thin A horizon. The charcoal fragments found within this layer were dated to ~3410 calendar years BP and indicate a soil development rate of just over 3 cm per 1,000 years during this time period. The second and third ash layers were located at a depth of 23 cm and 46 cm, and charcoal samples returned dates of ~4530 BP and ~4410 BP, respectively. The closeness in age of these two deposits indicates a possible mixing of sediments and mass wasting event. The fourth sample was taken from a depth of 77 cm and returned a date of ~8050 BP. The last charcoal sample was acquired from an ash layer at a depth of 97 cm and returned a date of ~9280 BP. This date correlates well with that obtained for the sample in Site A at 100 cm and indicates the area was likely forested after the last period of glaciation on Pikes Peak, the Pinedale, had ended over 10,000 years ago.

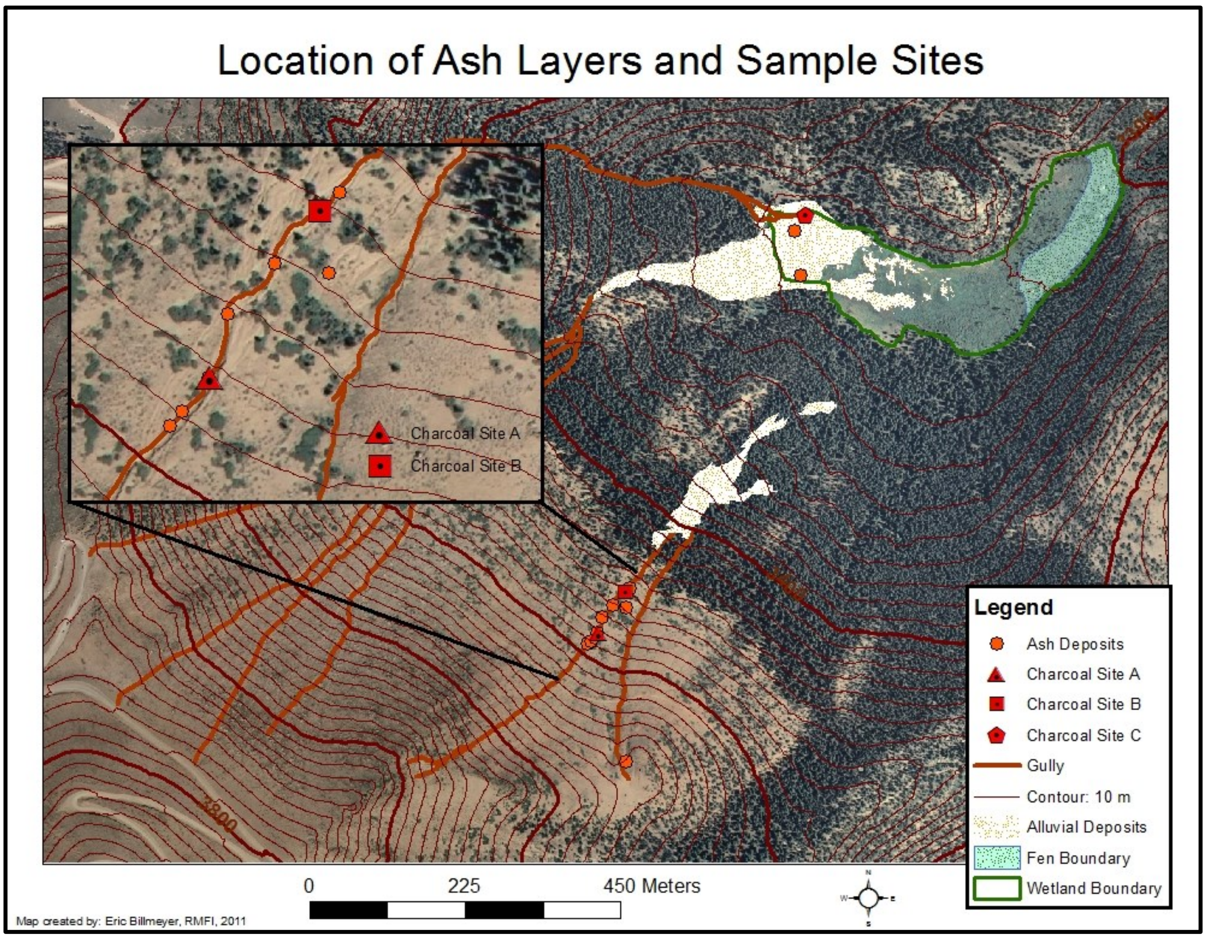


Figure 6. Location of ash layers along upper slopes and deposits found in wetland. Radiocarbon dating sample sites are also shown.

In addition to the ash layers found at Site A and Site B, ash layers were found within the strata of three bore holes hand augured in the lower portion of the alluvial fan extending into the wetland in 2008 and 2010 (see Figure 6). The three bore holes all had ash deposits at approximately the same depth, 147 cm +/- 4 cm. In an attempt to correlate these ash deposits with those found on the upper slopes, a charcoal sample from Site C was obtained from an ash layer found at a depth of 151 cm in 2010. Radiocarbon dating on this sample indicated that the ash was deposited ~1910 +/- 40 years. The most recent reported fire to have occurred in the basin was in the early 1850's. This fire burned a large area along Pikes Peak's north slope (Figure 7). The radiocarbon date of the ash layer indicates that the extensive mass wasting that formed the alluvial fan in this area occurred after the early 1850's fire and during a time of increased anthropogenic activity in the basin.

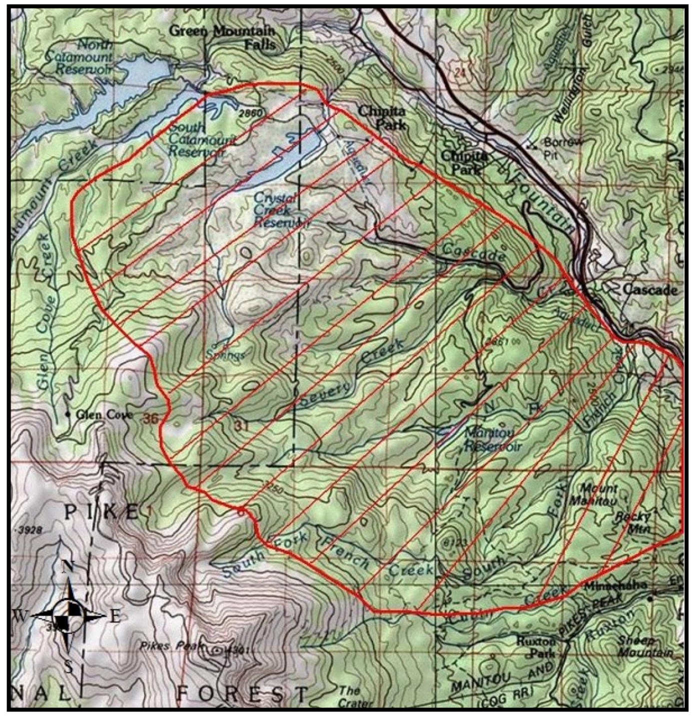


Figure 7. Estimated burn area of early 1850's fire, based off of drawings completed by Robert Gardner in 1903.

The cultural history of the basin is as varied as its geomorphic past. Anthropogenic activity in the basin could have begun as early as 10,000 years ago when the Tabeguache Band of the Ute Indians first entered the Pikes Peak area. Pikes Peak is known to the Ute People as “Tava,” which is interpreted to mean “Sun”. Fittingly, the name Tabeguache, means “People of Sun Mountain." For sustenance, the band would follow herds of wild animals throughout their lands, hunting elk, deer and buffalo. The wetland in the Severy Creek Basin provides excellent habitat for elk and deer and was a probable hunting ground for the Tabeguache. A chert spearhead of unknown origin was found near the vicinity of the wetland and provides anecdotal evidence of past hunting activity. The foundation to an old homesteader's cabin is also located near the wetland's boundary. Through the Homestead Act of 1862, many families claimed land on the north side of Pikes Peak and it is possible this cabin represents one of these attempts. Homesteading on the mountain ended in 1891 with the creation of the Pikes Peak Timber Reserve by the Department of Agriculture.

Near the end of the 19th century, the summit of Pikes Peak was becoming a tourist destination. The U.S. Army Signal Service had constructed a weather observatory at the summit in October of 1873 and over the years the station attracted a growing number of visitors. By 1882 the original signal station was replaced with a larger building to accommodate the growing tourist trade. In 1887, the Cascade and Pikes Peak Toll Road Company completed the first crude road to the summit of Pikes Peak offering visitors a substantially improved route. The path of the road was cut into the slopes of the upper reaches of the Severy Creek Basin forming what is now known as the "W" (Figure 8). During the same time, another road was constructed in the basin approximately 100-300 m below the toll road. This road traversed west to east across the entire length of the basin and was constructed to transport supplies and drilling equipment to access an ill-conceived mining operation located in the upper reaches of the adjacent North Fork of French Creek drainage. The mine operation, which never produced, closed in the early 1900's. In 1938 the Forest Service modified the old mining road by turning it into a trail for users to access the historic mine site. This trail is now known as the Elk Park Knoll Trail and provides a connection and alternate route to the summit of Pikes Peak via the Barr Trail.

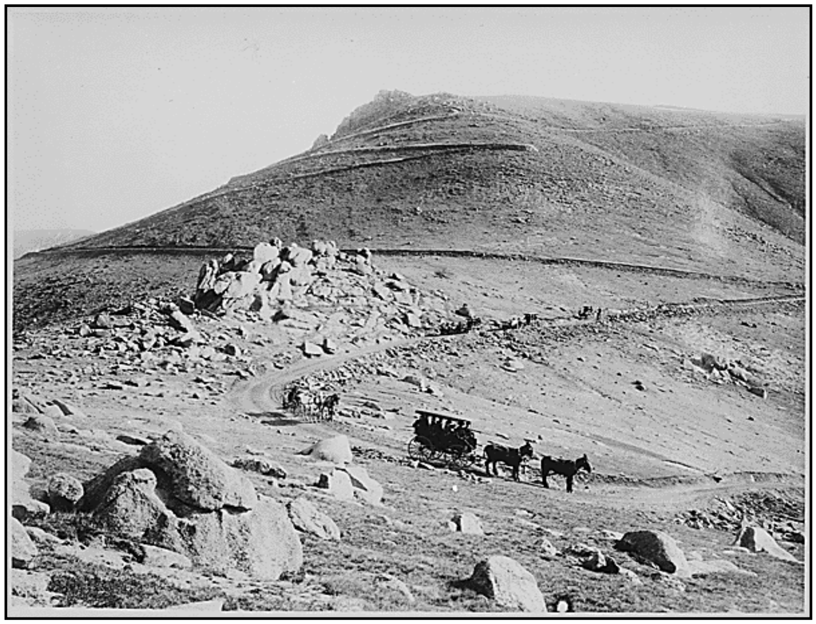


Figure 8. View of the Cascade and Pikes Peak toll road cutting across the upper slopes of the Severy Creek Basin. Photograph by William Henry Jackson, Courtesy of Special Collections, Pikes Peak Library District.

The Cascade and Pikes Peak Toll Road Company went defunct shortly after a faster and more comfortable way to access the summit of Pikes Peak was offered by a cog railway constructed in 1891. The toll road became a county road but fell into disrepair with a lack of maintenance and was abandoned. In 1915, Spencer Penrose, a wealthy business man who made a fortune in mining, requested permission from the Secretary of Agriculture to reestablish a toll road to the summit of Pikes Peak. Penrose request was granted and he spent $500,000 to upgrade the original carriage route so it could be used by automobiles. The Pikes Peak Toll

Road was allowed to operate under a 20-year permit. For reasons likely related to the Great Depression, Penrose did not renew the permit in 1935. The road was then added to the Colorado State Highway system but monies to maintain the road were unavailable and the road once again fell into disrepair. The roadway was almost abandoned until the City of Colorado Springs signed a 13-year agreement with the USDA Forest Service in 1948 to once again operate the road as a toll way (Nakada, 1991). The permit was renewed for a 30-year period both in 1961 and 1991. The City of Colorado Springs operates the toll road as the Pikes Peak Highway through an enterprise of the city under the moniker of Pikes Peak, America's Mountain.

One of the major problems of the Pikes Peak Highway, regarding erosion and sediment transport, has always been its design. The roadway runs along the crest of ridges and in the case of the Severy Creek Basin, across slopes greater than 35°. Runoff from the roadway unto unprotected slopes has resulted in the creation of over 120 gullies within the greater Pikes Peak watershed (Billmeyer, 2005). These gullies facilitate the transport of road material and have radically increased natural erosion rates. As a result, the streams, wetlands, and reservoirs within the watershed have been severely affected by sediment. As early as 1952, nearly a dozen reports and studies from several organizations and agencies have confirmed the environmental degradation caused by the road upon the surrounding landscape (Baumgartner, 1969, Chavez et al. 1993, Snyder et at. 1994, Drexel Barrell & Co, 1997, Cooper, 1998, Billmeyer, 2005). All of the reports agreed that the environmental impacts from the Pikes Peak Highway were a direct consequence of the highway being maintained as an unpaved road and that the lack of proper water control structures were a principal factor behind the degradation.

In 1998, citing lack of support and progress in addressing the erosion and sedimentation problems of the Pikes Peak Highway, the Pikes Peak Group of the Sierra Club filed suit in US District Court against the City of Colorado Springs and the USDA Forest Service alleging violations of the Clean Water Act under Section 401. The damage that was occurring in the Severy Creek Basin, and in particular to the wetland, was one of the driving factors behind the lawsuit (Personal Communication, Jim Lockhart). In 2000, the Court oversaw a settlement agreement in which the City of Colorado Springs and the USDA Forest Service were instructed to address the erosion and sedimentation problems of the highway and to bring the road into compliance with the provisions of the Clean Water Act within a timeline of 10 years. Since 2002, the City of Colorado Springs has been diligently working to address the storm water runoff by paving the highway and constructing erosion control structures to reduce sediment and attenuate the storm water flow. Paving of the entire highway and placement of all erosion control structures is scheduled to be completed by the end of 2012. Work on the highway in the Severy Creek Basin was completed in 2006 with the removal of all culverts and lead-off ditches except for a lead-off ditch above Elk Park Knoll at the far western boundary of the basin (Figure 9).

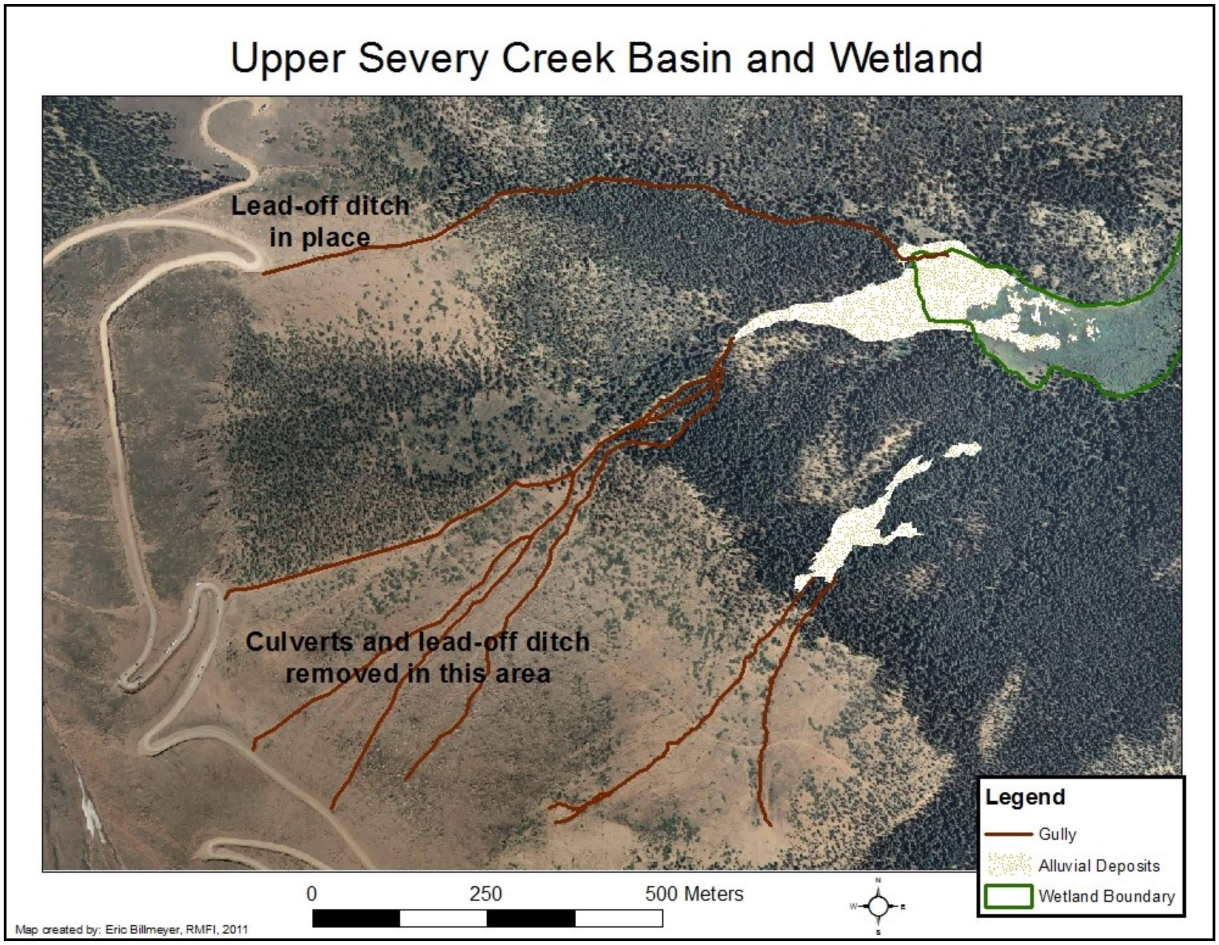


Figure 9. Map showing areas where highway improvements have been made in the upper Severy Creek Basin (base image is from 2005 before paving was completed).

Under the settlement, $600,000 dollars was also awarded to the Sierra Club for remediation and restoration work outside the highway corridor. These monies were placed into a fund (the Pikes Peak Fund), with the Sierra Club, the City of Colorado Springs, and the USDA Forest Service (USFS) acting as partners to ensure the best use of these monies for erosion control and restoration work. In 2003, the Rocky Mountain Field Institute (RMFI) was contracted by the Pikes Peak Fund to assess the environmental damage outside the highway corridor and begin prioritizing basins within the watershed for erosion control and restoration projects. This work was completed in 2005. That same year, the *Pikes Peak Watershed Restoration Project*, a large-scale, multi-year effort by the Pikes Peak Group of the Sierra Club, the City of Colorado Springs, the USDA Forest Service Pikes Peak Ranger District, and the Rocky Mountain Field Institute began in earnest. Since then, RMFI and its partners have completed five major projects within the watershed including work within the North Crystal Creek, Ski Creek, Glen Cove Creek, and West Fork of West Beaver Creek basins. These projects have resulted in over a mile and a half of stream channel restoration and stabilization and over 4.5 acres of restored forest lands.

The feasibility of restoring the Severy Creek Wetland has been under study since 2006 by RMFI. Once the erosion control and paving of the highway located within the Severy Creek Basin was completed, RMFI prepared a preliminary proposal (Billmeyer, 2006) that outlined restoration and erosion control techniques to mitigate past and potential new impacts to the wetland. This proposal became the basis for the Forest Service to begin steps to initiate an Environmental Assessment (EA) to examine the possible impacts associated with the proposed activities. As a part of the EA process, RMFI contracted Dr. David Cooper at Colorado State University (CSU) to complete a more detailed analysis of the wetland in preparation of developing a more thorough proposal for restoration. Hydrological and stratigraphy data was collected from July to October 2007 and a report on the study's findings was completed in early 2008 (Cooper & Gage, 2008).

The report presented here details additional data that was collected during the June to October period over the years 2008-10 to further ascertain the feasibility of restoration or mitigation efforts in the basin. This report presents new data regarding the basin's sediment transport and accumulation, precipitation, and groundwater and surficial hydrology. The analysis of the present and past geomorphic processes within the basin and affecting the wetland has allowed for a greater understanding of the complexities associated with any potential future restoration of the wetland.

B. Analysis of the Severy Creek Basin

Methods

Precipitation-

Precipitation records were used to examine any correlation between rainfall and changes in water table depths over the growing season within the wetland and sediment transport within the greater upper basin. Snowpack records were also examined to determine the timing and influence of the snowpack on water table depths. Precipitation data was obtained from 2 current and 3 historical stations located near the vicinity of the Severy Creek Basin (Figure 10). Primary precipitation data was collected from a USFS rain gauge located at Elk Park Knoll along the western divide between the Severy Creek and Glen Cove Creek drainages at an elevation of 3603 m. The gauge is a tipping bucket type (Onset Computer Corp.) equipped with an event data logger (HOBO) that records precipitation at .01 of an inch per tip. The gauge has provided precipitation data from May through September since 2003. Snowpack data was obtained from a Snowpack Telemetry (SNOTEL) station, located in the Glen Cove Creek drainage at 3467 m and approximately 2 kilometers west of the Severy Creek Wetland. This station provided total monthly snow precipitation data from 2005 through 2010.

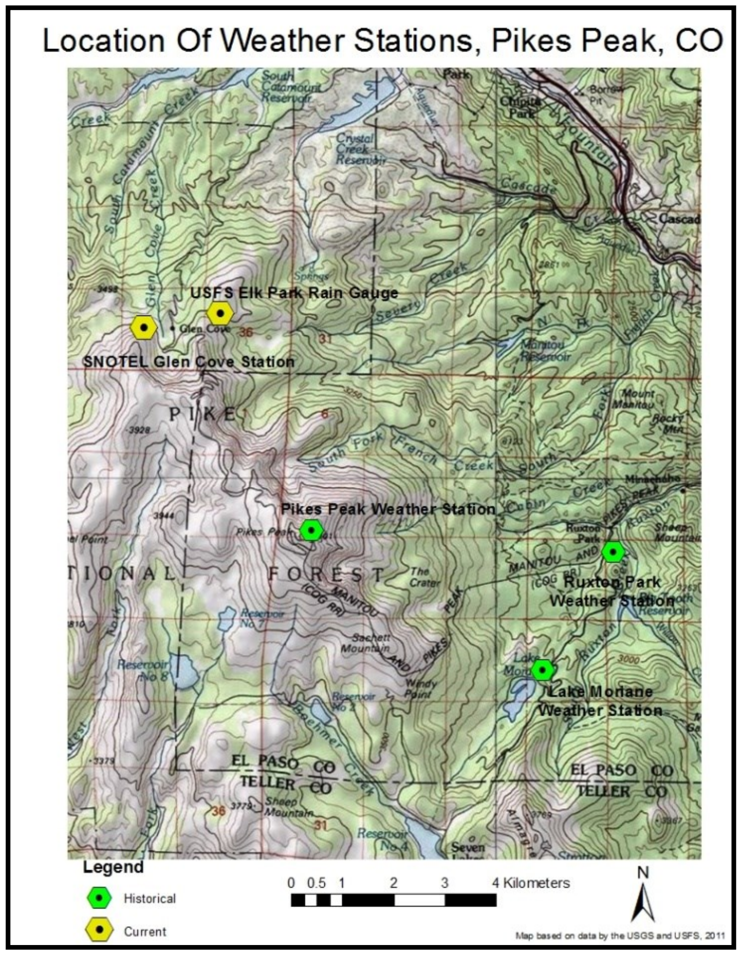


Figure 10. Location of current and historic weather stations on Pikes Peak.

Historical precipitation data was acquired from records of two USGS rain gauges located on Pikes Peak, Ruxton Park and Lake Moraine, as well as meteorological logs from the late 1880's Pikes Peak Weather Station. The Ruxton Park gauge is located 8 km southeast of the Severy Creek Wetland at an elevation of 2758 m. The gauge provides precipitation data from the 1960 to 2009 time period. The Lake Moraine gauge is located 8.3 km also southeast of the Severy Creek Wetland at an elevation of 3130 m. This gauge was in operation from 1931-1963. The Pikes Peak Weather Station, located on the summit of Pikes Peak, provided a record of a variety of meteorological conditions from 1874-1888. This station was sited at an elevation of 4302 m, 3.8 km from the study site.

Hydrology-

Surface water

A comprehensive survey of the basin’s hydrological input including all springs, seeps, gullies, and streams was completed. All features were collected using a Trimble GeoXH GPS receiver using TerraSync software and differentially corrected for errors in Trimble's Pathfinder Office software. The corrected data was then exported into ArcGIS and mapped. Classification of streams; ephemeral, intermittent, and perennial, were based on field observations from 2003 through 2010.

Groundwater

This study continued to measure thirty-nine groundwater monitoring wells which were installed in the wetland during the summer of 2007 by Dr. David Cooper and Edward Gage of Colorado State University (Cooper & Gage, 2008). The wells were established along eight transects within the wetland and were labeled "A” through "H" (Figure 11). From 2008-2010, the wells were monitored at least once a month late May/early June to October. Mean water table depths for this period were calculated for each year for the eight transects to quantify fluctuations in the water table over the course of the summer and to determine the influence, if any, of monsoonal precipitation. Data collected was compared to measurements recorded previously in 2007 (Cooper & Gage, 2008). Using the ArcHydro Groundwater toolset within ArcGIS, groundwater measurements were also used to produce maps of the modeled mean 2007-2009 June-September and mean three year (2007-2009) water table depths throughout the wetland.

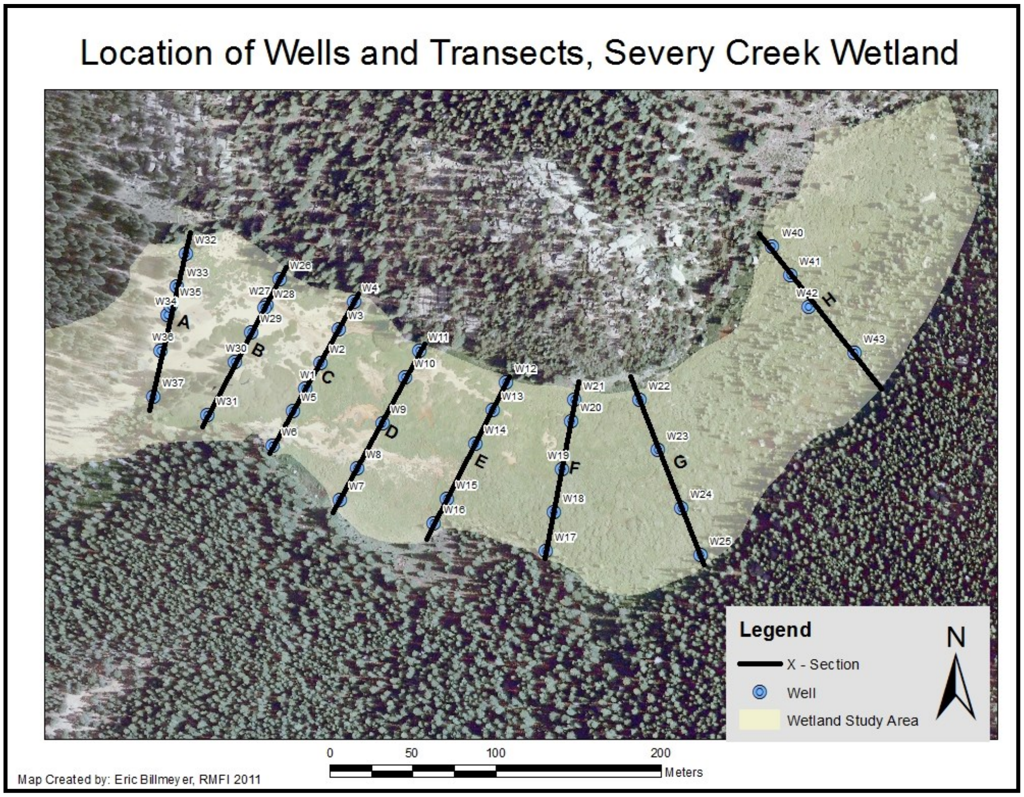


Figure 11. Transect and well location in the Severy Creek Wetland.

Sediment Transport and Deposition-

Sediment transport and deposition in the alluvial fan and wetland was studied using aerial photography, GPS, cross-section surveys, and pebble counts. The data presented for pebble counts and several of the cross-sections were provided by the USFS and was collected as part of the *Monitoring the Effectiveness and Validating Response to the Road Related Mitigation Practices Implemented on the Pikes Peak Highway* study (Troendle et al. 2010). This study was required as part of the settlement agreement associated with the lawsuit brought by the Sierra Club against the City of Colorado Springs and the USFS. The monitoring and validation study is collecting data for all watersheds impacted by the Pikes Peak Highway for a 15-year period from 2003 through 2018.

To measure changes in depositional areas within the wetland, both aerial photography and GPS data were examined. An October 1938 image was acquired from the Pike National Forest and was compared to additional imagery obtained from the USGS and El Paso County with the latest imagery from 2009. Areas of surficial sediment deposition were digitized into polygons from the aerial photographs and saved as shapefiles to be used in ArcGIS for analysis. On the ground area measurements of surficial sediment deposition were collected using a Trimble GeoXH receiver to create polygons that were then exported into ArcGIS and compared to estimates obtained from the aerial photographs.

Cross-section surveys were completed to assess changes in stream and gully bank morphology as well as to calculate any increase or reduction in sediment deposition at the toe of the alluvial fan. This study analyzed data collected by the USFS on five cross-sections installed during the summer of 2003 across a reach of the main channel through the alluvial fan. Data used in this study was collected in 2004 and 2006-2010; no data was collected in 2005. In the summer of 2008, RMFI installed two additional cross-sections; one located above the highest USFS cross-section and one below the lowest USFS cross-section on the alluvial fan (Figure 12). The new lower cross-section was required to capture changes in the channel location that were occurring downstream of the last USFS cross-section. A cross-section was also established along well transect “C” to ascertain if either sediment buildup or a reduction was occurring along the toe of the alluvial fan. Cross-sectional data was recorded by the USFS using a Trimble Robotics Total Station (Troendle et al. 2010). This study used a Lenmark T700 laser level calibrated to .01 of an inch.

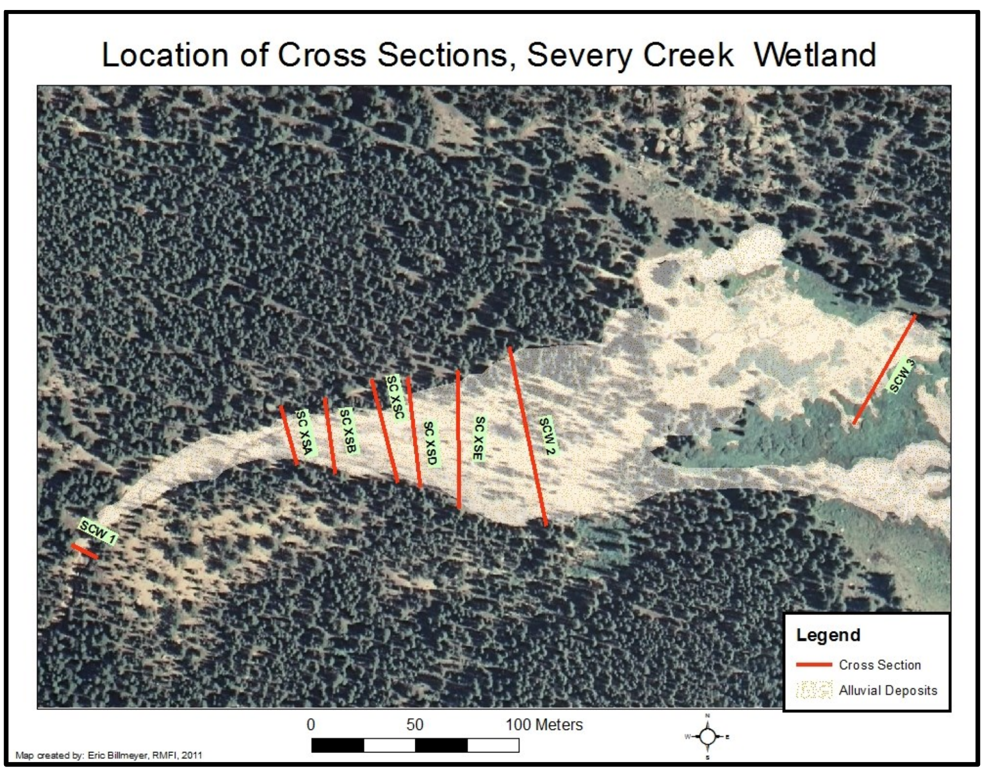


Figure 12. Location of RMFI (SCW 1-3) and USFS (SC XSA-E) cross-sections.

This study also examined pebble count data collected by the USFS on two reaches within the basin from 2003 through 2010 (no data was collected in 2005). The first reach is located between USFS cross-sections XSA and XSE. The second reach is located along Severy Creek within the wetland just downstream of well transect "G". Pebble counts were completed using the Bevenger and King Pebble Count Procedure (Bevenger and King, 1995). The pebble count data was examined to see if any significant changes were detectable in particle size distribution within the study area after the improvements to the Pikes Peak Highway were made in 2006. With a decrease in stormwater input and an expected associated reduction in sediment transport, the percentage of fine particles in the stream channel is expected to lessen over time with a greater percentage of the stream bed being composed of larger particles.

To calculate the depth of sediment deposition in the western portion of the wetland, this study re-examined data for 37 boreholes excavated during the 2007 study and included a fine scale analysis of an additional 4 boreholes dug during the dry summer of 2008. Maximum low water table depths from the 2007-2010 periods were also used to interpolate values between boreholes in the western portion of the wetland. Cross-sectional data and field observations were used to calculate depths of sediment deposition within the alluvial fan. A point feature class was created from the above data sources, including location and estimated depth of deposits. Using the 3D Analyst tool within ArcMap v.10, a raster surface representing the depth of sediment deposits was created from the point feature class. To calculate fill volume, the raster dataset was subtracted from a ground surface elevation raster model generated by bare earth Lidar data using 3D Analyst.

Two natural gullies were also examined in order to gain some understanding of the sediment transport capabilities of a heavily rilled slope area above the wetland to the south and east of the alluvial fan (Figure 13). The gullies are controlled by northeast trending joints and are not associated with any previous stormwater runoff from the Pikes Peak Highway. The gullies were chosen due to the discovery of a large alluvial deposit forming at their outlet and the observed dynamic nature of aggrading and downcutting of sediments within the gullies themselves. Three cross-sections each were installed across the two gully systems in 2008 with data collected before and after monsoonal precipitation through 2010. Surveys were completed using a Lenmark T700 Laser Level calibrated to .01 of an inch.

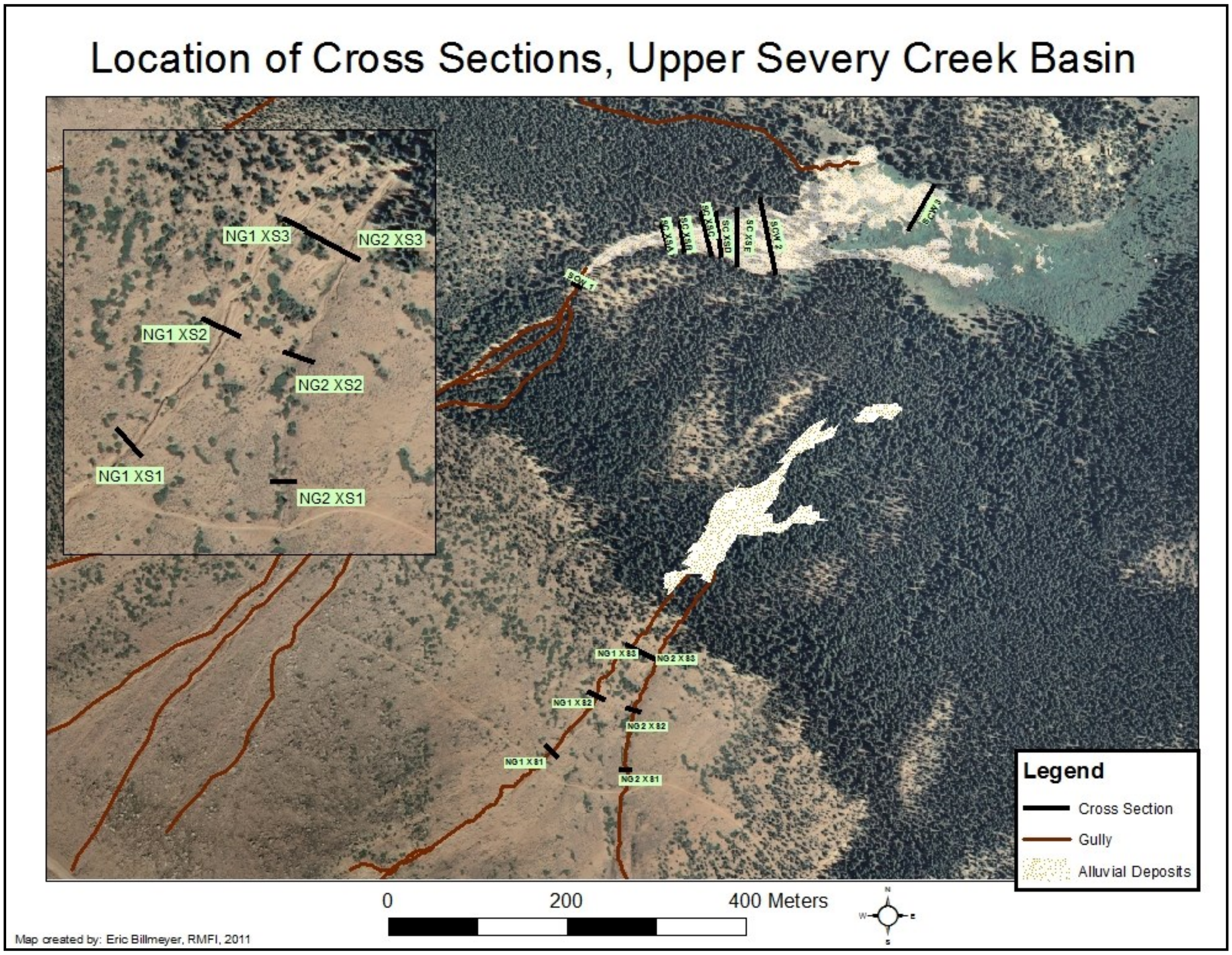


Figure 13. Location of cross-sections in the upper Severy Creek Basin.

Results

Precipitation-

Mean annual precipitation for the Ruxton Park and Lake Moraine stations were 60.96 cm (standard deviation of 10.72 cm) and 62.41 cm (standard deviation of 15.85 cm), respectively. At the Ruxton Park station, precipitation ranged from a low of 40.31 cm in 1962 to a high of 81 cm in 1969. The Lake Moraine station experienced a range of 42.47 in 1962 to 100.23 cm in 1957. Mean annual precipitation recorded at the Pikes Peak Weather Station was slightly higher at 75.21 cm with a greater standard deviation at 25.3 cm. This station recorded a low of 23.57 in 1884 and a high of 113.21 in 1881 (Table 2). The data show that annual precipitation on Pikes Peak can be extremely variable.

Historical Mean Annual Precipitation (cm), Pikes Peak				
Station	**Mean**	**Stdev**	**High**	**Low**
Ruxton Park (1960-2009)	60.96	10.22	81.00 (1969)	40.31 (1962)
Lake Moriane (1931-1963)	62.41	15.85	100.23 (1957)	42.47 (1962)
Pikes Peak WS (1874-1888)	75.21	25.3	113.21 (1881)	23.57 (1884)

Table 2. Comparison of historical mean annual precipitation from three stations on Pikes Peak.

Mean summer (defined here as June 1 through August 31) precipitation is similar over the three historic stations; Ruxton Park, 26.14 cm with a standard deviation of 7.93 cm; Lake Moraine, 25.5 cm with a standard deviation of 7.32 cm; Pikes Peak Weather Station, 25.93 cm with a standard deviation of 10.24 cm. The two stations closest to the study area, Elk Park Knoll and the Glen Cove SNOTEL station, record a higher mean summer precipitation of 29.6 cm (standard deviation of 8.35 cm) and 28.65 cm (standard deviation of 4.87 cm) respectively (Table 3).

Mean Summer Precipitation (cm), Pikes Peak		
Station	**Mean**	**Stdev**
Ruxton Park (1960-2009)	26.14	7.93
Lake Moriane (1931-1963)	25.50	7.32
Pikes Peak WS (1874-1888)	25.93	10.24
Elk Park Knoll (2003-2010)	29.60	8.35
Glen Cove SNOTEL (2005-2010)	28.65	4.87

Table 3. Comparison mean summer precipitation (June thru August) from all stations on Pikes Peak.

Mean annual summer precipitation can vary greatly. For example, the Pikes Peak Weather Station recorded a low of only 4 cm of total precipitation during the summer of 1884, while in the summer of 1881 over 47 cm was recorded. While not as extreme, the Elk Park Knoll station has also recorded significant variations. During the summer of 2003, precipitation was 18.36 cm compared to a high of 40.54 cm in 2006. Mean monthly precipitation for June, July, and August for the Elk Park Knoll station is 5.09, 10.58, and 13.81 cm, respectively, with standard deviations of 4.35, 5.1, and 5.37 cm, respectively (Table 4). The data from Elk Park Knoll show that all summer months experience a high degree of variability from year to year and that precipitation totals are heavily influenced by the strength and timing of the southwestern monsoonal flow.

Elk Knoll Station					Summer (June-Aug)		
Month	Year	Precip_cm	Rank		Year	Precip	Rank
June	2003	4.14			2003	18.36	Low
June	2004	13.41	High		2004	39.78	
June	2005	3.53			2005	24.23	
June	2006	3.15			2006	40.54	High
June	2007	1.73	Low		2007	36.09	
June	2008	2.21			2008	22.12	
June	2009	10.39			2009	29.54	
June	2010	2.16			2010	26.11	
	Avg/Stdev	**5.09**	**4.35**		Avg/Stdev	**29.60**	**8.35**
July	2003	4.04					
July	2004	14.45					
July	2005	3.91	Low				
July	2006	17.63	High				
July	2007	11.58					
July	2008	6.88					
July	2009	14.35					
July	2010	11.76					
	Avg/Stdev	**10.58**	**5.10**				
August	2003	10.19					
August	2004	11.91					
August	2005	16.79					
August	2006	19.76					
August	2007	21.36	High				
August	2008	13.51					
August	2009	4.80	Low				
August	2010	12.19					
	Avg/Stdev	**13.81**	**5.37**				

Table 4. Monthly precipitation totals with mean and standard deviation calculated for the data record. Data shows high variability from year to year in monthly precipitation and in mean summer precipitation.

October 1st through May 1st mean precipitation data was acquired from the SNOTEL Glen Cove station. For the period 2005 through 2010 the mean is 42.42 cm with a standard deviation of 10.22 cm. Mean precipitation was greatest in 2007 with 55.63 cm and lowest in 2006 with 27.18 cm. Snowpack, as measured by its Snow Water Equivalent (SWE), was greatest on May 1st for four out of the six years in the data record. The data show that precipitation in April plays an important role in increasing the overall SWE. In 2007 and 2009, SWE increased from 19.56 and 2.79 cm on April 1, respectively, to 33.27 and 20.32 cm on May 1, respectively. Five of the six years show complete melt out by June 1st with the exception of 2007 when the station was still recording a SWE of 9.6 cm (Table 5).

SNOTEL Glen Cove Station						
(Oct-May)			Snow Water Equivalent (SWE)			
Year	Precip_cm	Rank	Year	Total SWE in cm as of		
				April 1	May 1	June 1
2005	47.24		2005	21.59	30.23	0
2006	27.18	Low	2006	3	2.29	0
2007	55.63	High	2007	19.56	33.27	9.65
2008	34.29		2008	15.49	12.95	0
2009	42.67		2009	2.79	20.32	0
2010	47.5		2010	24.13	27.43	0
Avg/Stdev	**42.42**	**10.22**	Avg	**14.43**	**21.08**	**1.61**

Table 5. Annual precipitation totals (Oct-May) with mean and standard deviation calculated for the data record including total Snow Water Equivalent measurements April 1, May 1, and June 1.

An analysis of rainfall intensity within the basin was also completed from precipitation recorded at the Elk Park Knoll station from 2003 through 2009. All storm events that had a thirty or sixty minute intensity greater than 10 mm were calculated from the data sets. For all storms that met this criteria, total storm precipitation and total storm duration was also calculated. The analysis shows that 31 storm events had an intensity equal to or greater than 10 mm. Of these 31 events, nine had an intensity equal to or greater than 13 mm (Table 6). As shown by the data, the most intense period of precipitation is from mid-July to mid-August and corresponds well to the summer monsoonal pattern experienced in the Pikes Peak area.

Elk Park Knoll Rain Gauge Precipitaion totals (Events of =>10 mm for 30/60 min intensity)					
# Events	Date	Intensity-30min	Intensity-60min	Precip-Total Storm	Duration_Total Storm (hr)
1	7/15/2003	12.19		12.19	0.30
	7/15/2004	9.40	11.94	13.21	1.28
	7/16/2004	16.51	18.80	41.15	5.48
	7/22/2004	7.37	11.18	13.21	1.59
	8/4/2004	16.51	18.03	18.54	1.04
	8/28/2004	6.35	10.41	10.41	1.00
6	9/19/2004	6.10	12.95	12.95	0.52
	8/4/2005	9.91	10.92	16.26	2.10
2	8/20/2005	7.62	12.45	33.02	3.01
	7/10/2006	5.84	10.41	10.41	0.58
	7/11/2006	9.65	12.95	17.78	1.55
	7/25/2006	12.70	17.27	19.56	1.55
	8/6/2006	9.91	10.92	14.73	2.29
	8/7/2006	10.16	16.51	42.67	4.07
	8/12/2006	8.13	13.72	35.81	4.29
	8/18/2006	14.48	17.78	20.07	1.23
8	9/11/2006	7.11	11.18	13.21	1.14
	8/2/2007	16.76	19.56	19.56	0.59
	8/3/2007	8.38	12.70	13.21	1.20
	8/4/2007	20.32	24.89	30.23	2.59
	8/7/2007	23.37	34.04	53.34	3.00
	8/14/2007	12.95		12.95	0.24
6	8/15/2007	13.46	17.53	31.75	3.52
	7/25/2008	10.67	11.68	15.24	6.25
	8/6/2008	16.00	18.80	19.81	1.23
3	8/6/2008	13.72	25.40	36.32	3.45
	6/2/2009	9.65	17.53	26.42	1.56
	7/2/2009	6.86	10.92	18.80	1.5
	7/4/2009	12.19	16.00	20.57	4.13
	7/11/2009	8.64	10.41	11.68	2.18
5	9/6/2009	7.11	12.19	14.73	1.37
31 events		9 events =>13 mm	14 events =>13 mm	9 events =>25mm	

Table 6. Record of all storms between 2003 and 2009 with a thirty or sixty minute intensity equal to or greater than 10 mm. Time stamp data was not available for 2010 precipitation data.

Hydrology

Surface-

Thirty-six springs and three seeps have been found within the upper Severy Creek Basin on the slopes above the wetland (Figure 14). Of these, eight springs are associated with the gully systems stemming from the Pikes Peak Highway that feed into the large alluvial fan. The flow from these springs is largely perennial and the streams they feed are augmented by snowmelt and summer monsoonal precipitation. During the spring melt and after summer storms, the flow of these streams is sufficient to pass through the alluvial fan and into the wetland proper. During other periods, these streams dissipate into the alluvium deposits near the toe of the fan. The majority of the springs are not associated with the gully systems and come together to form several small streams that lead toward the wetland. Only one of these streams actually carries enough surface flow to make it into the wetland proper as a perennial stream. The stream is found entering the wetland along its southwestern side (Figure 14). The remaining springs and streams disappear into the colluvium and alluvium that forms the transition zone between the slopes of the basin and the wetland. The presence of the large number of springs indicates that the bedrock underlying the slopes just to the south of the wetland is highly fractured and that the springs are likely associated with the north to northeast trending joints found in the area during the geological survey of the basin (Morgan & Billmeyer, 2010). The springs are a primary contributor to groundwater flow recharging the wetland below. It is interesting to note that as of 2010, none of the mapped streams on the upper slopes ever physically connect to the main Severy Creek channel within the wetland except after major storm events or the spring snow melt.

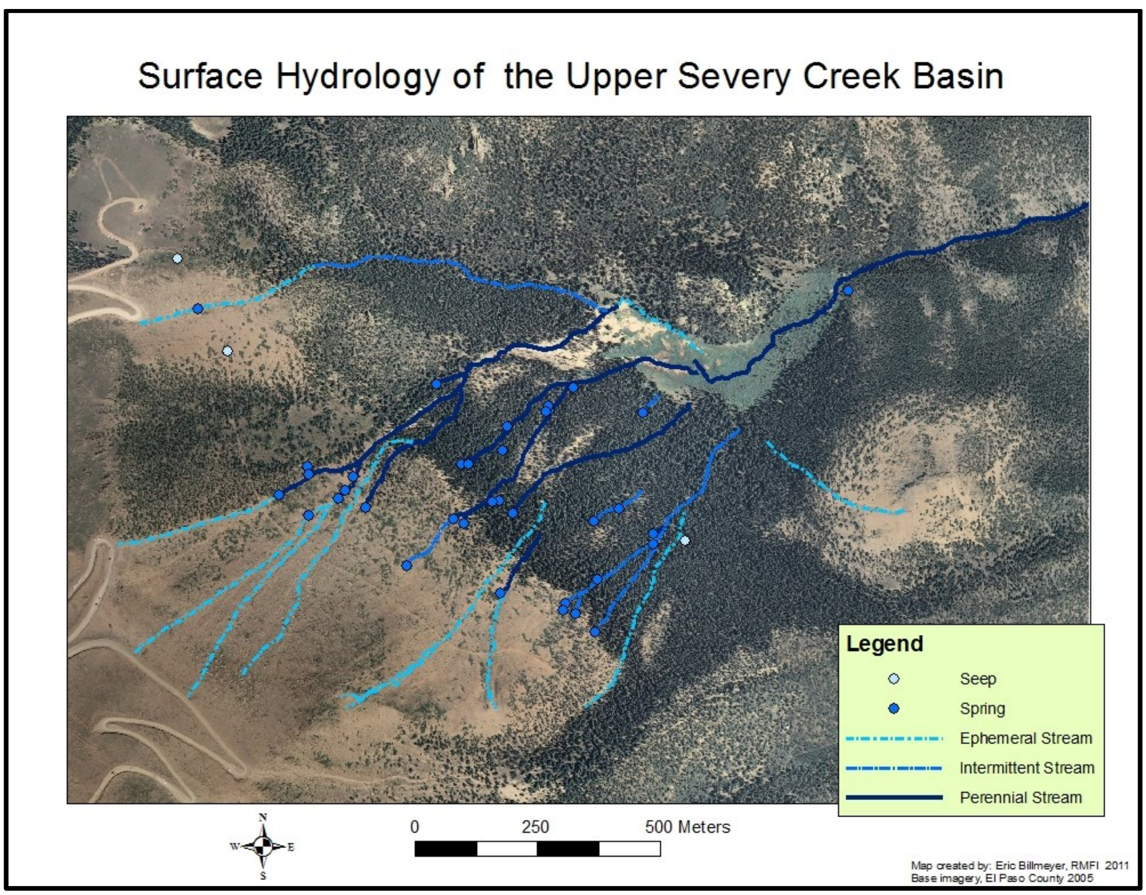


Figure 14. Surface hydrology of the Severy Creek Basin.

Groundwater-

Analysis of the well data over the 2008-2010 time period confirms the findings of the 2007 study (Cooper & Gage, 2008). In general, water table elevation depths are greatest, and fluctuate the most, in the western portion of the wetland (cross-sections A through E) where significant burial by alluvial deposition has occurred (Table 7). Depth to water tables in the eastern portion (cross-sections F through H) show elevations generally at or near the ground surface (<15 cm) over the summer growing season (June through August). Water table depths throughout the wetland are at their greatest height in late spring/early summer and, in general, reach their lowest elevation by October. It does not appear that the previous winter snowpack has a strong influence over early season water table depths. As shown in the Snow Water Equivalent (SWE) data for May 1st, snowpack as measured by its SWE was 12.95 cm in 2008 and 27.43 cm in 2010. Even with an additional 14.48 cm in SWE in 2010, the difference in mean May water table depth for all cross-sections between the two years was only ~5 cm (Table 7).

Mean Water Table Depth

X-Sec A

Month	2007	2008	2009	2010
May	n/a	-0.29	n/a	-0.31
June	n/a	-1.40	-0.41	-1.36
July	-1.32	-1.96	-1.30	-1.94
August	-0.70	-1.95	-1.82	-0.92
September	-1.02	-1.96	-1.99	-1.99
October	-1.64	-1.96	-1.95	-1.98
All Months	-1.17	-1.59	-1.49	-1.42

Mean Water Table Depth

X-Sec B

Month	2007	2008	2009	2010
May	n/a	-0.11	n/a	-0.16
June	n/a	-0.49	-0.14	-0.49
July	-0.72	-0.82	-0.46	-0.81
August	-0.23	-0.84	-0.69	-0.33
September	-0.39	-0.84	-0.83	-0.85
October	-0.93	-0.84	-0.84	-0.85
All Months	-0.57	-0.65	-0.59	-0.58

Mean Water Table Depth

X-Sec C

Month	2007	2008	2009	2010
May	n/a	-0.02	n/a	-0.02
June	n/a	-0.11	-0.05	-0.09
July	-0.15	-0.70	-0.09	-0.32
August	-0.07	-0.69	-0.14	-0.04
September	-0.07	-0.72	-0.42	-0.53
October	-0.46	-0.74	-0.50	-0.67
All Months	-0.19	-0.49	-0.24	-0.28

Mean Water Table Depth

X-Sec D

Month	2007	2008	2009	2010
May	n/a	-0.11	n/a	-0.11
June	n/a	-0.18	-0.10	-0.18
July	-0.19	-0.57	-0.14	-0.27
August	-0.12	-0.55	-0.20	-0.14
September	-0.16	-0.59	-0.28	-0.36
October	-0.32	-0.60	-0.37	-0.54
All Months	-0.20	-0.43	-0.22	-0.27

Mean Water Table Depth

X-Sec E

Month	2007	2008	2009	2010
May	n/a	-0.09	n/a	-0.08
June	n/a	-0.17	-0.04	-0.14
July	-0.16	-0.35	-0.08	-0.20
August	-0.10	-0.31	-0.15	-0.10
September	-0.12	-0.35	-0.18	-0.24
October	-0.22	-0.38	-0.25	-0.37
All Months	-0.15	-0.27	-0.14	-0.19

Mean Water Table Depth

X-Sec F

Month	2007	2008	2009	2010
May	n/a	-0.09	n/a	-0.04
June	n/a	-0.08	-0.04	-0.06
July	-0.08	-0.18	-0.04	-0.08
August	-0.04	-0.16	-0.07	-0.03
September	-0.04	-0.20	-0.09	-0.07
October	-0.07	-0.23	-0.12	-0.14
All Months	-0.06	-0.16	-0.07	-0.07

Mean Water Table Depth

X-Sec G

Month	2007	2008	2009	2010
May	n/a	-0.09	n/a	-0.06
June	n/a	-0.10	-0.08	-0.07
July	-0.12	-0.13	-0.08	-0.08
August	-0.06	-0.10	-0.08	-0.06
September	-0.08	-0.14	-0.08	-0.07
October	-0.08	-0.13	-0.08	-0.08
All Months	-0.09	-0.11	-0.08	-0.07

Mean Water Table Depth

X-Sec H

Month	2007	2008	2009	2010
May	n/a	-0.04	n/a	0.00
June	n/a	-0.07	-0.01	-0.03
July	0.00	-0.09	-0.02	-0.03
August	-0.02	-0.03	-0.04	-0.01
September	-0.01	-0.10	-0.03	-0.03
October	-0.02	-0.09	-0.03	-0.03
All Months	-0.01	-0.07	-0.03	-0.02

Table 7. Annual comparison of changes in mean water table depths (m) for all cross-sections for May thru October.

Mean annual depth to water table data clearly shows the distinction between water table depths in the western section of the wetland area versus the eastern portion. The data show that water table depths for all years are significantly below the surface in cross-sections A and B. Water table depths for all years progressively get closer to the surface and correlation between annual means also trend more closely when moving eastward across the wetland from cross-sections C though H (Table 8).

X-Section A

Year	Mean Water Table Depth	
2007	-1.17	
2008	-1.59	
2009	-1.49	
2010	-1.42	
Avg/StDev	**-1.42**	**0.22**

X-Section B

Year	Mean Water Table Depth	
2007	-0.57	
2008	-0.66	
2009	-0.59	
2010	-0.58	
Avg/StDev	**-0.60**	**0.05**

X-Section C

Year	Mean Water Table Depth	
2007	-0.19	
2008	-0.49	
2009	-0.24	
2010	-0.28	
Avg/StDev	**-0.30**	**0.16**

X-Section D

Year	Mean Water Table Depth	
2007	-0.20	
2008	-0.43	
2009	-0.22	
2010	-0.27	
Avg/StDev	**-0.28**	**0.13**

X-Section E

Year	Mean Water Table Depth	
2007	-0.15	
2008	-0.27	
2009	-0.14	
2010	-0.19	
Avg/StDev	**-0.19**	**0.07**

X-Section F

Year	Mean Water Table Depth	
2007	-0.06	
2008	-0.16	
2009	-0.07	
2010	-0.07	
Avg/StDev	**-0.09**	**0.06**

X-Section G

Year	Mean Water Table Depth	
2007	-0.09	
2008	-0.11	
2009	-0.08	
2010	-0.07	
Avg/StDev	**-0.09**	**0.02**

X-Section H

Year	Mean Water Table Depth	
2007	-0.01	
2008	-0.07	
2009	-0.03	
2010	-0.02	
Avg/StDev	**-0.03**	**0.03**

Table 8. Comparison of the annual mean June-September water table depth (m) for all cross-sections including the calculated three year average and standard deviation.

The timing and strength of monsoonal precipitation has the greatest impact on water table elevations in the western section of the wetland. Water table depths at several wells in this section can decline to over 2 meters and then quickly rebound by a meter or more after a significant period of rainfall. This type of flashy response has been observed several times over the course of this study (Figure 15). The pattern was first recorded during the 2007 study when water tables in the western section rose dramatically after a series of storm events starting on August 2nd dropped over 13.44 cm of rain in 6 days. The Elk Park Knoll station recorded the storm event on August 7th as the largest during the period with 5.33 cm of precipitation falling in less than 3 hours. The mean August water table depth for wells in cross-sections A and B increased by ~50 cm over the pre-storm July means after this event in 2007. The second major response occurred in 2010 when 12.52 cm of rain fell over nine consecutive days from July 29th to August 5th. The largest storm event was 3.4 cm on August 3rd. The mean August water table depth for wells in cross-sections A and B increased by over 1 m and 47 cm, respectively, over the pre-storm July means (see Table 7).

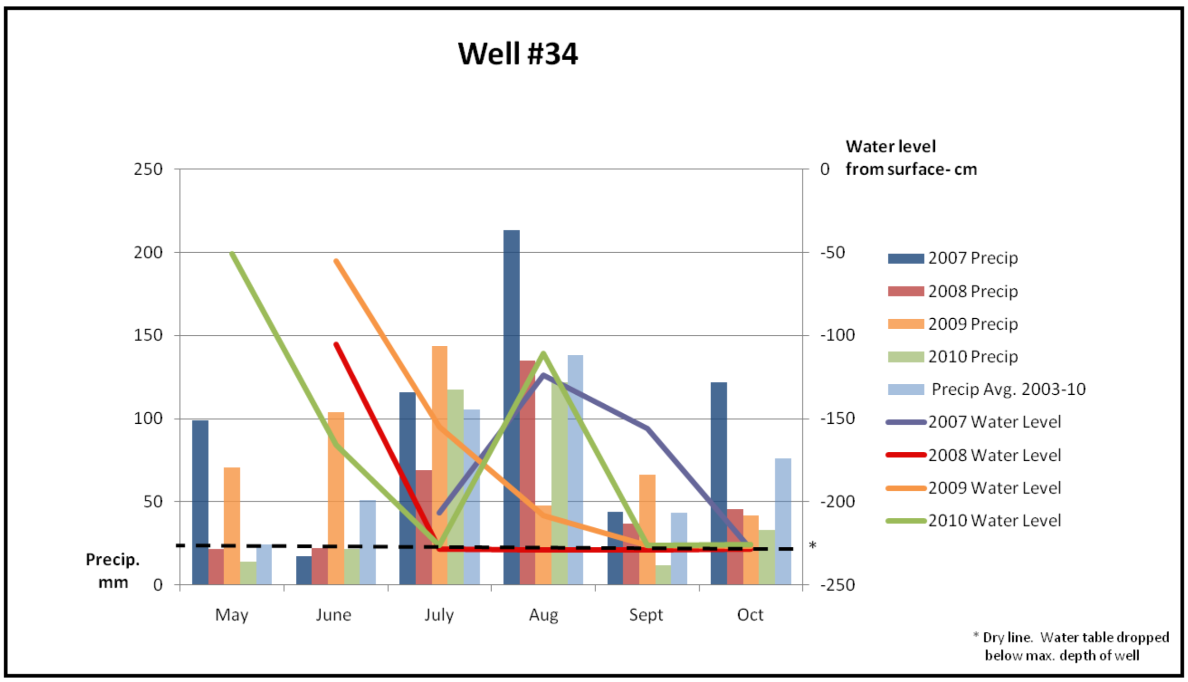


Figure 15. Comparison of the mean annual water table and monthly precipitation between study years for Well #34.

The monsoonal flow in 2008 and 2009 was weak and disorganized, resulting in no identifiable response along cross-sections A and B. However, measurements in 2008 did show a small, positive response in cross-sections C and D after 5.6 cm of rain fell over the course of two storms on August 6th, 2008 (Figure 16).

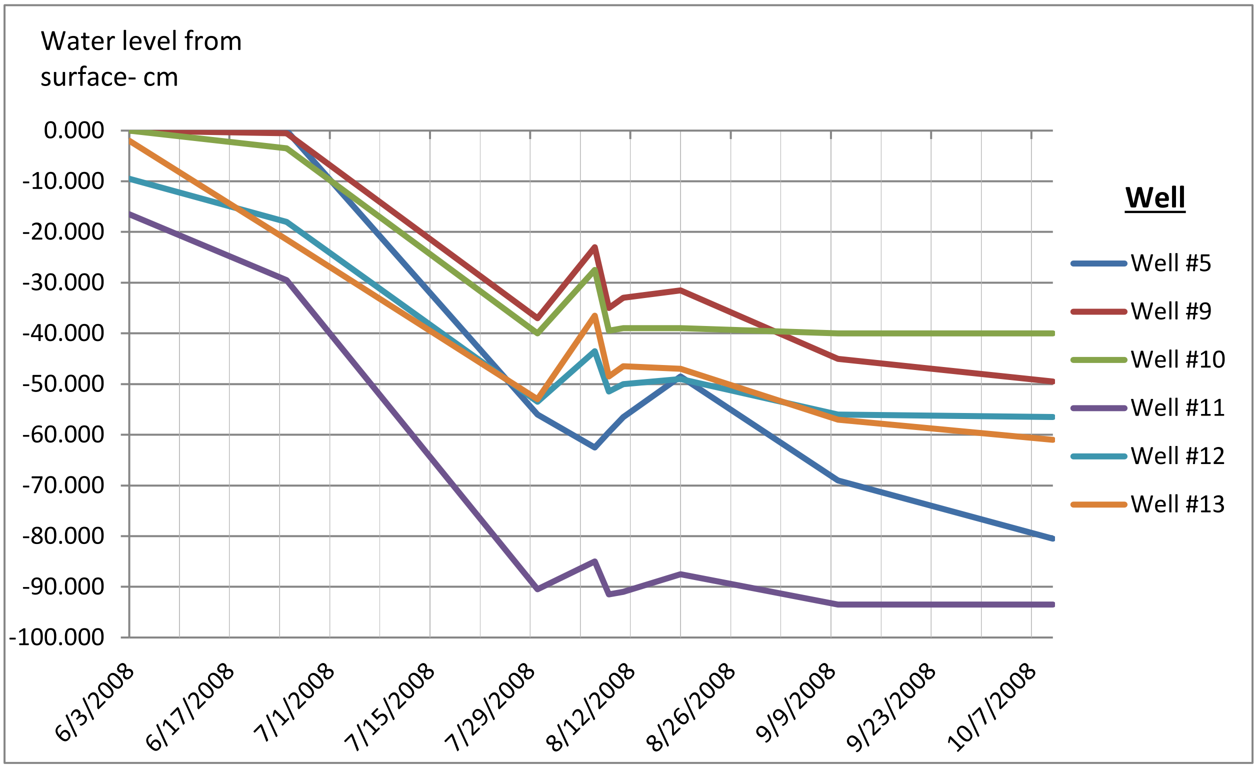
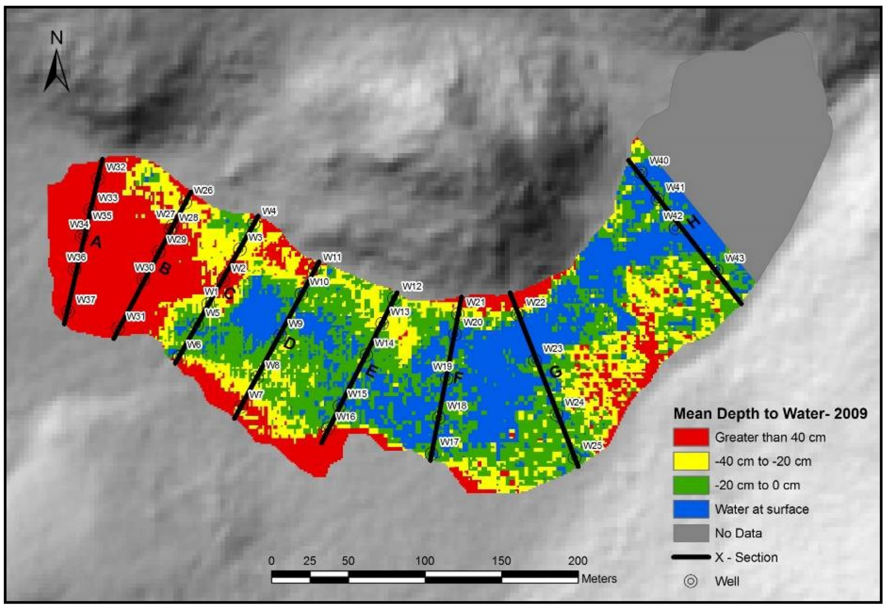


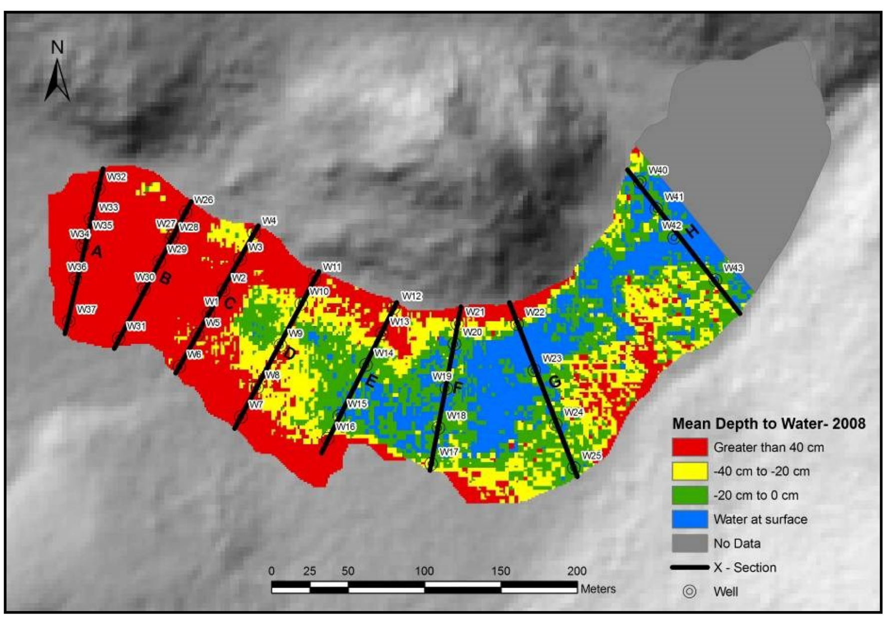
Figure 16. 2008 hydrograph for wells located along cross-sections C and D showing response to early August precipitation.

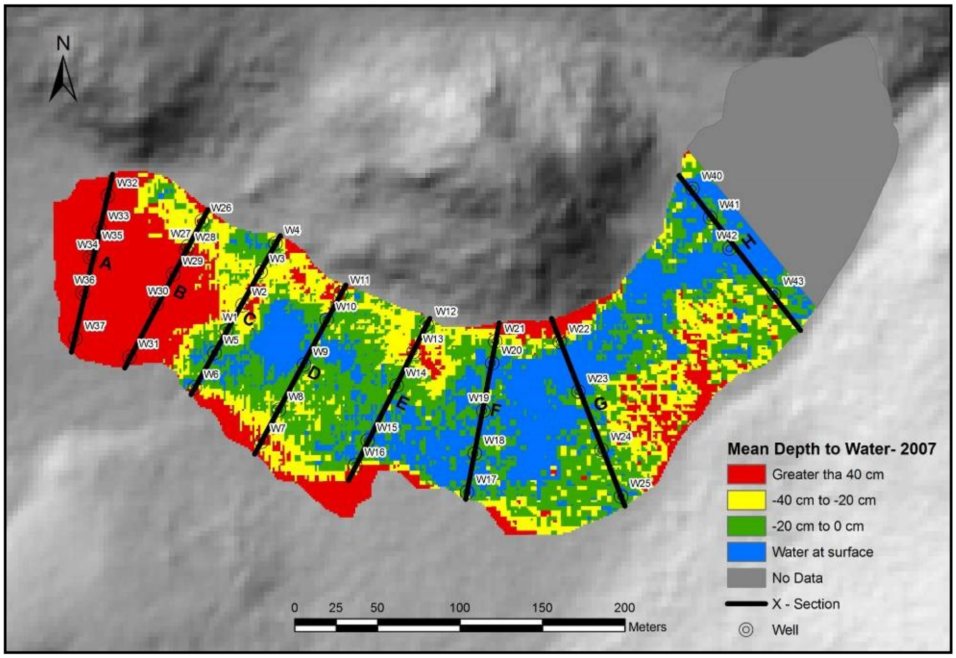
In the eastern portion of the wetland, mean water tables for all years are generally high throughout the summer and show a minor positive response to monsoonal precipitation. Of the 13 wells located in cross sections F through G, ten wells have water tables at the surface or within 15 cm over the entire summer (See Appendix B for graphs of all well data). The three exceptions are for those wells found on the periphery of the wetland. In the eastern section, water tables generally decline in July as the natural increase in evapotranspiration rates exceeds precipitation. Monsoonal precipitation at the end of July/early August then recharges water levels generally back to early summer levels before slightly declining again into October.

Lastly, raster maps of the modeled June-September mean water table depths were created to analyze the fluctuation of the water table throughout the wetland over the 2007 to 2009 study years. Water table depths were classified based on methodology by Cooper using field observations of sedge roots (Cooper et al. 1998). The classification provides a means in which to model areas within the wetland that can sustain wetland flora. Areas with depths greater than 40 cm were considered to be below the root zone. Depths from -40 cm to -20 cm represent the lower part of the root zone while depths from -20 cm to 0 cm represent the upper root zone.

Water tables within the wetland constricted severely during the 2008 dry summer. Water table depths recovered in 2009 but not to the same extent as 2007 (Figure 17). Field observations indicate that the east wetland area between transects G and H is much wetter than indicated in the model and that the water table here is actually at or within 20 cm of the surface. All maps show that water tables are consistently below 40 cm throughout the summer growing season across the western section. Those areas shown to have an average water table depth within 40 cm of the surface over the 2007-09 period would be suitable for seeding or transplanting native wetland vegetation.







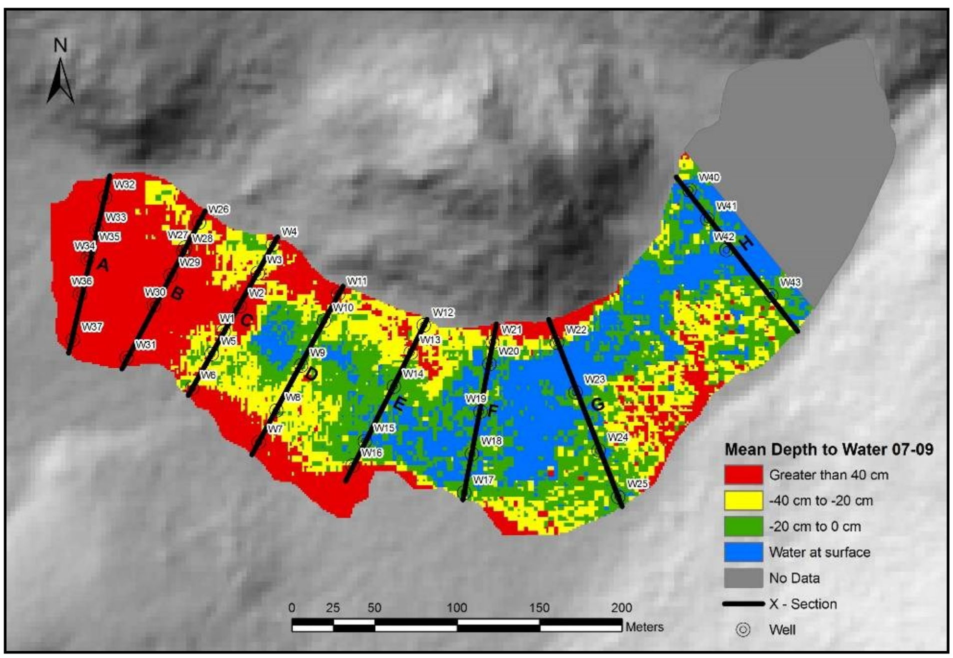


Figure 17. Maps of mean June-September and three year average for depth to water for the Severy Creek Wetland.

Surficial Sediment Deposition

Twentieth century deposition within the wetland was examined using aerial photographs of the Severy Creek Wetland from 1938[1], 1953[2], 1975[1], 2003[3], 2005[3], 2007[3], and 2009[3] ([1]USFS, [2]USGS, [3]El Paso County). The 1938 image clearly shows the western portion of the wetland as being unaffected by the sediment debris flows that are visible beginning in 1953 and in all later images (Figure 18). In 1938, no formal maintenance on the Pikes Peak roadway was being conducted and the road was essentially abandoned. The City of Colorado Springs took over maintenance and operation of the road in 1948. Maintenance activities on the roadway began to have a noticeable effect on the surrounding environment as early as 1952, as detailed by J.P. Reddick, a Forest Service specialist (Reddick, 1952). The main deficiencies noted were the lack of water attenuation structures, inadequate spacing of culverts, and improper placement of culverts. In the Severy Basin, these deficiencies led to the highly incised channels that formed below the culverts and facilitated the transport of sediments down into the valley and wetland (Figure 19).

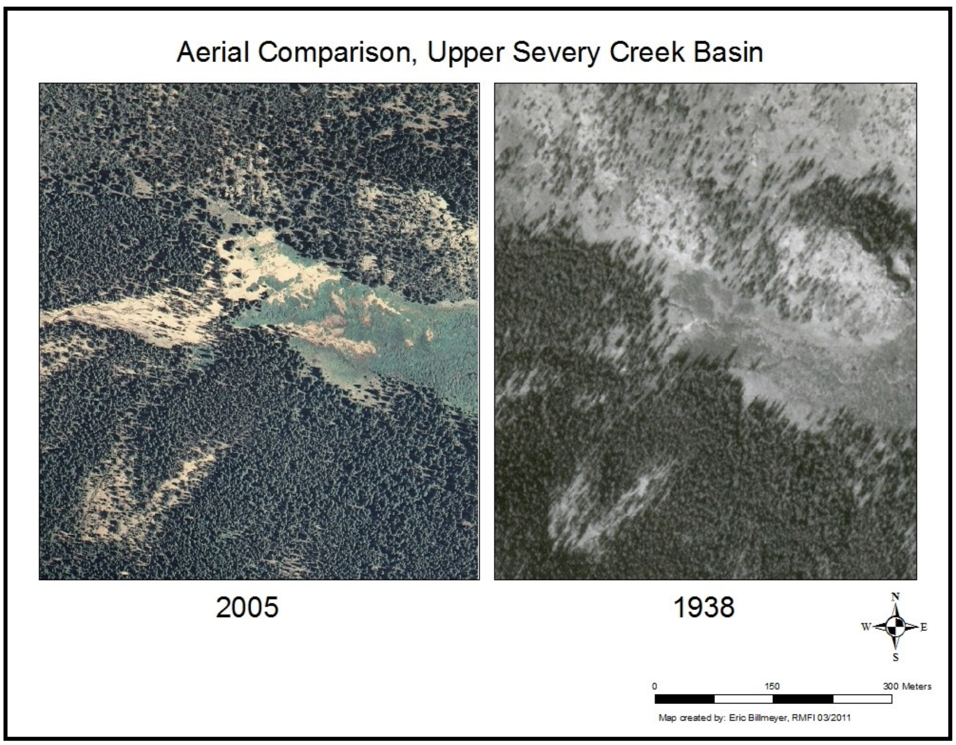


Figure 18. Comparison between the 1938 and 2005 aerial imagery of the Severy Creek Wetland.

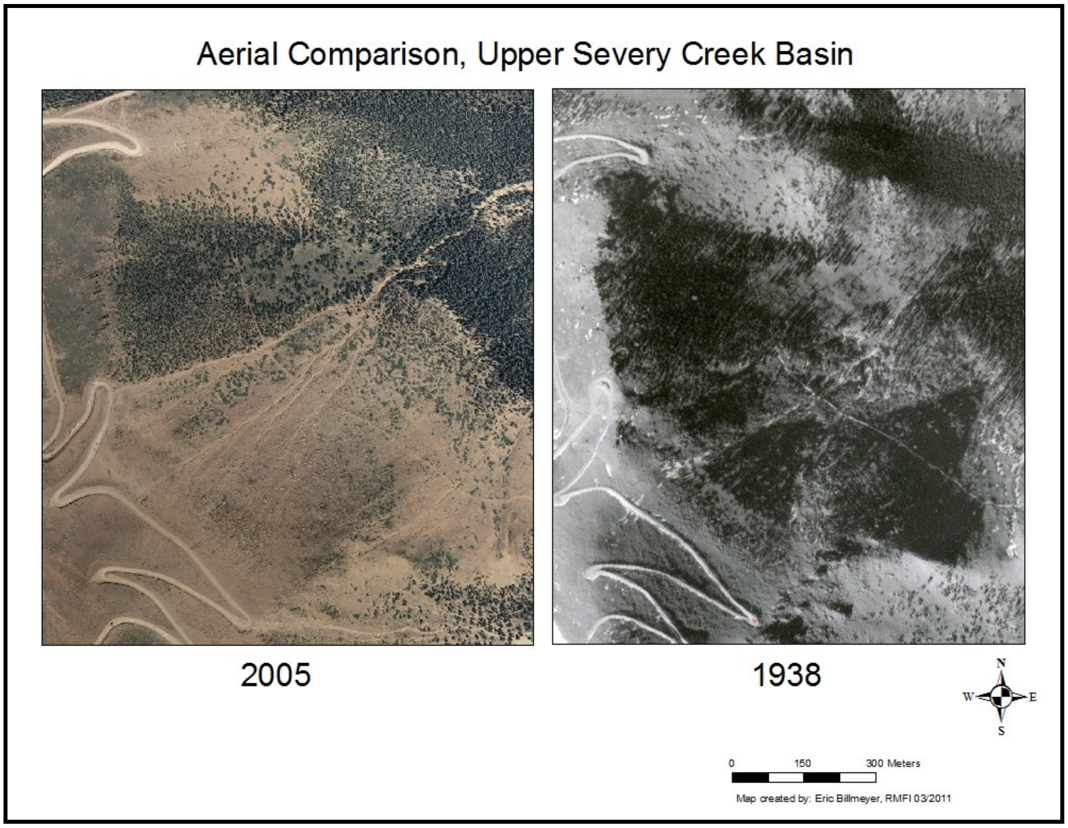


Figure 19. Comparison between the 1938 and 2005 aerial imagery of the slopes above the Severy Creek Wetland.

Estimated extent of surficial sediment deposition within the wetland from 1938 to 1975 was based on visible sediment deposits in the imagery and likely underestimates the actual amount *in situ* at that time. The extent of surface sediment deposits were estimated to be 118 m^2 in 1938, 4,463 m^2 in 1953, and 17,758m^2 in 1975 (Figure 20). The dramatic rise in visible sediment deposition between 1953 and 1975 (298% increase) was likely due to several major depositional events in the area thought to have occurred in 1948, 1957, and 1968. Dates were interpolated through a tree ring analysis of standing dead Engelmann spruce trees within the alluvial fan above the wetland (Cooper, 1998). The dates correspond with the death of sampled trees from across the fan. The death of the trees was likely due to a substantial increase in sediment deposition around the tree's root system. This can cause tree species like Engelmann spruce to die from asphyxiation within a short period of time if the roots remain buried.

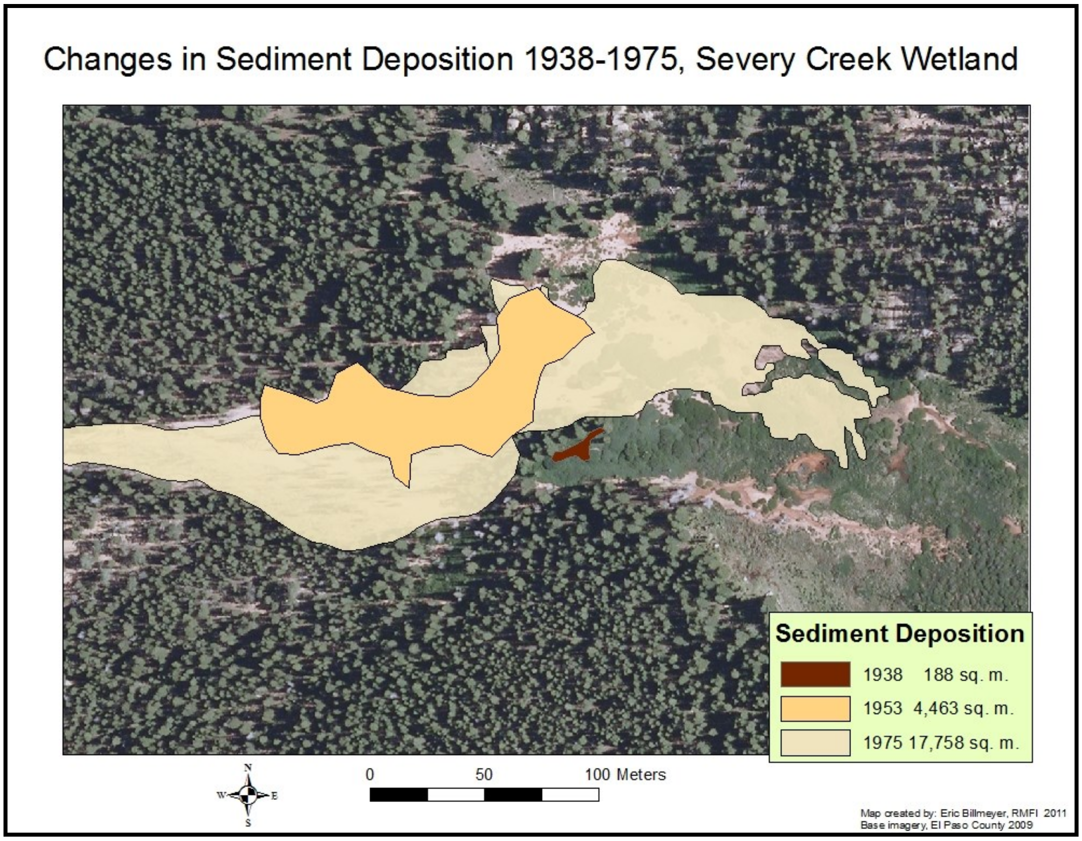


Figure 20. Estimated total surficial extent of sediment deposits 1938, 1953, and 1975.

Estimated extent of surficial deposits from 2003-2010 were based off of GPS data points in comparison with the available aerial photography. The change in surficial deposits from 2003-2010 shows continuing deposition, however since 2005 the rate of year to year increase has been ~2% or less; likely related to the paving and removal of culverts along the highway in the basin in 2006 (Table 9).

Change in Surficial Sediment Deposits, Severy Creek Wetland

Year	Sq. Meters	Hectares	% Change from previous
1938	118	0.01	n/a
1953	4463	0.45	3682.2
1975	17758	1.78	297.9
2003	22055	2.21	24.2
2005	23633	2.36	7.2
2007	23860	2.39	1.0
2009	24381	2.44	2.2
2010	24573	2.46	0.8

Table 9. Temporal change in surficial sediment deposits from 1938 to 2010.

The observed deposition from 2003 to 2010 is taking place along the wetland's far northwestern boundary and along the sediment plume flowing from the west to the east along the southern portion of the wetland (Figure 21).

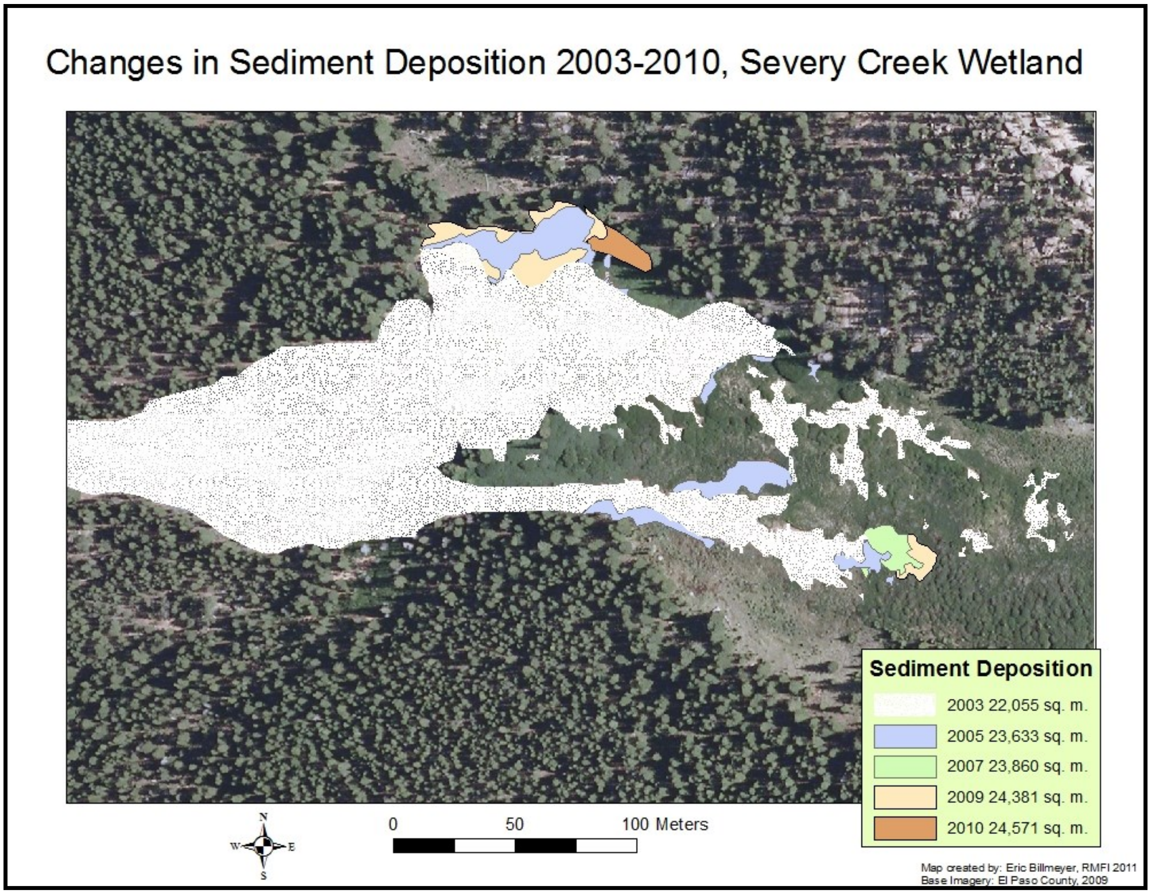


Figure 21. Estimated total surficial extent of sediment deposits 2003, 2005, 2007, 2009, and 2010 (no data for 2004 and 2006).

Deposition and Stream Channel Migration

The sediment deposition in the northwestern part of the wetland is due to two compounding factors. The first is the gully channel that feeds stormwater from the highway into this portion of the wetland is still active due to a lead-off ditch that was left in place after paving in 2006 (see Figure 9). The second factor is a significant change in the channel location of the stream that is flowing through the alluvial fan in this location (Figure 22). The stream cut a new channel into the alluvial deposition in late summer 2007 after the significant precipitation event on August 7th when 5.33 cm of rain fell within 3 hrs after 8.11 cm had fallen over the previous five days. After this event, the main stream channel through the fan moved 13 m to the north at the location of transect SCW 2 and ~100 m^3 of sediment was deposited in the former channel (Figure 23). The channel has continued to migrate to the northwest and since 2009, its stream flow has been combined with that of the flow of the stream entering from the northwest that is connected to the gully channel. The increase in stream flow is allowing sediment to be carried further into areas that had probably not seen sediment deposition in the 20th century.

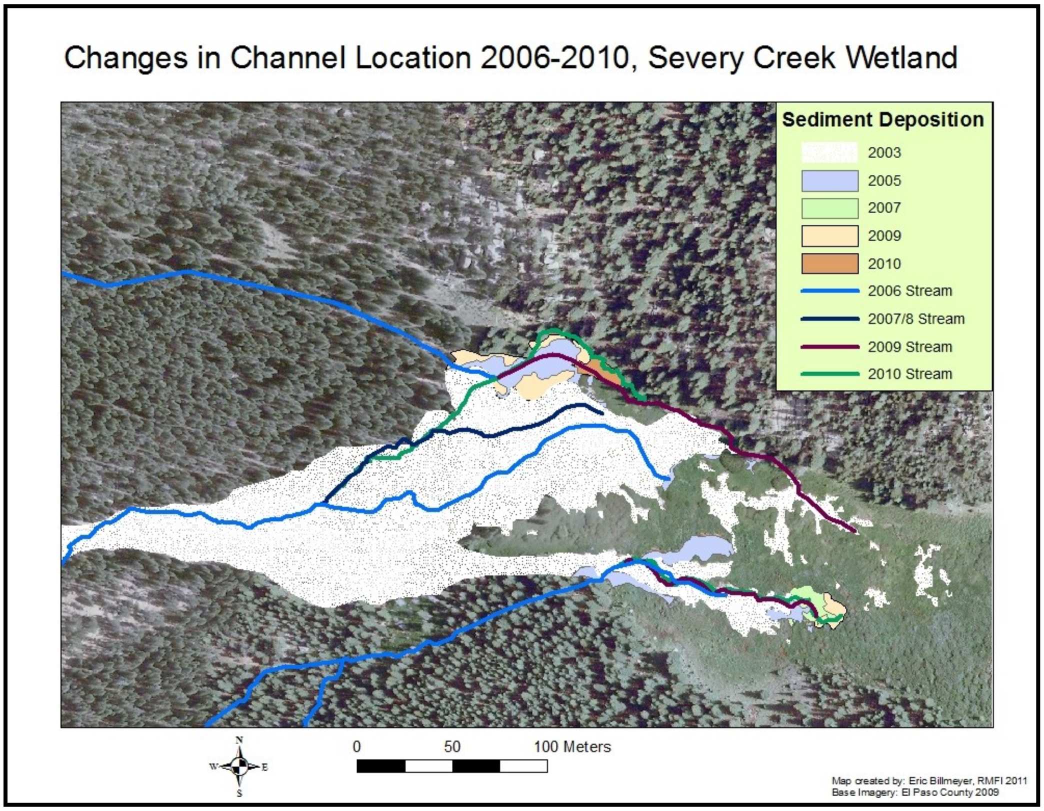


Figure 22. Changes in channel location and its influence on sediment deposition 2006-2010.

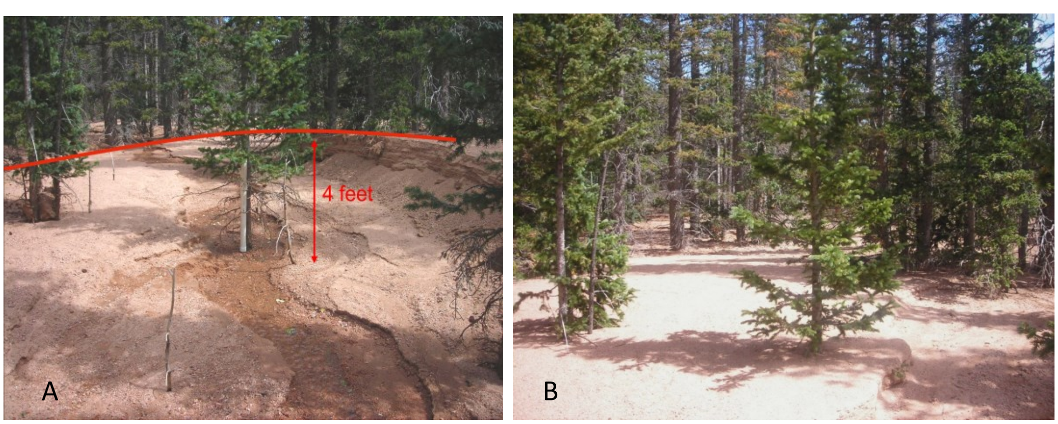


Figure 23. View of stream channel in 2006 (A) and same location in September 2007 (B).

The origin of the current sediment plume in the southern portion of the wetland appears to be from a change in channel location of the stream flowing through the alluvial fan sometime pre- 1997 and likely after 1993. A 1993 USGS aerial photograph of the wetland does not appear to show any deposition in this portion of the wetland. However, a 1997 photograph of the wetland taken from a location on the Elk Park Knoll trail does show the sediment plume. The probable course of the stream during this time was hand digitized in ArcGIS using the 1997 photograph for reference. During field observations, an abandoned channel scar that runs along the southern side of the alluvial fan and into the area of the sediment plume was found. The abandoned channel scar starts at a higher location than that estimated for the channel in the 1997 photograph and is likely from an earlier time (Figure 24). Aerial photography of the basin taken in 2003, clearly shows that the stream channel moved to a more central location within the alluvial fan sometime after 1997.

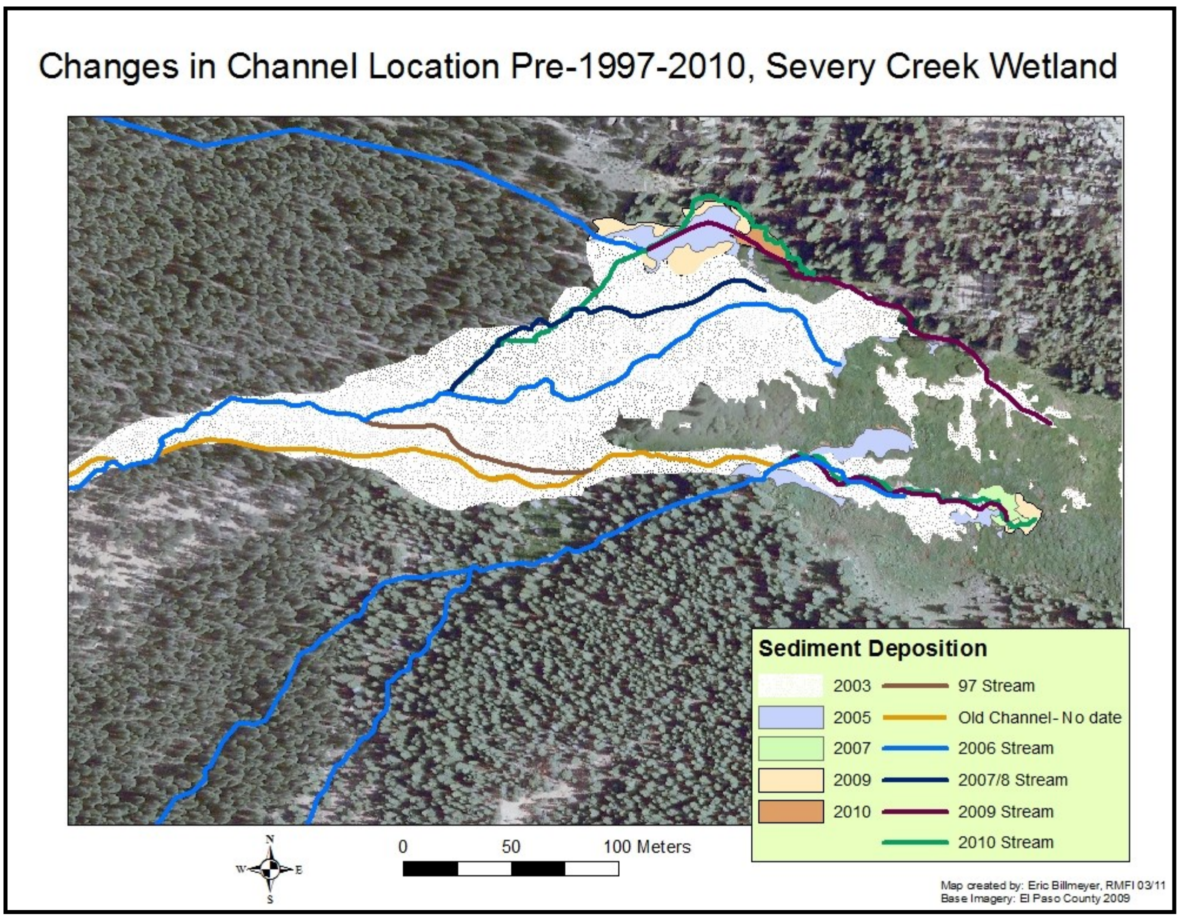


Figure 24. Changes in channel location and its influence on sediment deposits in the southern plume.

The current expansion of sediment deposition in the plume to the south appears to be due to an increase in stream flow. This stream is spring fed, and from field observations, the length of the stream through the plume has been steadily increasing since 2005. In 2010, the flow of the stream was sufficient to have surface flow to within 2 m of an established channel within the wetland. In addition, the stream flow in 2010 persisted through the summer and into late October with surface flow reaching the distal end of the deposition. In previous years, the maximum distance of flow was maintained until approximately mid-August; generally after the peak monsoonal precipitation. With the increase in surface flow is a corresponding increase in sediment transport of course sand and small gravel further into the wetland. If the current trend persists, it is likely the surface flow of this stream will join with the established channel within the next couple years; increasing sediment transport into the wetland.

Alluvial Fan Stream Channel Morphology

In an effort to understand the sediment dynamics within the main channel through the alluvial fan, an analysis of the USFS cross-section measurements for transects XSA through XSE for the years 2004 and 2006-2010 was completed. Overall the cross-section data show little change to the morphology of the stream during the study period with regards to bank location and width of channel. Changes in channel depth were observed along transects XSC-XSE, but transects XSA and XSB remained virtually unchanged (see Appendix C). Transect XSC showed significant downcutting of ~50 cm during 2007 with the new increased channel depth maintained through 2010 (Figure 25). This material was redistributed downstream where the channel across transect XSD decreased in depth by approximately the same amount during the same period. The new higher elevation was maintained through 2010. Transect XSE showed consistent downcutting of the channel beginning in 2006 and continuing through 2010. The channel is moving gradually to the northern edge of the alluvial fan in this location as well (Figure 26).

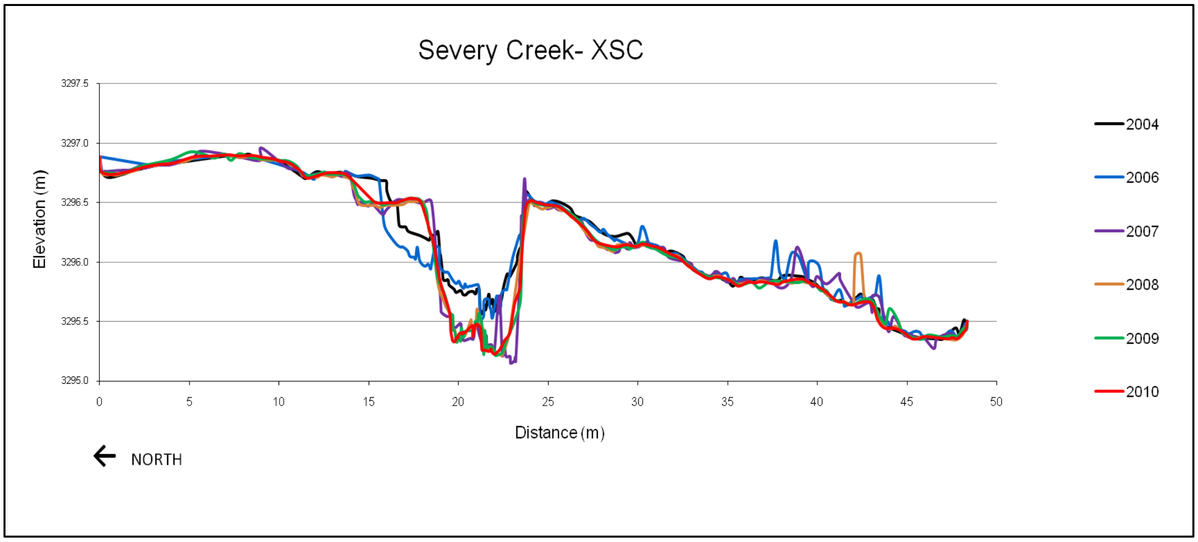


Figure 25. USFS cross-section XSC data- 2004,2006-2010.

Figure 26. USFS cross-section XSE data- 2004,2006-2010.

The USFS cross-sections were located above what turned out to be the hinge point for the stream and did not record an extremely significant change in the channel's location after the major storm event in August of 2007 when the channel moved 15 m to the west. In an effort to record future changes in channel location, RMFI installed a new cross-section (SCW 2) thirty meters downstream of transect XSE during the summer of 2008. Data show that since 2008, the stream continues to downcut the channel at this location. The location and width of the channel banks have remained unchanged (Figure 27). An additional cross-section was also installed by

RMFI above the first USFS transect XSA. Like USFS transects XSA and XSB, this cross-section, SCW 1, has not shown any change in channel depth or width since 2008 (see Appendix D).

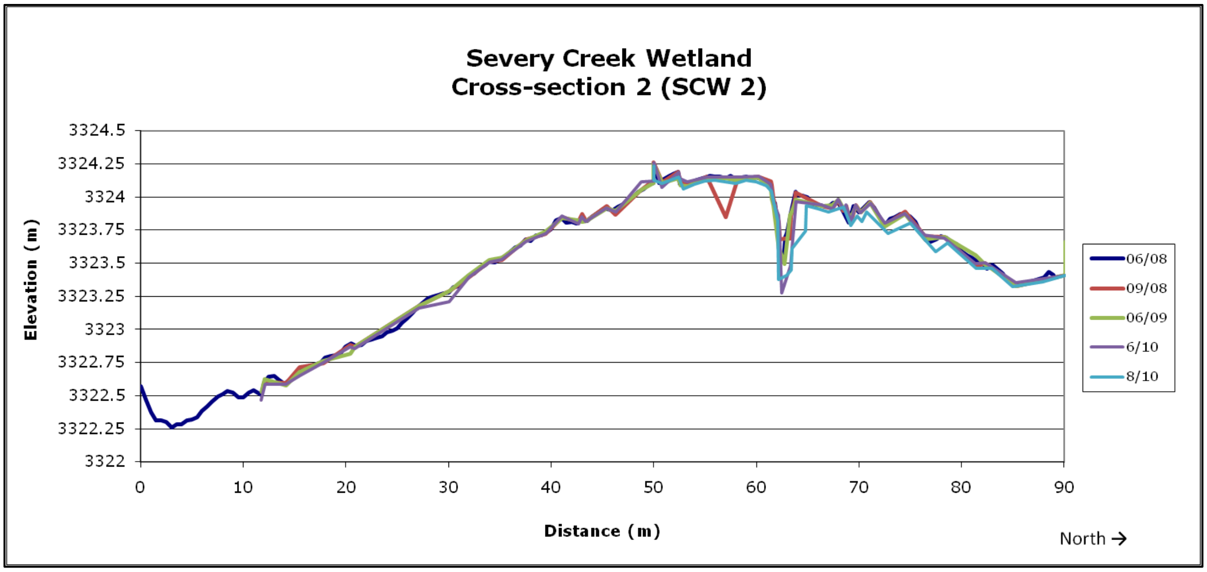


Figure 27. RMFI cross-section SCW 2 data- 06/2008-08/2010.

Particle Size Distribution

The analysis of the particle size distribution for the two study reaches show that the mean particle size (D_{50}) has increased when comparing the averaged D_{50} for the years 2003-06 to the averaged D_{50} for the years 2007-10 (Table 10). Improvements to the section of the Pikes Peak Highway in the Severy Basin were completed in 2006. The data show that after stormwater input from the highway was eliminated from these reaches, the composition of the stream bed has changed over time resulting in an increase in the D_{50} particle size. Overall, the lower percentage of fine particles suggests a reduction in sediment transport in the stream channel. The trend of the percentage of finer particles decreasing is evident when comparing the cumulative particle size distribution for only the years 2003 and 2010 for the two study reaches (Fig 28). Data from Severy Creek Reach 1 show that 88% of all particles were finer than 8 mm in 2003 as compared to 73% in 2010. Statistical analysis of the data using methodology by Potyondy and Bunte (2002) indicate a significant difference at the 1% level of significance (99% confidence level) when comparing the percentage of particles 8 mm or less between the two study years.

Severy Creek Reach 1	Particle Size Distribution (mm)				
Year	D15	D35	D50	D84	D95
2003	0.000	0.064	0.212	2.939	663.982
2004	0.000	0.156	0.369	13.028	443.405
2006	0.000	0.068	0.286	3.152	156.767
2007	0.000	2.773	4.445	9.045	12.620
2008	0.112	0.247	2.919	13.925	64.000
2009	0.094	0.230	1.859	7.773	15.587
2010	0.110	2.097	4.147	11.485	24.000
2003-06 Avg	0.000	0.096	0.289	6.373	421.385
2007-10 Avg	0.079	1.337	3.342	10.557	29.052
Severy Creek Reach 2	Particle Size Distribution (mm)				
Year	D15	D35	D50	D84	D95
2003	0.392	1.425	6.628	70.333	296.748
2004	0.321	0.669	2.164	39.192	153.276
2006	0.271	1.852	3.210	16.000	78.384
2007	0.737	2.326	5.880	39.742	78.066
2008	2.000	5.835	9.193	45.299	109.094
2009	1.250	2.828	5.899	30.935	61.004
2010	2.274	8.000	13.637	79.078	161.374
2003-06 Avg	0.328	1.315	4.001	41.842	176.136
2007-10 Avg	1.565	4.747	8.652	48.763	102.384
* No data collected in 2005					

Table 10. Change in D_{50} particle size from 2003-2010 for Severy Creek Reach 1 and 2.

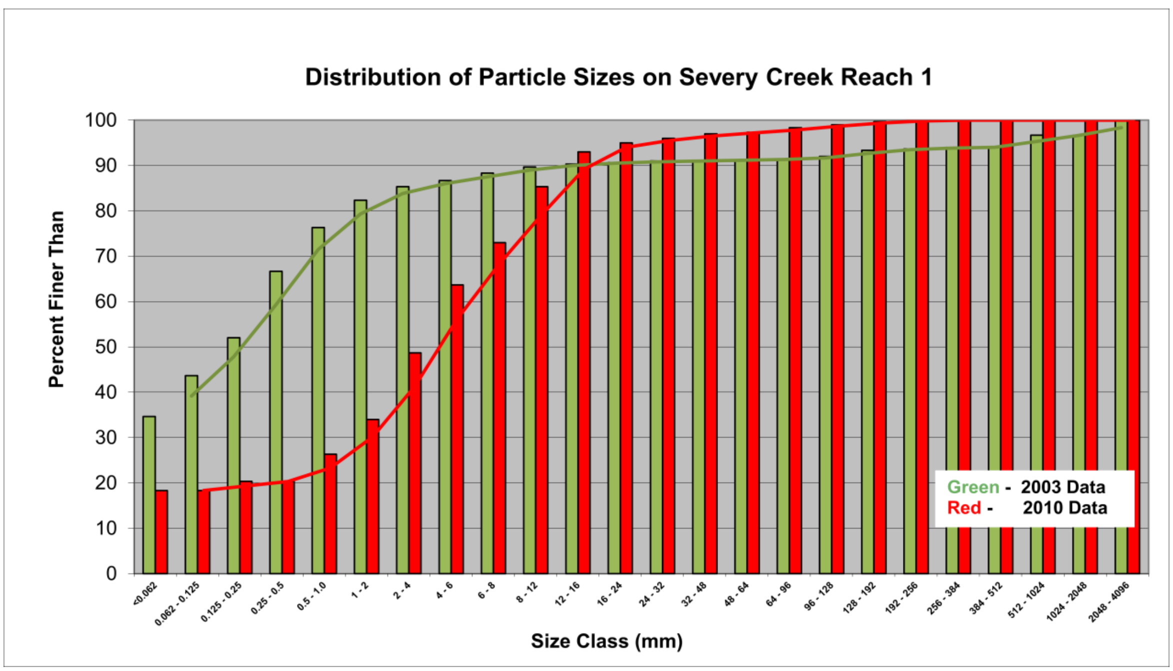


Figure 28. Comparison of cumulative particle size distribution between 2003 and 2010, Severy Creek Reach 1. (see Appendix F for all pebble count charts.)

Alluvial Fan Deposition

Using the aerial estimates of surficial deposits, data from the cross-sections and boreholes, and the interpolation of the average lowest ground water table across the impacted portion of the wetland, sediment depths across the wetland were calculated (Figure 29). This study estimates that the volume of sediment deposition within the wetland and alluvial fan is 32,478 m^3. This figure assumes an average depth of 84 cm of sediment throughout the estimated 38,664 m^2 of area that has been subjected to alluvial deposition since 1938. This volume exceeds the 20,237m^3 calculated in the 2007 study (Cooper and Gage) and is due to better estimates of fill in the alluvial fan provided by additional bore holes and cross-sectional data.

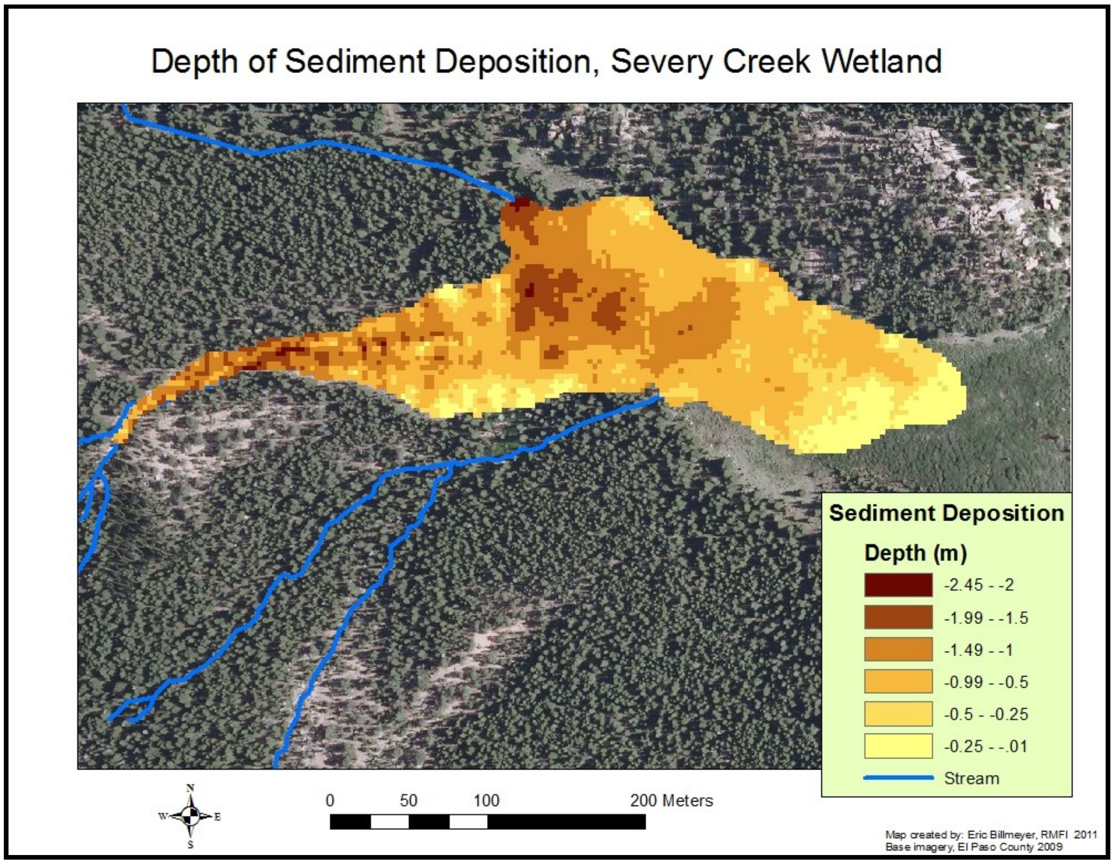


Figure 29. Estimated depth of sediment deposits throughout the alluvial fan and western portion of the wetland.

Natural Gully Morphology and Deposition

Analysis of the cross-section data measuring changes in the morphology of the natural gully channels to the southwest of the alluvial fan (see Figure 13) show a similar pattern to those noted above. Data shows little change with regards to bank location and width of channel with occasional significant changes in channel depth. Along gully NG1, significant changes in channel depth were recorded in 2010 along transects XS1 and XS2. Channel depth increased by 1.15 m along cross-section XS1 between measurements taken in June, 2010 and mid-August, 2010 (Figure 30). The material that was removed from the channel floor along this reach was re-deposited in the channel eighty meters further down at cross-section XS2. Here the channel depth increased by an average of 1.13 m (Figure 31). Since data were first collected in 2008 the channel in this area has aggraded over 2 m to where it is now almost completely refilled (Figure 32).

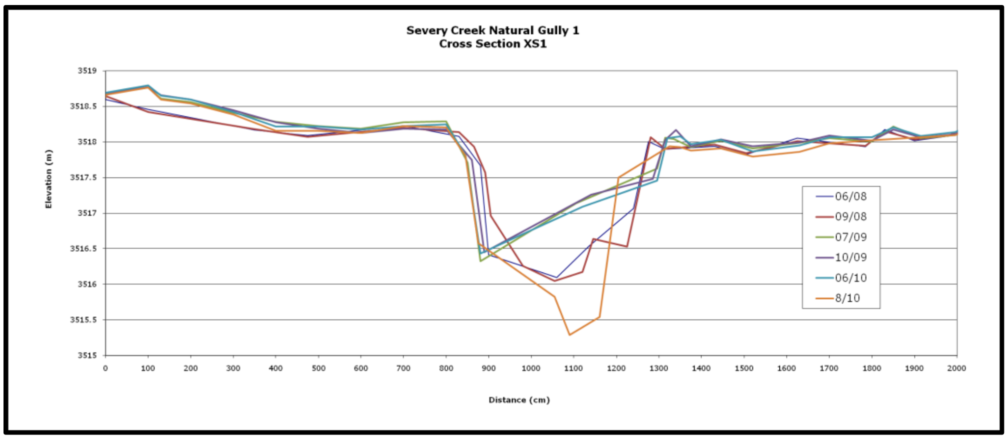


Figure 30. Gully morphology changes over the 6/2008 to 08/2010 time period for cross-section XS1.

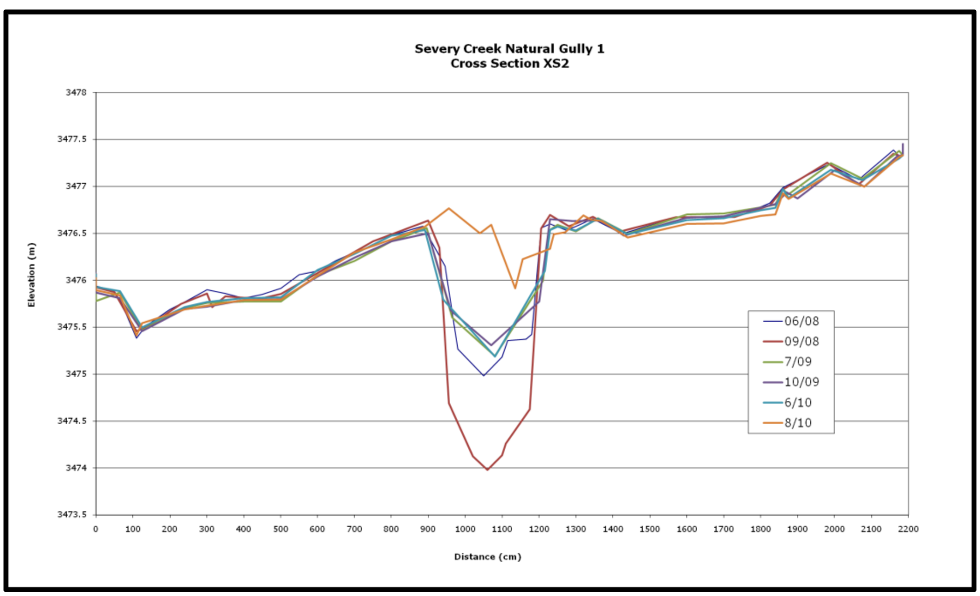


Figure 31. Gully morphology changes over the 6/2008 to 08/2010 time period for cross-section XS2.

Figure 32. Sediment aggradation during the summer of 2010 along cross-section XS2.

Just downstream of cross-section XS2, the runoff has been diverted by the buildup of sediment and is now flowing down through a newly formed rill channel to the northwest (Figure 33). This explains the lack of any significant change in the gully morphology along cross-section XS3 (see Appendix E).

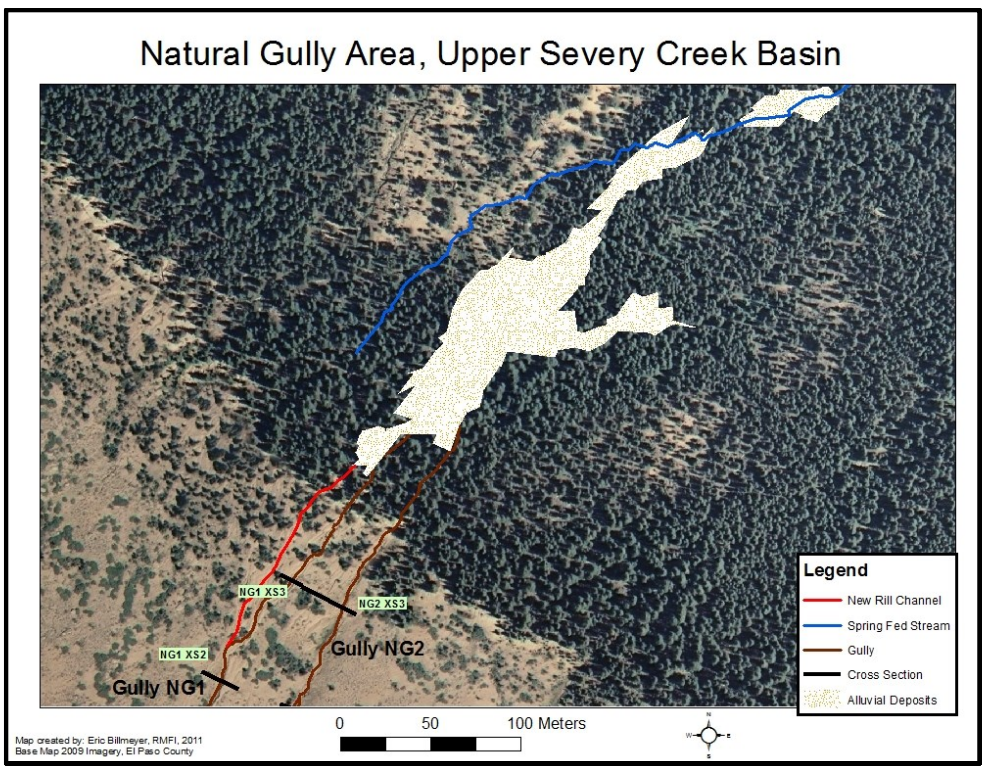


Figure 33. Location of alluvial deposition and new rill channel.

Data from cross-sections along gully NG2 also showed little change in gully morphology across the transects except for the last cross-section in this area. Within this cross-section, NG2

XS3, several side channels have developed along with the main gully channel. All channels within the cross-section down cut in 2010 with the greatest change recorded being just over 50 cm (see Appendix E).

Sediments transported downslope from the two natural gully systems have resulted in the formation of a large alluvial fan within the forest (Figure 33). The surficial areal extent of sediment deposition was mapped and calculated to be 8,801 sq. m. Hand augured bore holes found that the maximum thickness of the deposition is 75 cm. It is estimated that the volume of sediment deposition that has occurred in this area is 3,080 cubic meters. The sediment deposits are being carried further toward the wetland by a spring fed stream that runs to the northwest of the alluvial deposit before intercepting the deposit closer to the wetland. Field observations show that the flow through this portion of the deposit is facilitating the transportation of fine sands and silt to the edge of the wetland boundary.

C. Discussion

This study examined a multitude of processes and factors, both past and present, within the upper Severy Creek Basin that are or have the ability to affect the health of the Severy Creek Wetland. While fire and mass wasting events have had a significant impact on the wetlands health in the past, the long recurrence interval of these events precludes them from being considered as an imminent threat. The greatest immediate threat to the wetland remains to be the large alluvial fan that has spread into the western portion of the wetland and the immense quantity of sediment it holds in storage. Currently, new sediment deposition is taking place in the far northern section of the alluvial fan's toe (see Figure 21). However, field observations do not show a buildup of coarse gravels (16 mm-32 mm) or larger material, indicating that stream discharge has been insufficient to carry heavy sediment loads since 2009 when the stream migrated to this area. Sediment accumulation may also be due in part to increased unnatural flows from stormwater runoff being conveyed by the stream that enters the wetland at this location from the north. This stream is still connected to stormwater flow off of the Pikes Peak Highway. Closure of the lead-off ditch from the highway into this channel would be the most effective solution in reducing sediment transport into the wetland from the stream. If closure is not possible, construction of additional check dams below the lead-off ditch may be successful in sufficiently attenuating stormwater runoff to reduce sediment transport. Completing an analysis of the total sediment yield for this stream and the main stream through the fan would be highly beneficial and is planned to begin in 2011. In addition, a cross-section will be placed along this depositional area to further our understanding of the current rate of sediment deposition.

Overall, data from the transects across the main stream through the alluvial fan show that little change has occurred to the morphology of the channel since stormwater from the highway was diverted from the gullies leading into the fan in 2005 and the significant precipitation event in 2007. However, the topography of the alluvial fan suggests that the current trend of the stream migrating to the north at transect XSE is a temporary adjustment and that the channel will begin moving back to the south. Along both transects XSC and XSD the fan's elevation is lower along its southern border and it would be natural for the stream to migrate in this direction as it has slowly begun to do since 2006 along transect XSD (Figure 34).

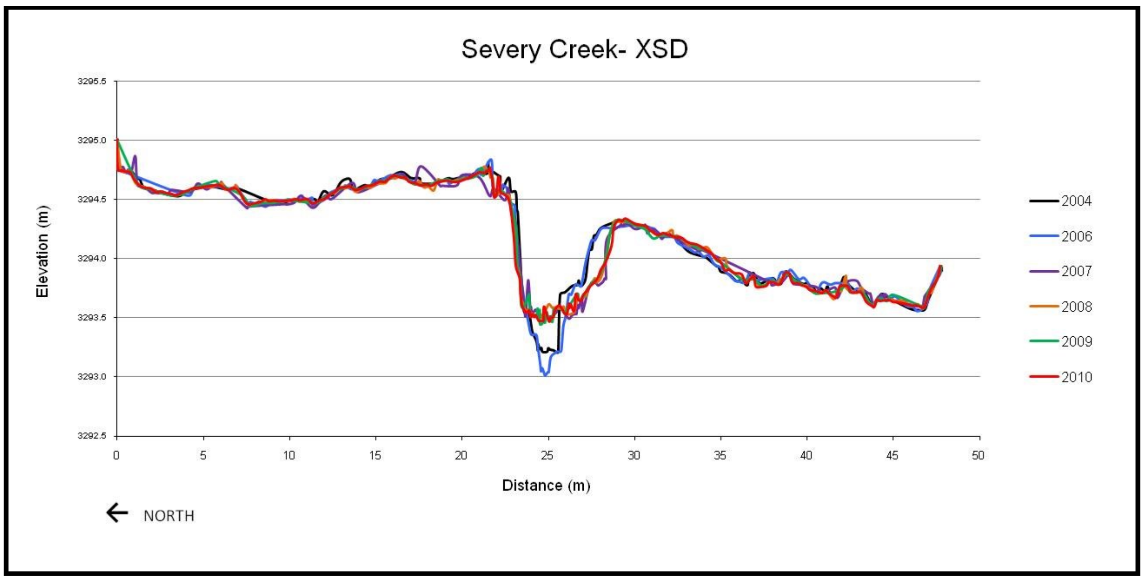


Figure 34. Transect XSD showing migration of stream channel to the south.

This trend is concerning because of the potential for the massive relocation of sediments to areas along the eastern and southernmost portion of the fan's toe. If the stream migrates completely back to the southernmost portion of the fan, and reoccupies its former channel circa 1997, then the potential for a substantial increase in sediment deposition currently associated with the spring fed stream would increase dramatically. This would pose the greatest threat to wetland areas so far unimpacted by sediment (see Figure 24).

It is also possible that the stream may reoccupy either one of the two older channels nearer the head of the alluvial fan. Both are at risk of being reactivated due to their location just on the other side of an actively eroding debris bank (Figure 35). The upper, northern most channel is the most likely to be reoccupied and could increase stream energy on the bank protecting the lower, southern channel. Reactivation of the southern channel would intersect with the channel believed to be occupied in 1997 and cause the same sediment issues as mentioned above.

Figure 35. Photographs showing the debris banks protecting reactivating old channels within the upper fan.

The most permanent option to deal with the sediment in the alluvial fan would be for its removal to a safe location preferably outside of the basin. The construction of a new road into the basin would be required for such an operation and is undesirable due to the impact that construction activity would have on forest lands above the wetland. Previous reports have proposed removing the sediment through the use of heavy machinery flown into the project area by helicopter and then finding a suitable site within the basin for storage (Cooper, 1998, Cooper & Gage, 2008). Based on the calculations from this study of the amount of sediment deposition in the alluvial fan, a mound of sediment with a radius of 40 m and a height of 20 m would be required. There is not a suitable area within the basin that could contain such an immense volume of sediment other than keeping it within the confines of the existing alluvial fan deposit. This would be an undesirable option considering the expense and technical difficulties of removing and stabilizing the sediment only to leave it within an area where it could potentially impact the restored areas.

Without the option of removing the sediment, the primary goal of the project would change from that of restoration of the impacted areas of the wetland to one of mitigating the transport of sediment to protect the remaining undisturbed areas. Several prescriptions, completed in conjunction with one another, could be implemented to meet this goal. Technically and logistically the most difficult prescription would be to harden the existing channel so that its current location within the fan would be maintained and the transport and location of sediment deposition controlled. There is sufficient boulder material throughout the alluvial fan that could be used for such a project. Stream and bank stabilization designs already implemented within similarly degraded streams on Pikes Peak provide case examples (Billmeyer, 2007, 2009, 2010). Possible techniques implemented in the Severy Basin would include the construction of cross-vanes to provide grade control for the channel and the use of felled trees and boulders to protect banks. Implementation of these prescriptions would require the use of a small skid-steer and excavator. The machinery would need to be flown into the site as suggested by previous proposals and adequate BMP's put into place to protect the stream during construction. By successfully maintaining the channel's current position, the threat of channel migration and the relocation of sediment into undesired areas would be eliminated. Sediment that is transported by the stream would continue to accumulate in the northernmost section of the fan's toe. This area provides a 3,200 m^2 zone for additional sediment accumulation to occur and is over 100 m from the fan's most eastern extent.

Along with stabilizing the stream channel, prescriptions would be implemented to increase vegetation cover throughout the fan. Already, Engelmann spruce saplings are re-colonizing areas in the upper fan that have now been stable for an estimated 15 to 20 years (Figure 36). It is recommended that additional saplings of both Engelmann spruce and Blue spruce be planted throughout the fan where appropriate to provide stability to the soils. Seeding of native grasses and forbs would provide additional cover and further stabilization. It is highly recommended that seed be collected within the basin starting in the summer of 2011 in order to provide for the seed stock needed to effectively revegetate the fan.

Figure 36. View of upper alluvial fan with Engelmann spruce saplings.

Based off of the average depth to water from 2007-2009, the northeastern section of the fan's toe would provide suitable conditions for the transplanting of willow sprigs and sedge from potential donor sites located in the basin. Average water tables in this area are between 20 and 40 cm below the surface (Figure 37). Establishment of willow stands would aid in the detention of sediment that would be directed here with the stabilization of the main stream channel. The data also shows that additional planting of willow along the southern sediment plume would be possible. This would help to attenuate stream flow and provide additional sediment storage, protecting unimpacted areas of the wetland just to the east. Small depositional areas within the wetland also meet the criteria for the transplanting of *Carex aquatilis* (water sedge) with water tables averaging a depth of 20 cm or less. A set of protocols for plant collection and establishment within the wetland has been developed and would be implemented (Cooper & Gage, 2008).

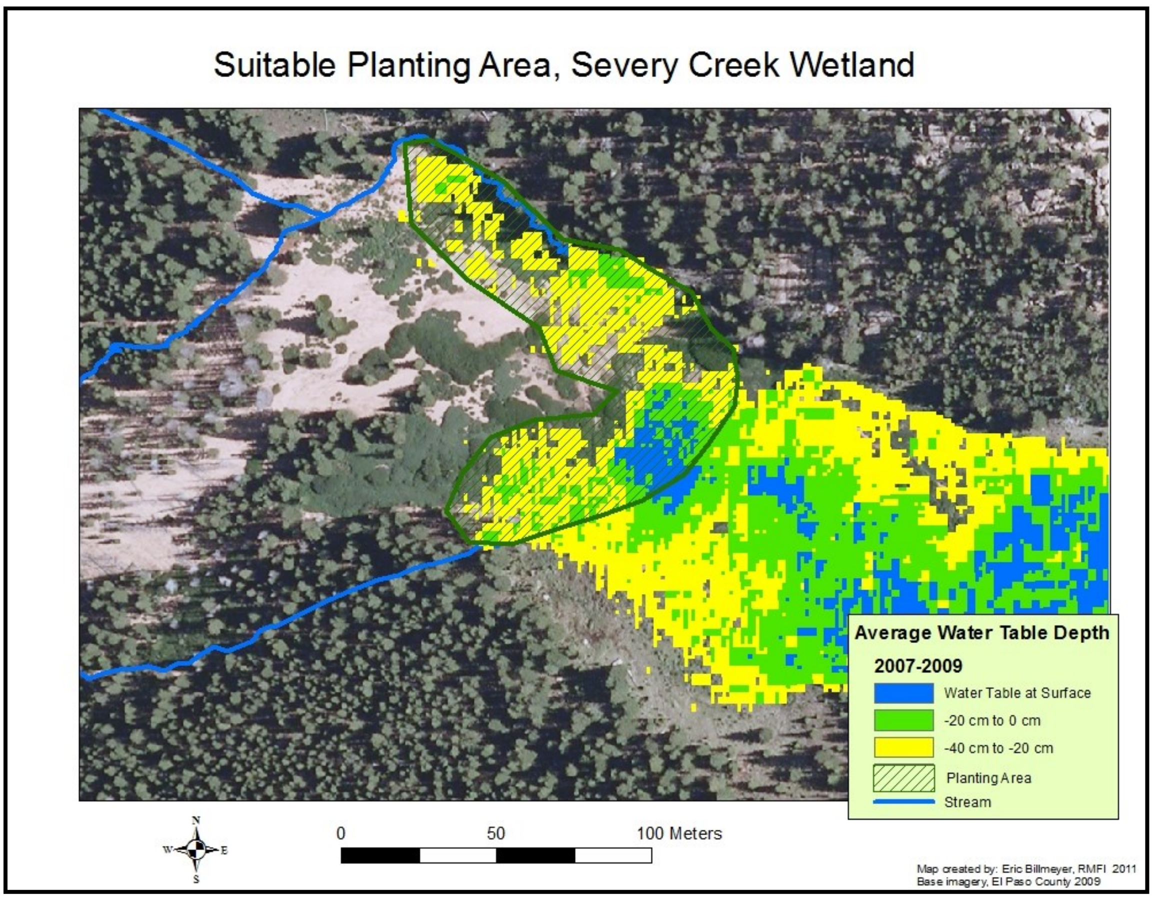


Figure 37. Suitable planting areas for willow and sedge, northwestern area of Severy Creek Wetland.

A lesser but growing threat of sediment deposition into the wetland comes from the alluvial fan that is developing below the two natural gullies. Stabilization of this fan by using directionally felled logs is suggested. Felled trees should be placed according to designs developed by the National Resource Conservation Service (Figure 38). Field observations of naturally felled logs within the fan show that they are an effective means to trap sediment. Felled logs should be placed beginning at the fan's toe and continuing to the fan's mid-point. In addition, logs should be directionally placed to prevent sediment from being carried by the spring fed stream that flows across the lower portion of the fan. Additional data should be collected on how the morphology of the natural gullies continue to change in response to high intensity precipitation events. This data will help to further our limited understanding of natural gully and rill development in high alpine environs.

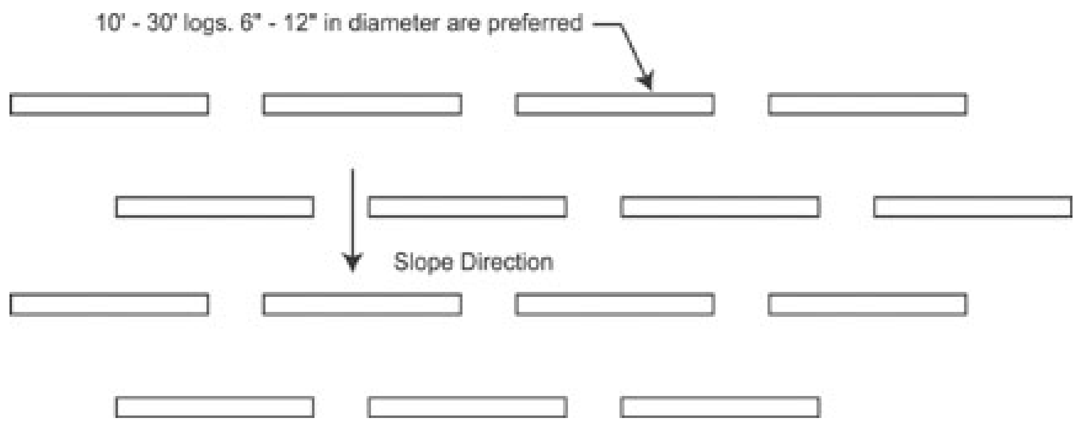


Figure 38. Erosion Log Barriers. (NRCS, 2004).

The expansion of sediment that is occurring in the southern portion of the fan due to the spring fed stream will likely reach the main flowing channel within the wetland over the next few years. Field observations show that this stream is naturally occurring and a portion of its sediment load is not related to alluvium from the fan. As long as the main channel through the alluvial fan is not allowed to push additional sediment into this area, the only action recommended is the planting of willow, as mentioned previously, to help to attenuate the stream's flow and provide additional sediment storage capacity.

This report has examined and provided a general overview of the multitude of processes affecting the health of the Severy Creek wetland. From past mass wasting and fire events to more recent anthropogenic disturbances, each one of these processes and their associated affect on the basin would be deserving of their own dedicated research study. It is clear from the data presented in this report that the processes acting on the basin are quite dynamic and the entire system is still adjusting and trying to reach a state of geomorphic equilibrium. Given enough time, perhaps 1,000's of years and a continued respite from major mass wasting or fire events, the anthropogenically caused gullies and alluvial fan will eventually stabilize on their own. However, the biological importance of the wetland and the looming threat of additional loss of wetland due to sediment encroachment from the alluvial fan precludes taking no action. Therefore it is recommended that the prescriptions suggested in this report be put forward for implementation.

D. Literature Cited

Baumgartner, D. 1969. The Hydrologic Analysis of the North Slope of Pikes Peak. USDA Forest Service File 2530.

Bevenger, G, and King, B. 1995. A Pebble Count Procedure for Assessing Watershed Cumulative Effects. Res. Pap. RM-RP-319. Rocky Mountain Forest and Range Experiment Station, USDA Forest Service. Fort Collins, CO.

Billmeyer, E. 2005. Investigating Reservoir Sedimentation and Watershed Erosion: A Comparative Analysis of the GeoWEPP and RUSLE Erosion Prediction Models. Master's Thesis. University of Colorado Colorado Springs.

Billmeyer, E. 2006. Pikes Peak Watershed Erosion Control and Restoration Project: Severy Creek Wetland and Ski Creek Proposal. Rocky Mountain Field Institute, Colorado Springs, CO.

Billmeyer, E. 2007. Final Report: Upper Ski Creek Watershed Erosion Control and Restoration Project- Phase 1. Rocky Mountain Field Institute, Colorado Springs, CO. Prepared for the Colorado Water Conservation Board.

Billmeyer, E. 2009. Final Report: Upper Ski Creek Watershed Erosion Control and Restoration Project- Phase 2. Rocky Mountain Field Institute, Colorado Springs, CO. Prepared for the Colorado Water Conservation Board.

Billmeyer, E., Clouse, W, Rodman, K. 2010. Evaluation of Gully Erosion Control and Restoration Techniques in the North Crystal Creek Basin, Pikes Peak. Rocky Mountain Field Institute, Colorado Springs, CO. Prepared for the Pike National Forest.

Chavez, R., Bruggink, J., Cosyleon, S., Nakada M. 1993. Erosion and Sediment Analysis, Pikes Peak Highway. Unpublished Report, U.S. Forest Service, Pike and San Isabel National Forests.

Chimner, R. A., Cooper, D.J., Parton, W.J. 2002, Modeling Carbon Accumulation in Rocky Mountain Fens. *Wetlands* 22:100-110

Chimner, R.A., and Cooper,D.J., 2003 Carbon Dynamics of Pristine and Hydrologically Modified Fens in the Southern Rocky Mountains. *Canadian Journal of Botany* 81:477-491.

Cooper, D.J. 1998. Effect of the Pikes Peak Auto Road on Wetlands of Pikes Peak. Unpublished Report prepared for the Sierra Club, Rocky Mountain Chapter.

Cooper, D.J, MacDonald, L.H., Wenger, S.K., Woods, S.W. 1998 Hydrologic Restoration of a Fen in Rocky Mountain National Park, Colorado, USA. *Wetlands* 18:335-345

Cooper, D.J., and Gage, E., 2008. Severy Creek Wetland Restoration Evaluation, Unpublished report prepared for the Rocky Mountain Field Institute.

Drexel Barrell & CO. 1997. Drainage, Erosion, & Sediment Control Plan and Preliminary Road Design for the Pikes Peak Highway. Unpublished report prepared for the City of Colorado Springs.

Fayette, K. 1999. Biological Survey of the Pikes Peak Area. Colorado Natural Heritage Program. Ft. Collins, Colorado. Prepared for Design Workshop, Inc. and Colorado Springs Utilities.

Jarrett, R. 2001. Paleohydrologic Estimates of Convective Rainfall in the Rocky Mountains. *Symposium on Precipitation Extremes: Predictions, Impacts, and Responses*. J2.14:J40-43

Lockhart, J. 2006. Review of Severy Creek Wetland Project Proposal. Personal communication.

Moody J, Martin D. 2001. Hydrologic and Geomorphic Response to Wildfire: Buffalo Creek and Spring Creek Fires. *Earth Surface Processes and Landforms* 24:1049-1070

Morgan, M., Billmeyer, E. 2010. Geologic Map of the Severy Creek Watershed, Teller and El Paso Counties, Colorado. Colorado Geological Society. CGS Publication 41-1.

Nakada, M. 1991. Tip Notes- Pikes Peak Highway and Ski Area. USDA internal report dated September 12, 1991. Prepared for the Pikes Peak Ranger District.

Potyondy, J. and Bunte, K. 2002. Analyzing Pebble Count Data Collected by Size Classes. RMRS-GTR-74. Rocky Mountain Research Station, USDA Forest Service. Moscow, Idaho.

Reddick, J.P. 1952. Condition Survey of Pikes Peak Highway. USDA Forest Service Report 6200-7

Robichaud, P. and Wagenbrenner, J. 2006. Hayman Fire Rehabilitation Treatment Monitoring Progress Report, 2002-2005. Rocky Mountain Research Station, USDA Forest Service. Moscow, Idaho.

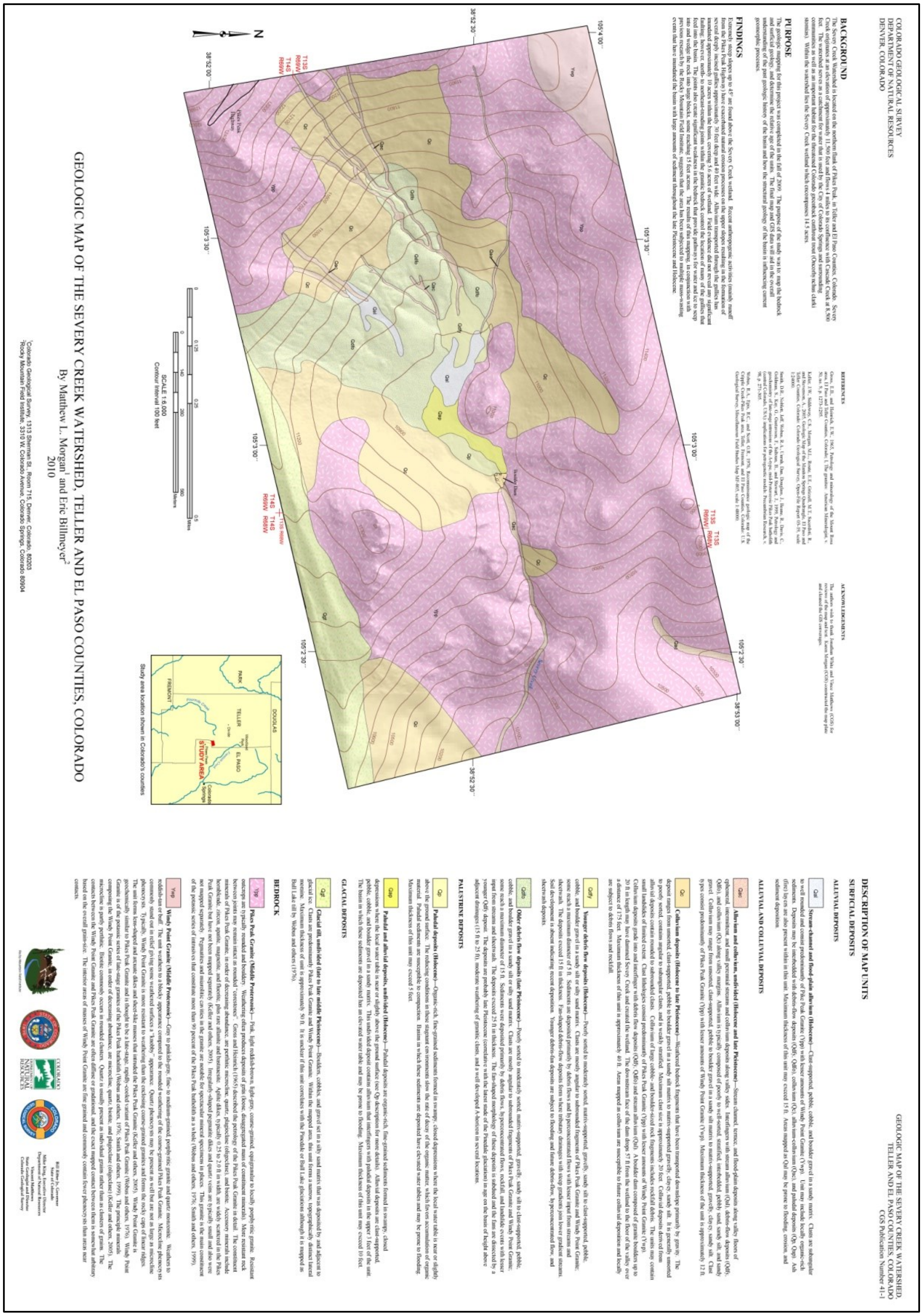
Smith, D.R., Noblett, J. Wobus, R.A., Unruh, D., Chamberlain, K.R., et al., 1999. A Review of the Pikes Peak Batholith, Front Range, central Colorado. *Rocky Mountain Geology* 34:289-312

Snyder G, Anderson R, Huber TP. 1994. Pikes Peak Highway Erosion and Sedimentation Study. Unpublished Report prepared for City of Colorado Springs, Department of Transportation.

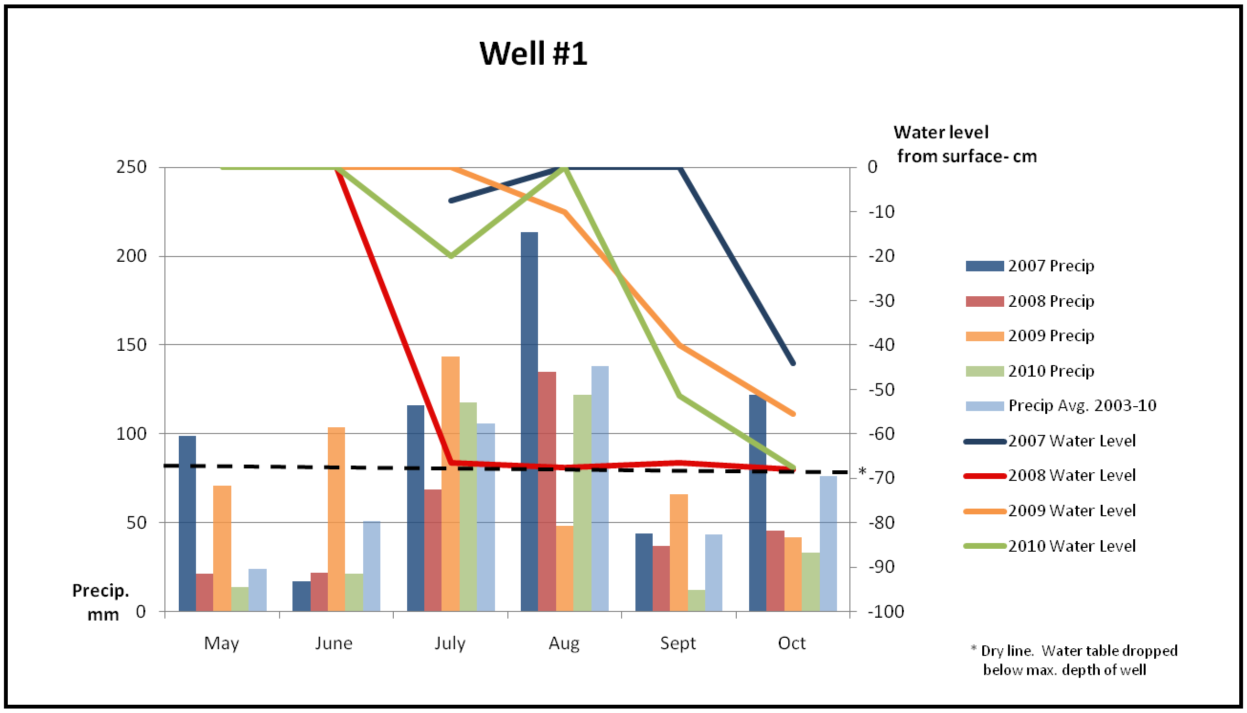
Troendle, C.A., Winkler, S., VonLoh, J., Derengowski J., 2010. Monitoring the Effectiveness and Validating Response to the Road Related Mitigation Practices Implemented on the Pikes Peak Highway. Unpublished report prepared for the USDA Forest Service. METI,Inc, El Paso, Texas.

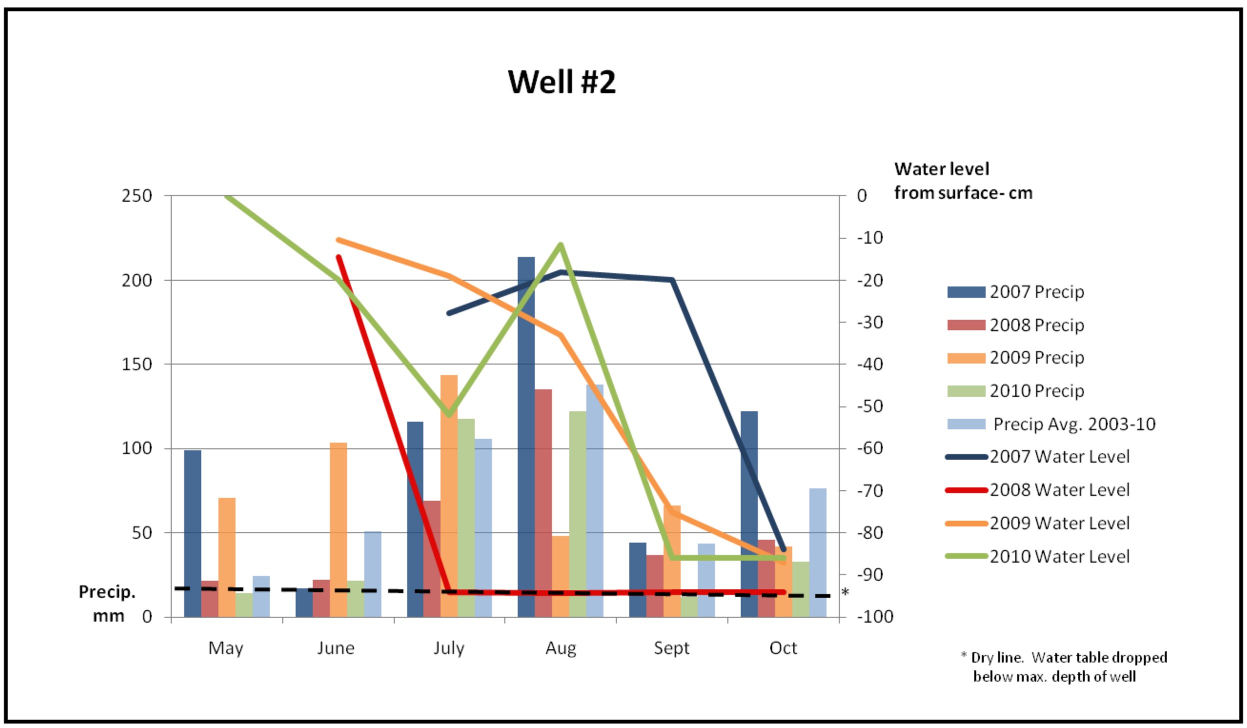
Weaver, R., 2010. Biological Assessment and Biological Evaluation For Threatened, Endangered, and Sensitive Species. Unpublished report prepared for the Pike National Forest. AMEC Earth & Environmental, Inc, Boulder, CO.

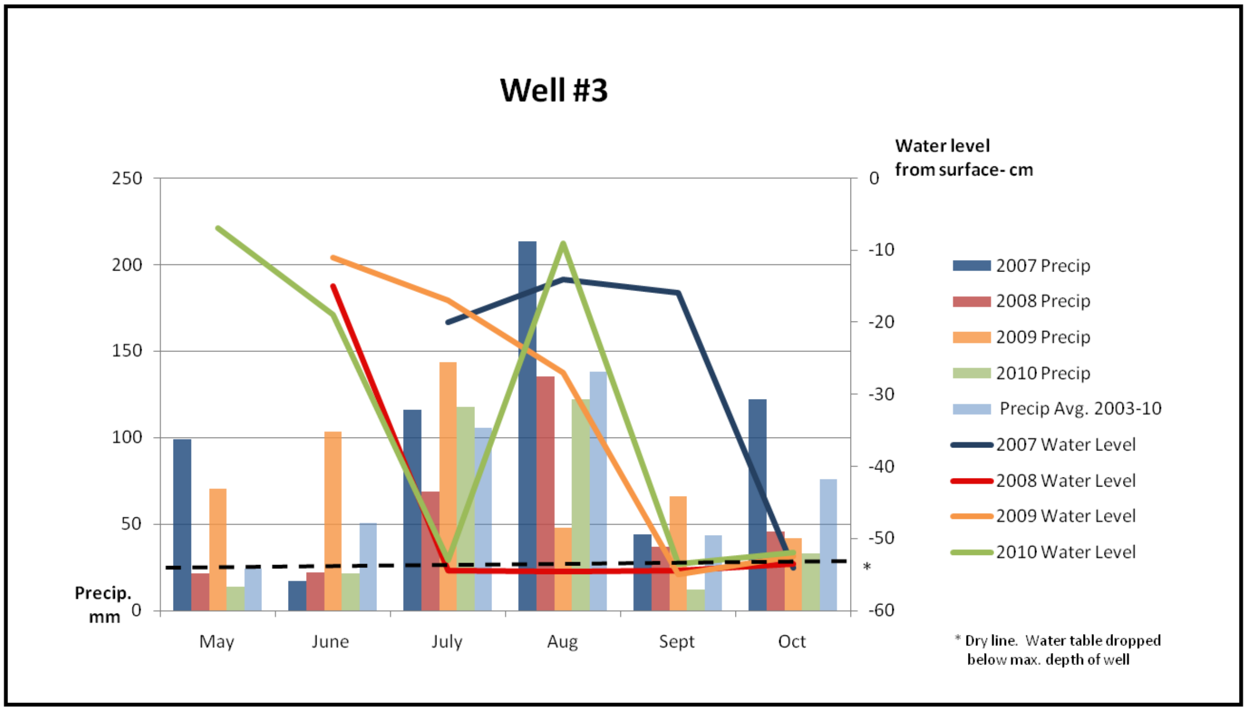
Appendix A. Geologic Map of the Upper Severy Creek Watershed

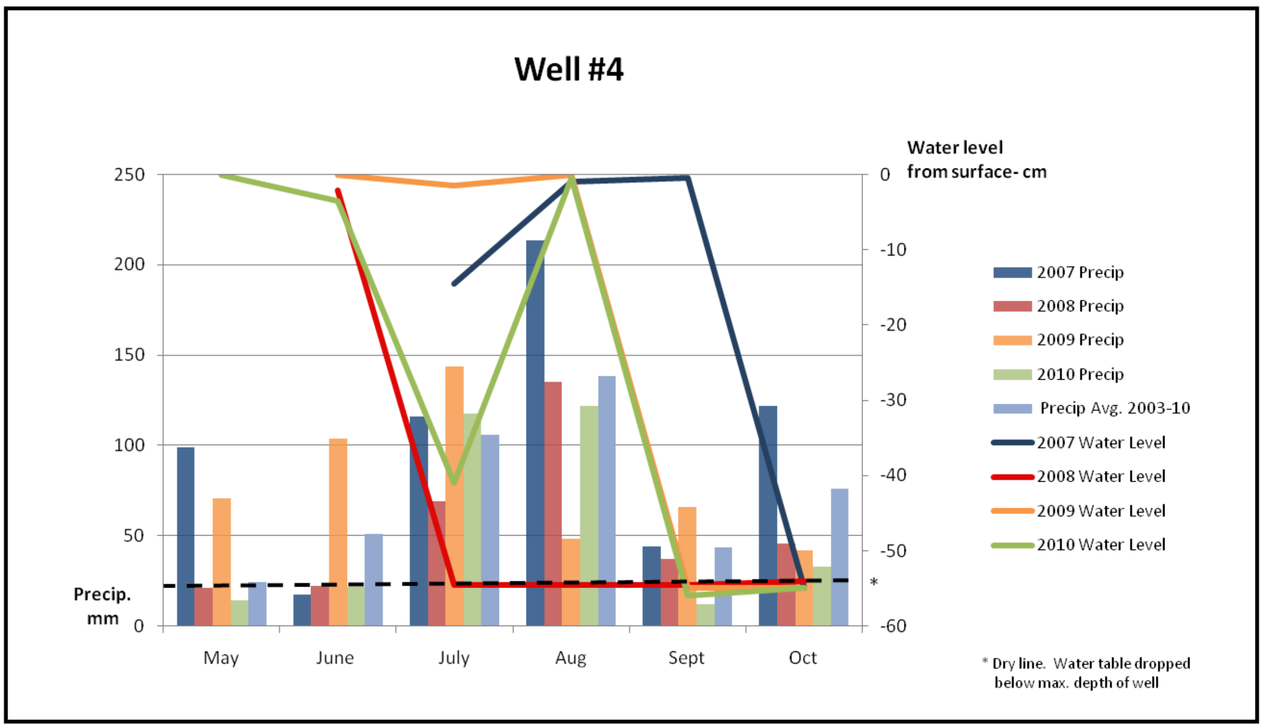


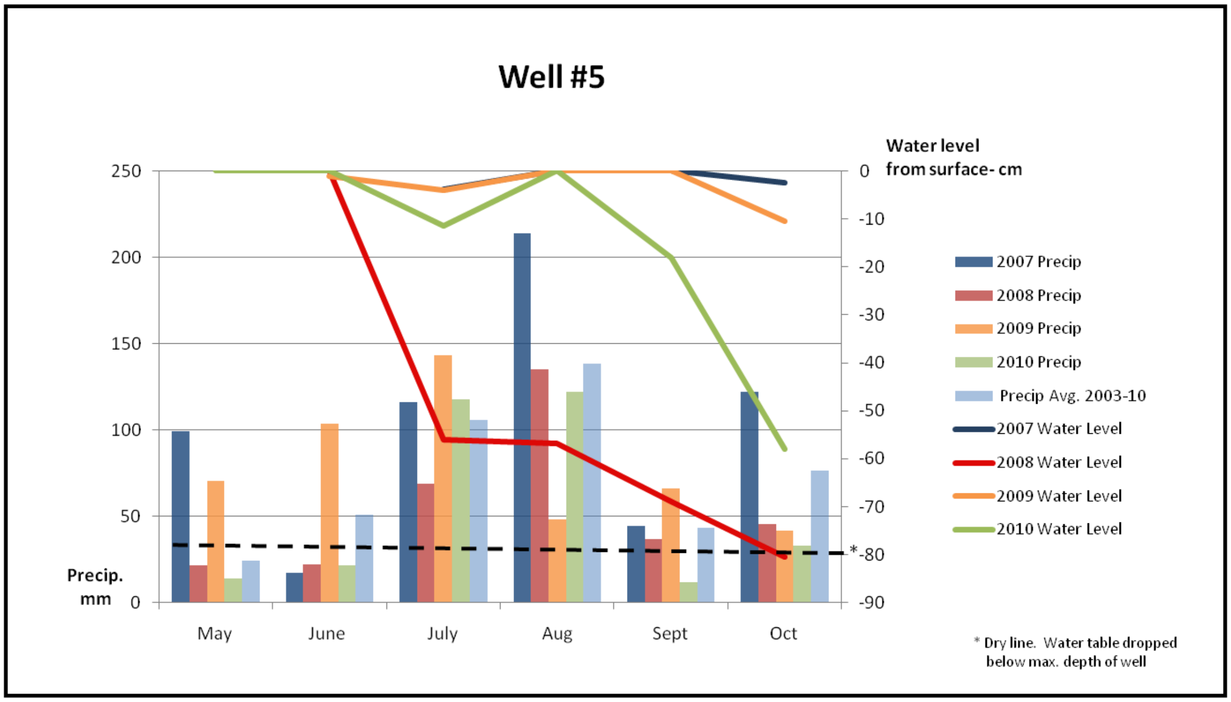
Appendix B. Individual Well Data Showing Changes in Water Table Depth from May to October, 2007-10






Well #3
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-10
-20
-30
-40
-50
-60
*
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well


Well #4
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-10
-20
-30
-40
-50
-60
*
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well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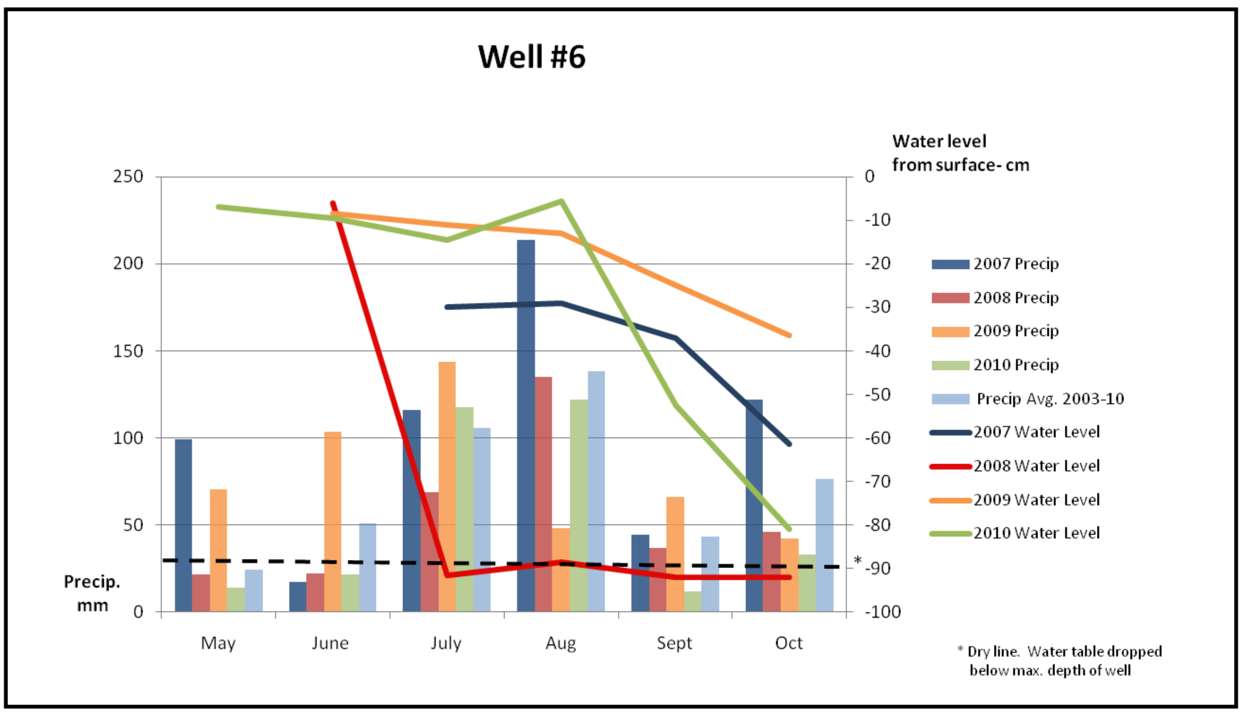
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
*
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well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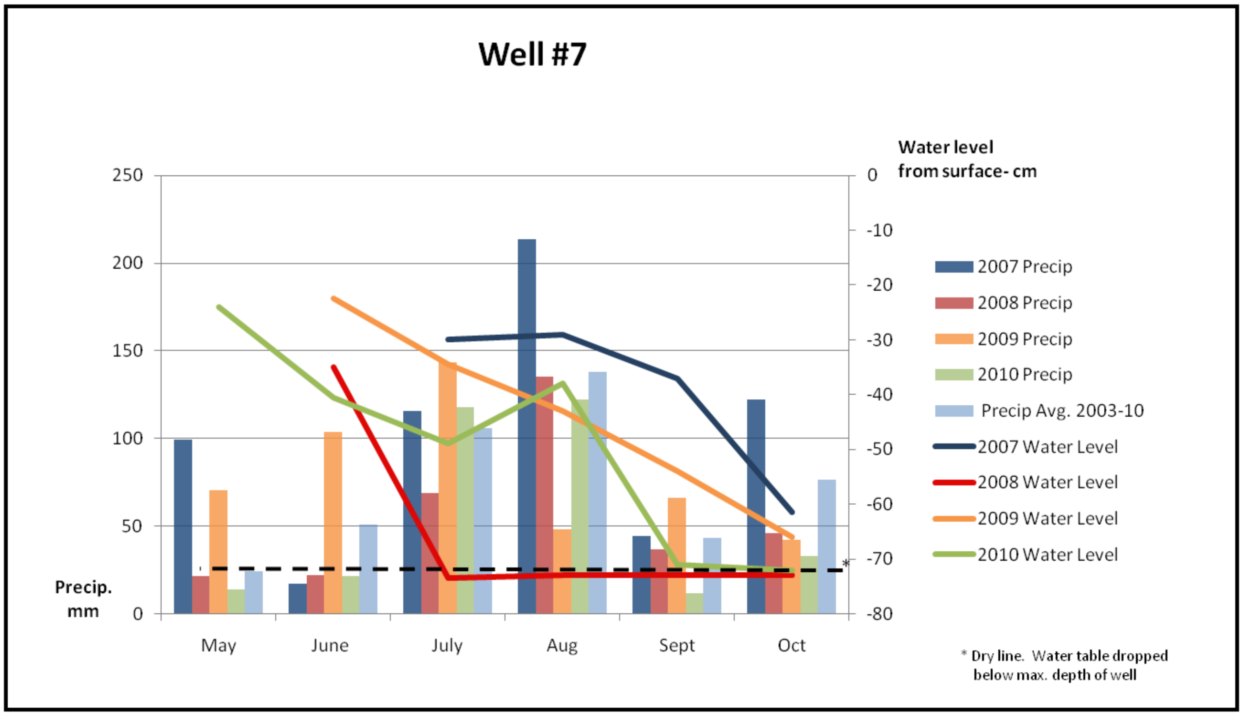
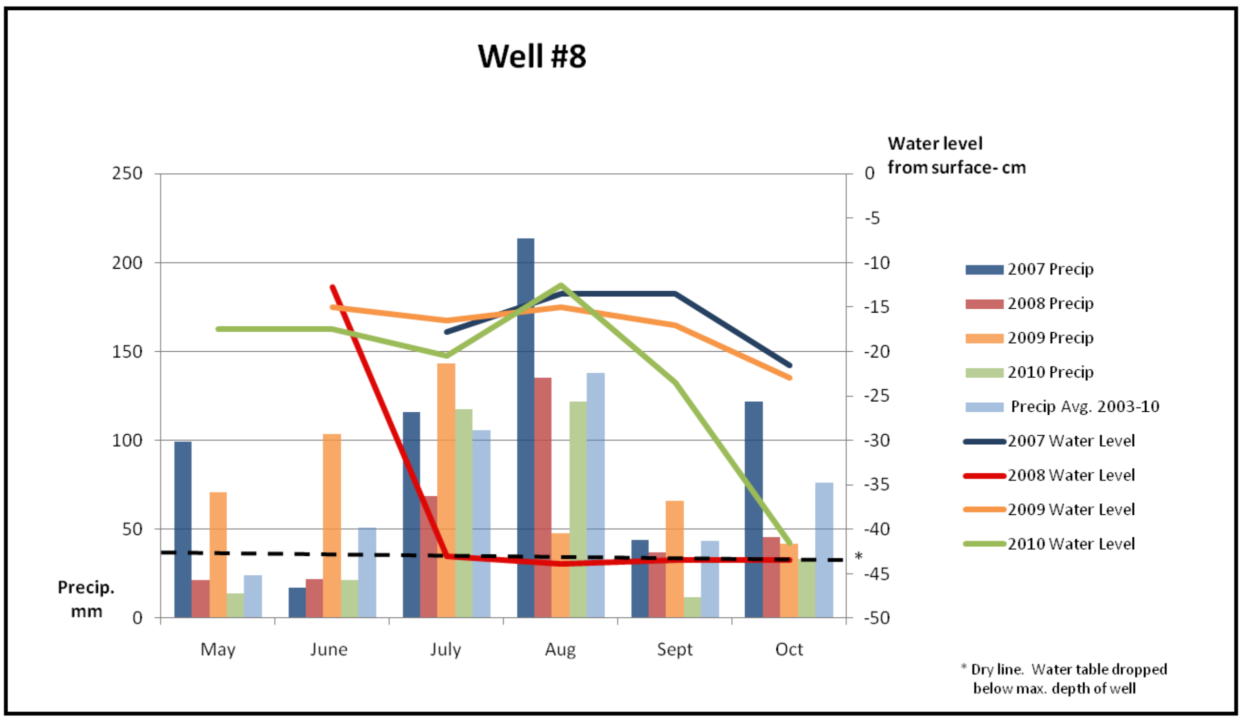
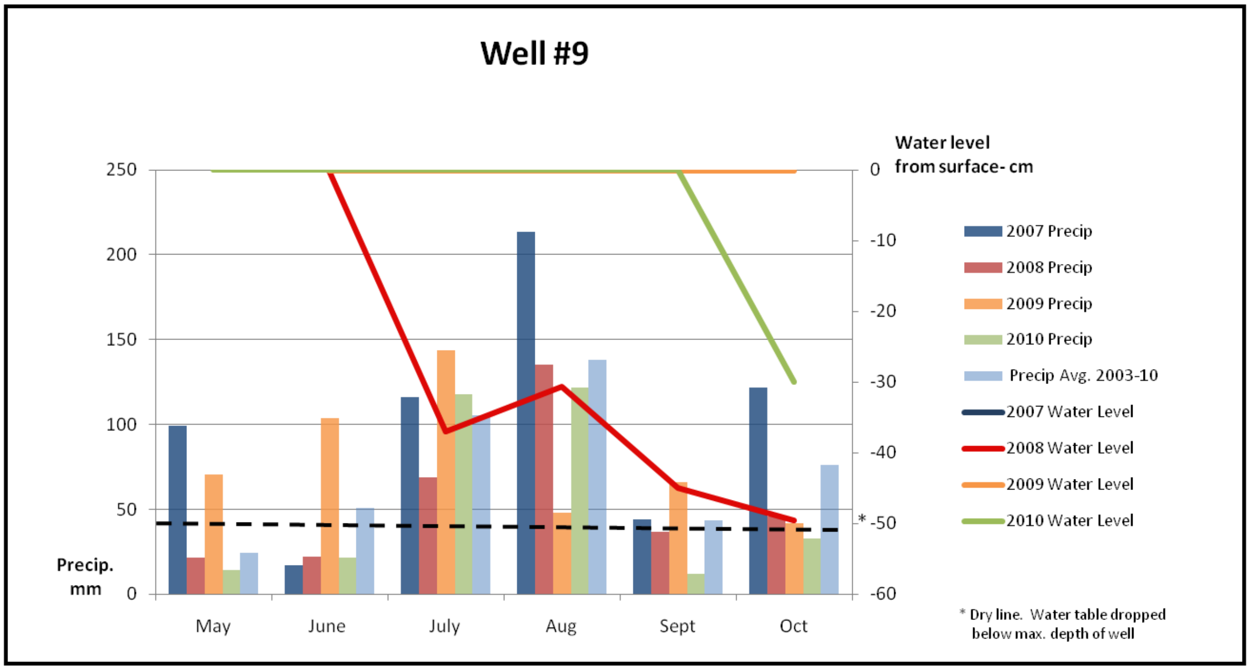
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
*
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well



Well #7
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-10
-20
-30
-40
-50
-60
-70
-80
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well



Well #8
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well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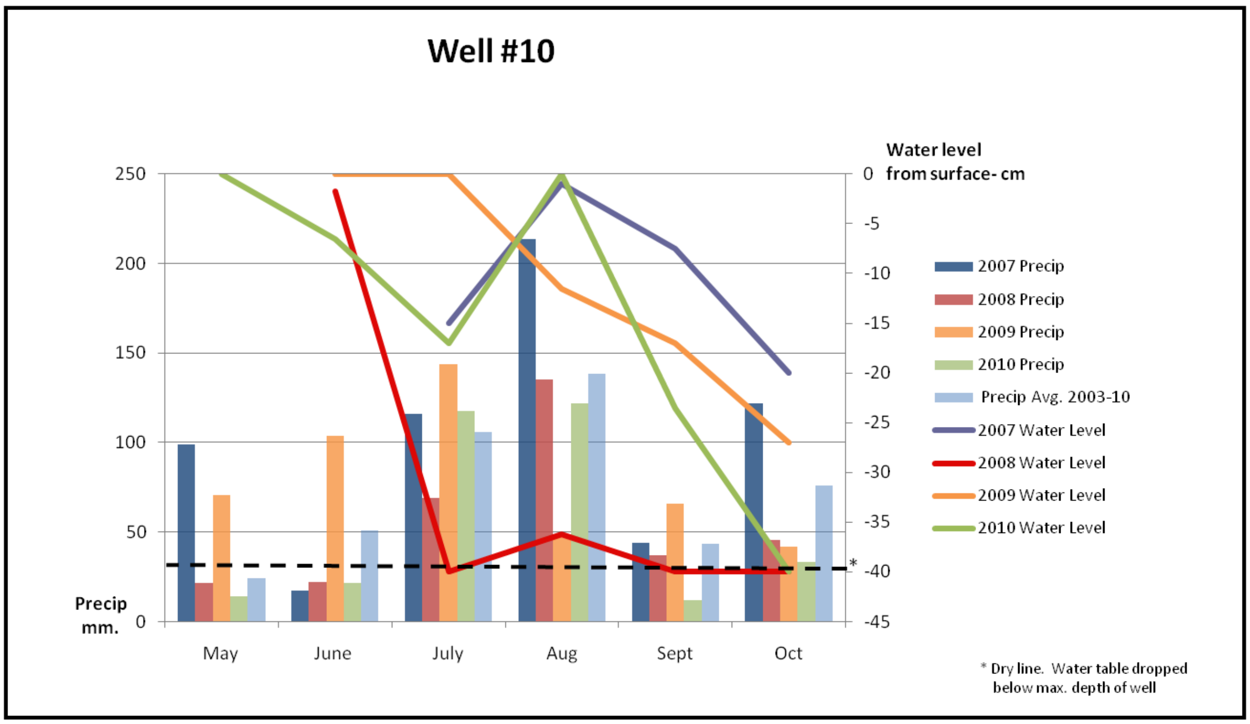
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-10
-20
-30
-40
-50
-60
*
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well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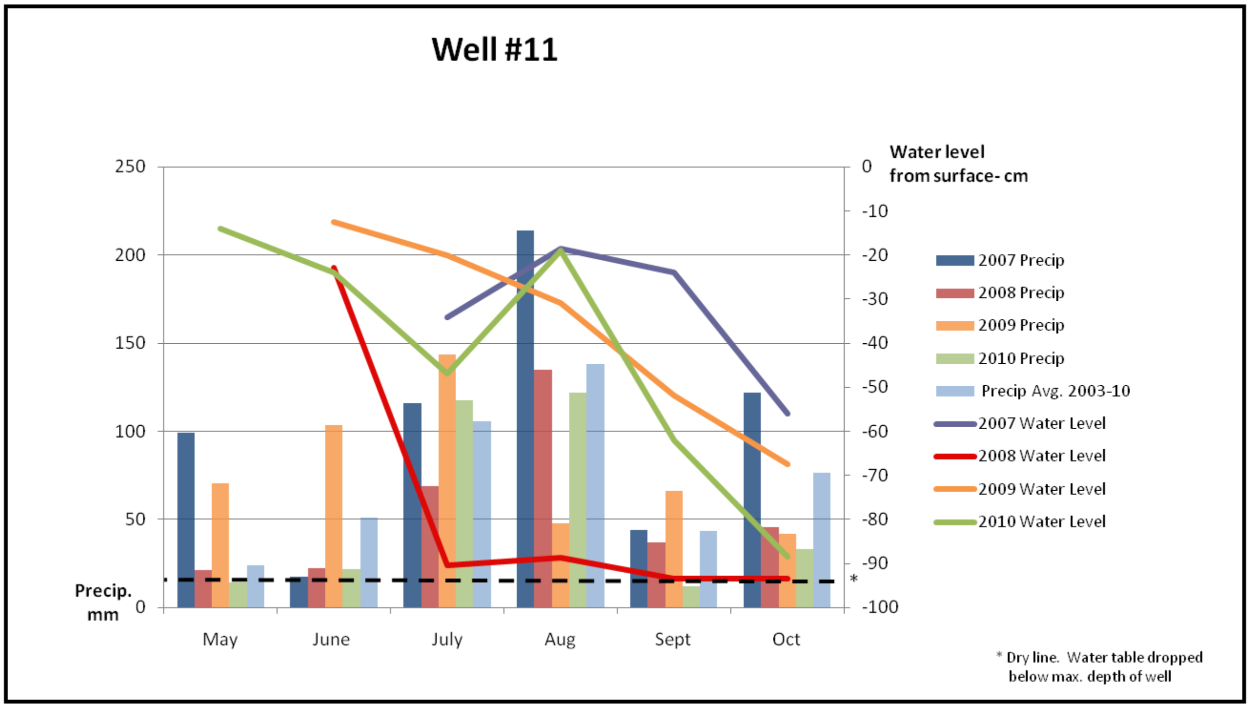
Water level
from surface- cm
250
200
150
100
50
0
Precip
mm.
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
*
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well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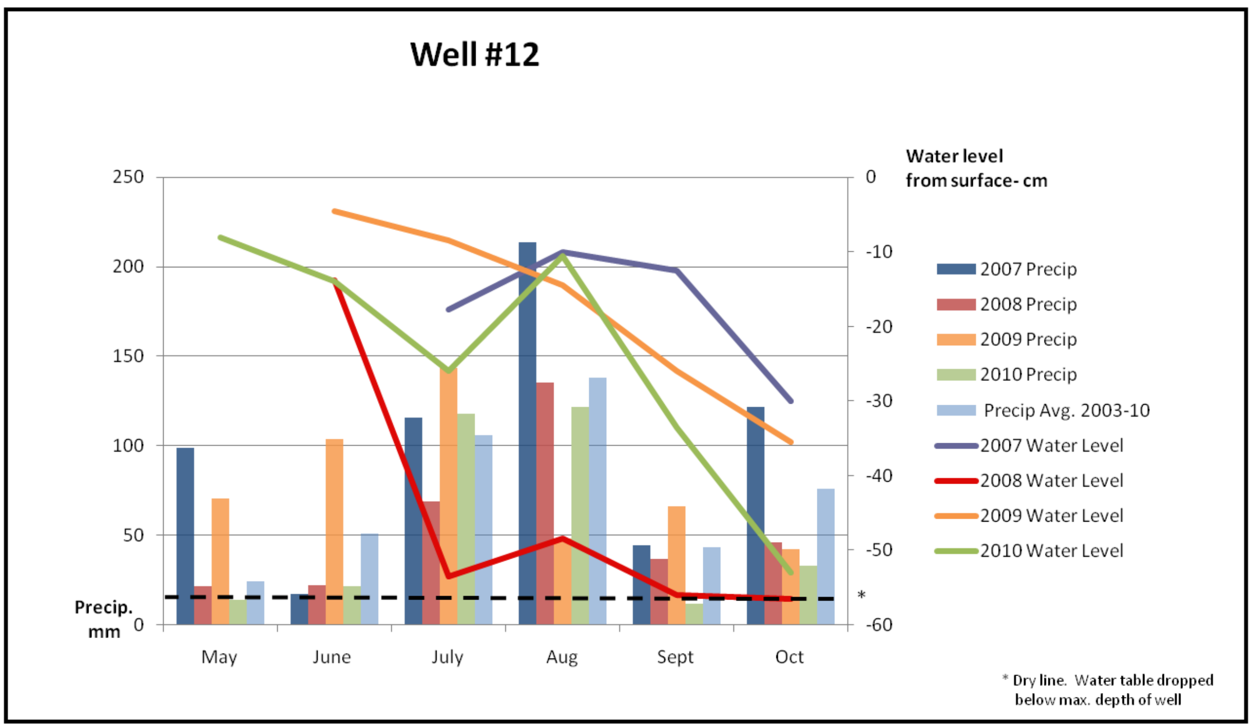
Water level from surface- cm
250
200
150
100
50
0
Precip. mm
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
*
* Dry line. Water table dropped below max. depth of well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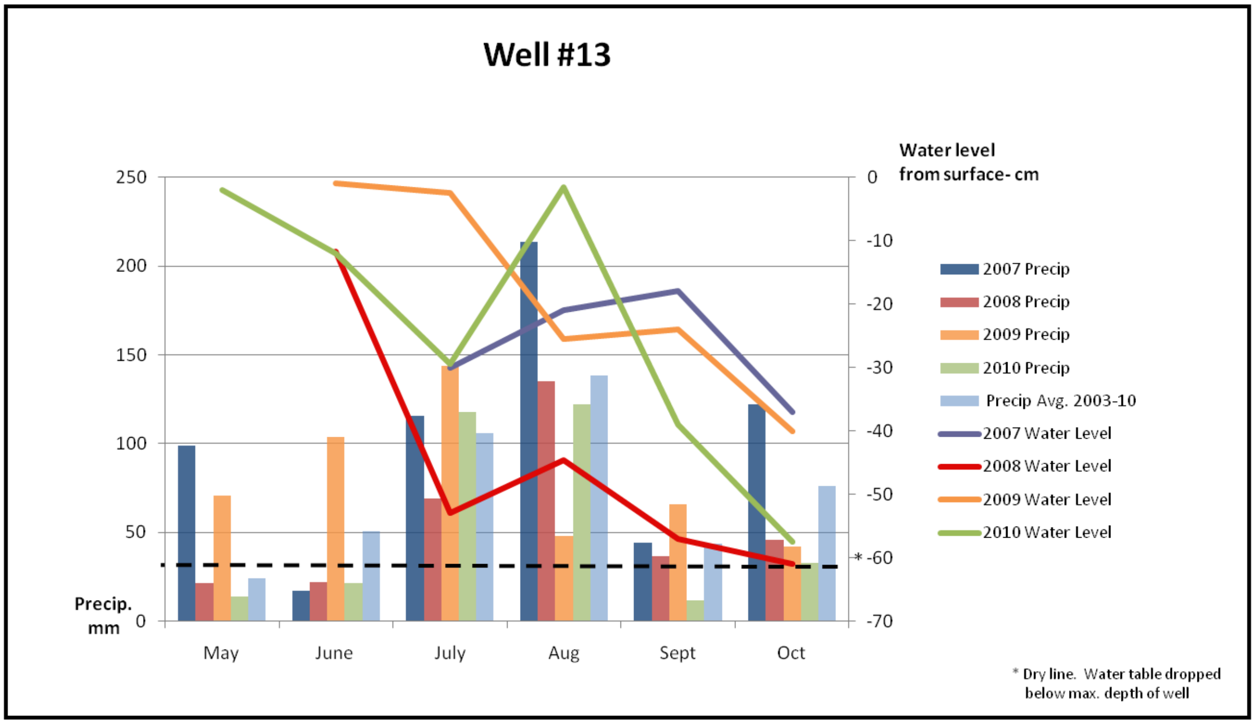
Water level from surface- cm
250
200
150
100
50
0
Precip. mm
0
-10
-20
-30
-40
-50
-60
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
*
* Dry line. Water table dropped below max. depth of well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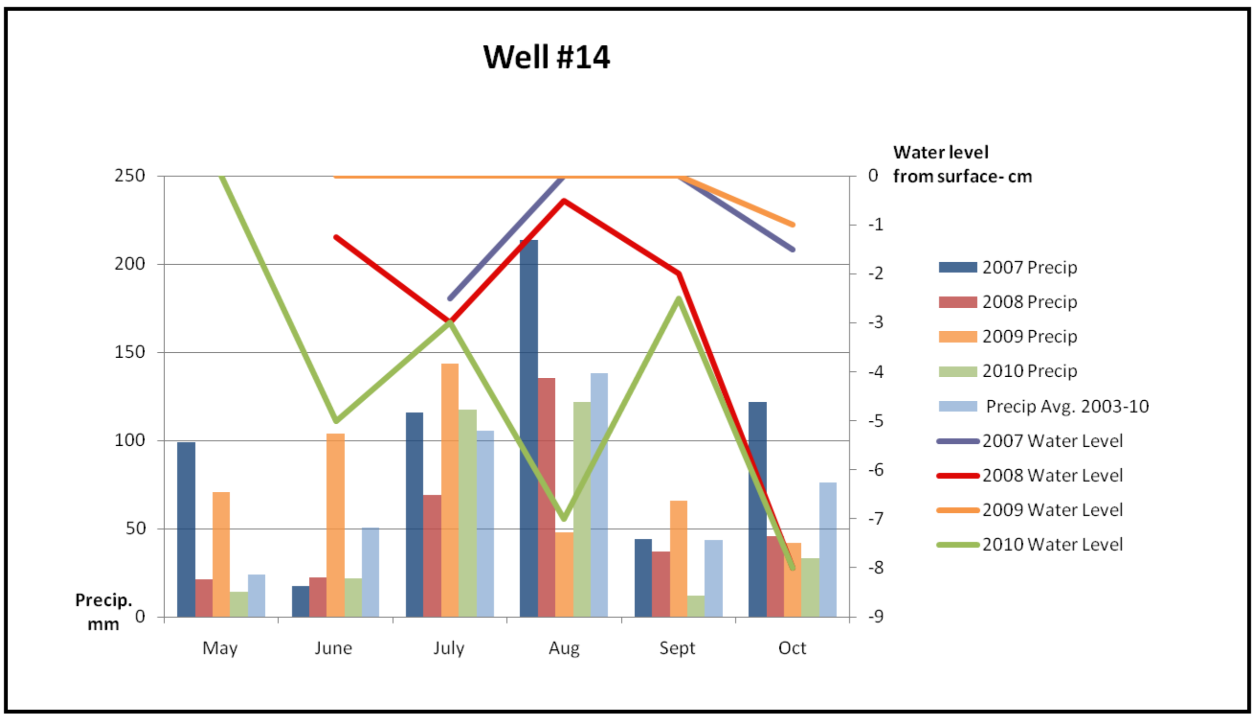
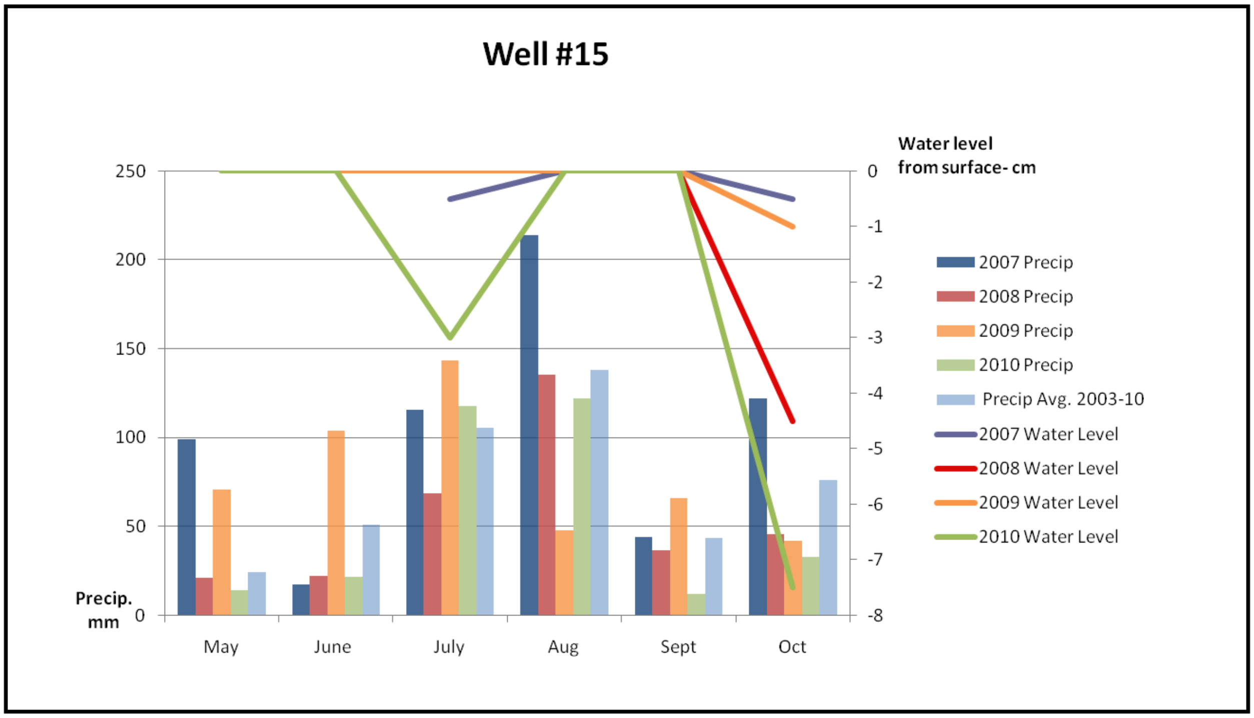
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-10
-20
-30
-40
-50
* -60
-70
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped
below max. depth of well


Well #14
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level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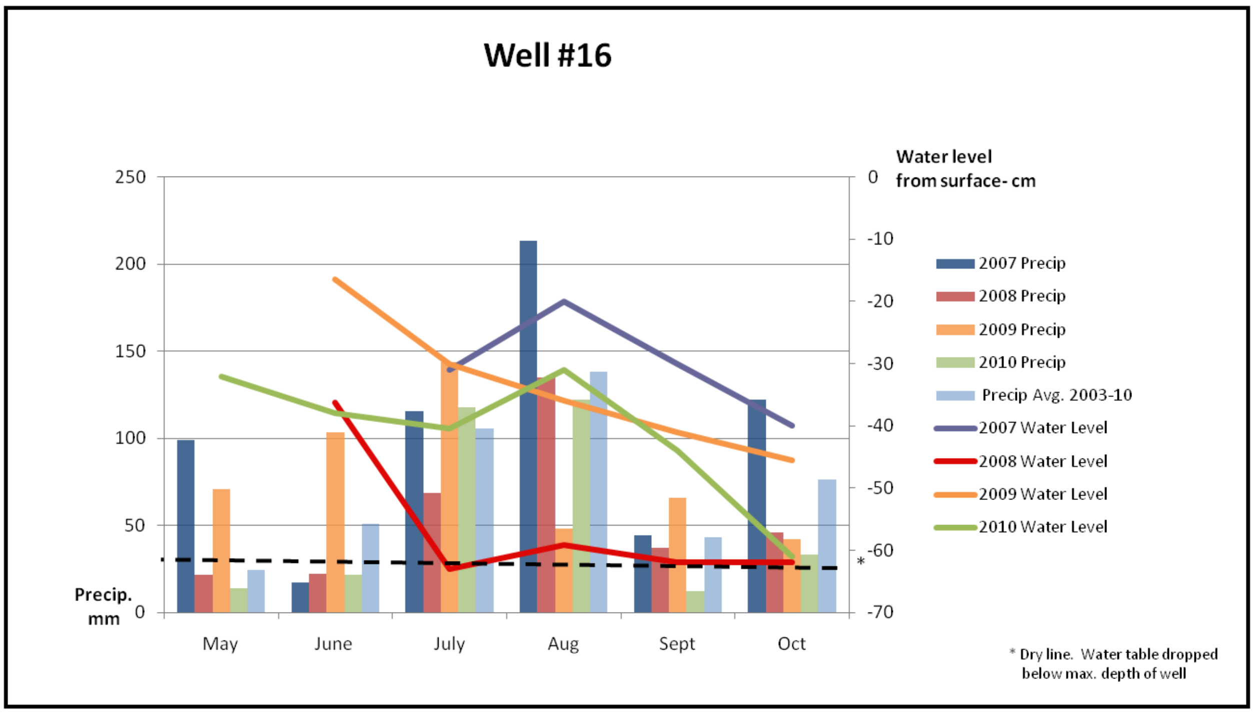
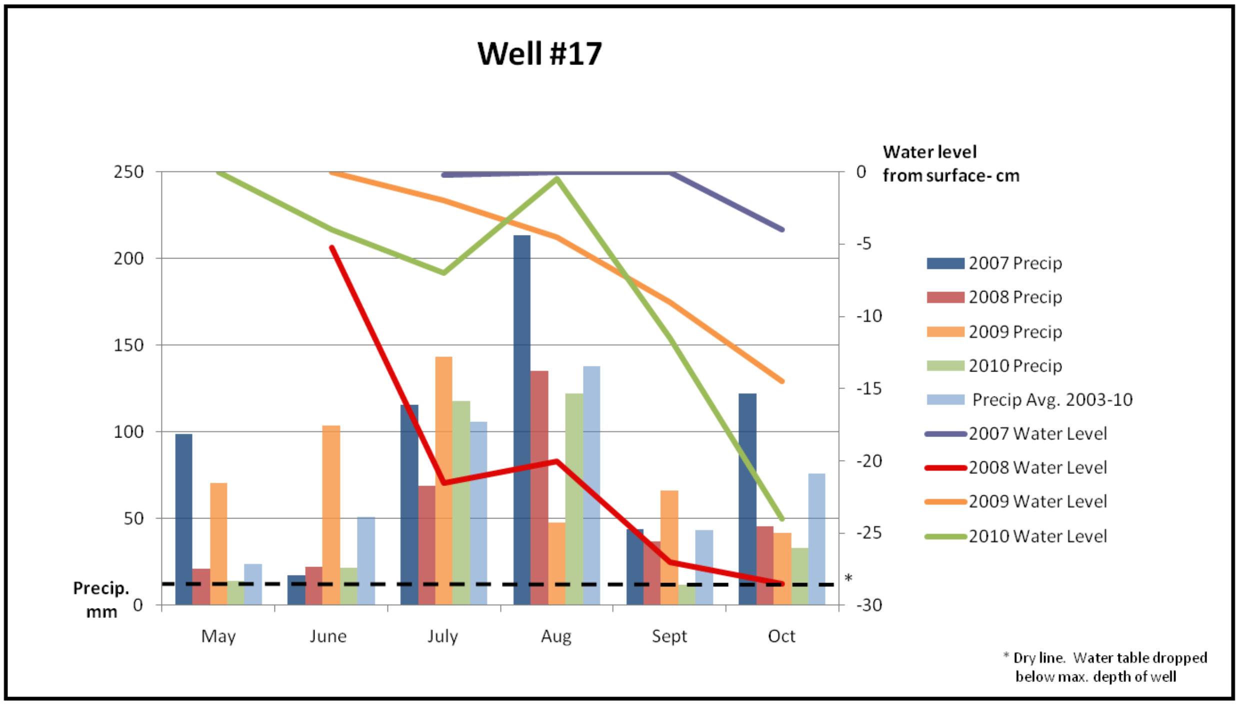
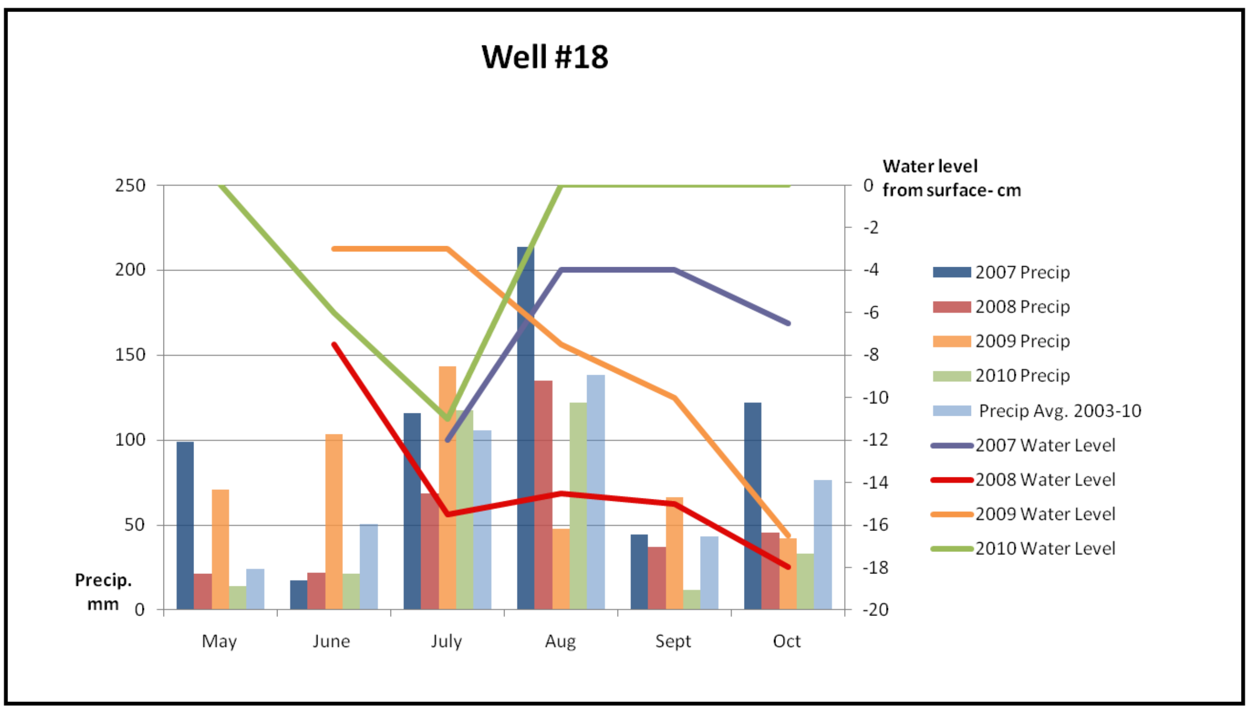
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-1
-2
-3
-4
-5
-6
-7
-8
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level


Well #16
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-10
-20
-30
-40
-50
-60
-70
*
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped
below max. depth of well


Well #17
250
200
150
100
50
Precip.
mm
0
0
-5
-10
-15
-20
-25
-30
Water level
from surface- cm
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
*
* Dry line. Water table dropped below max. depth of well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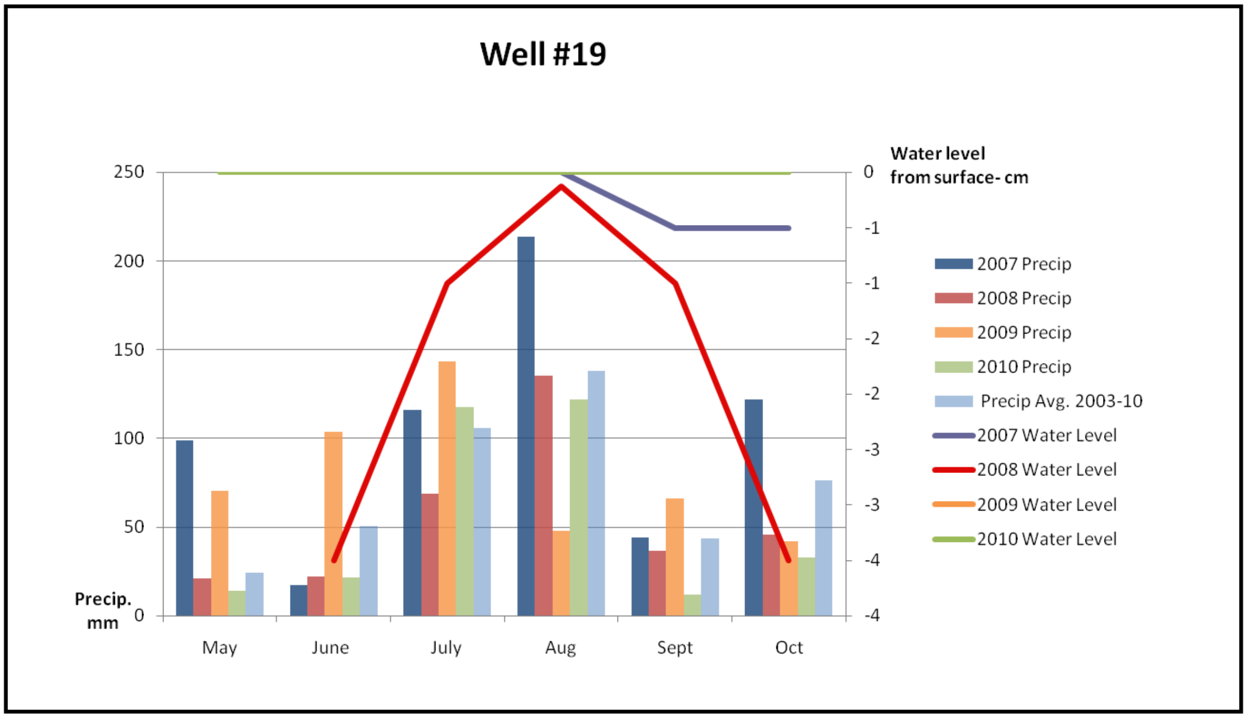
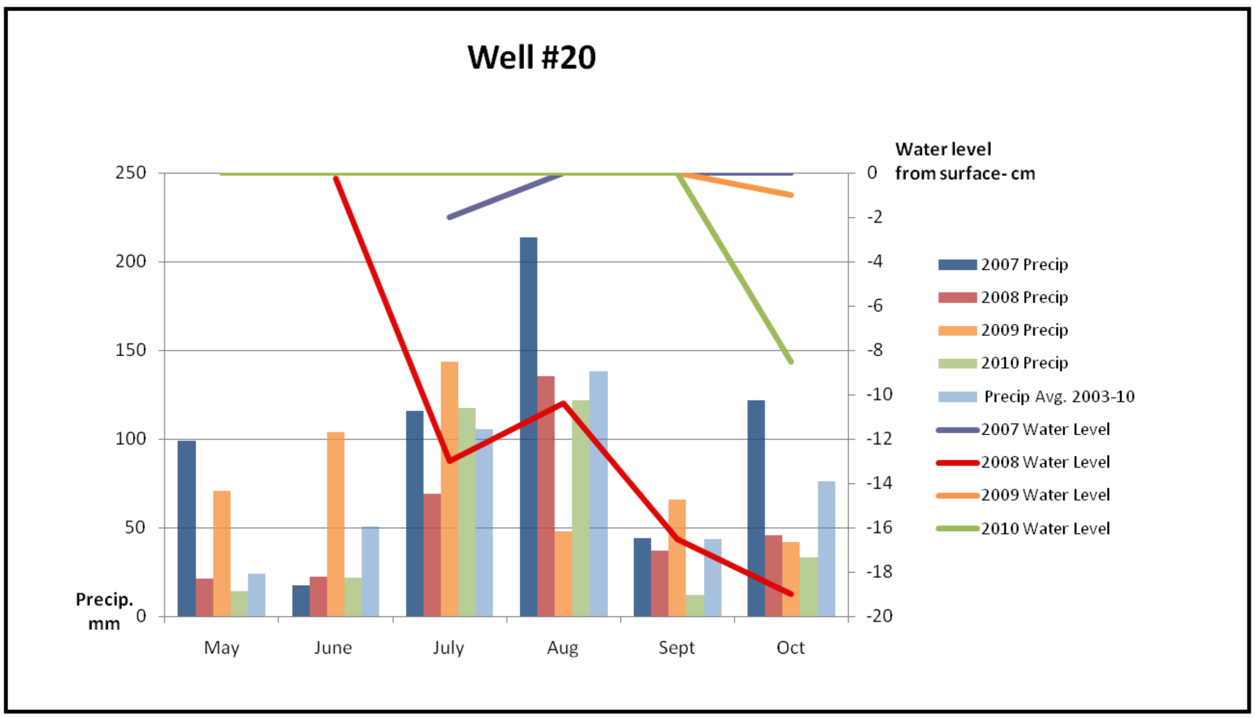
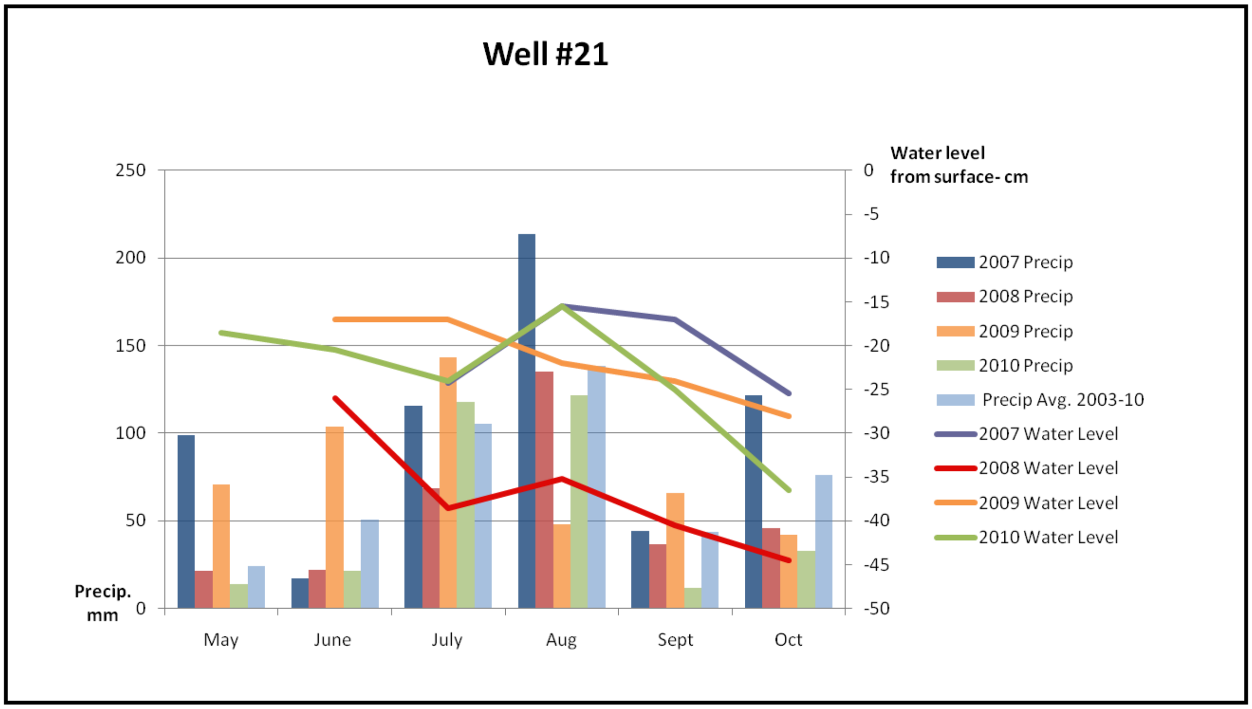
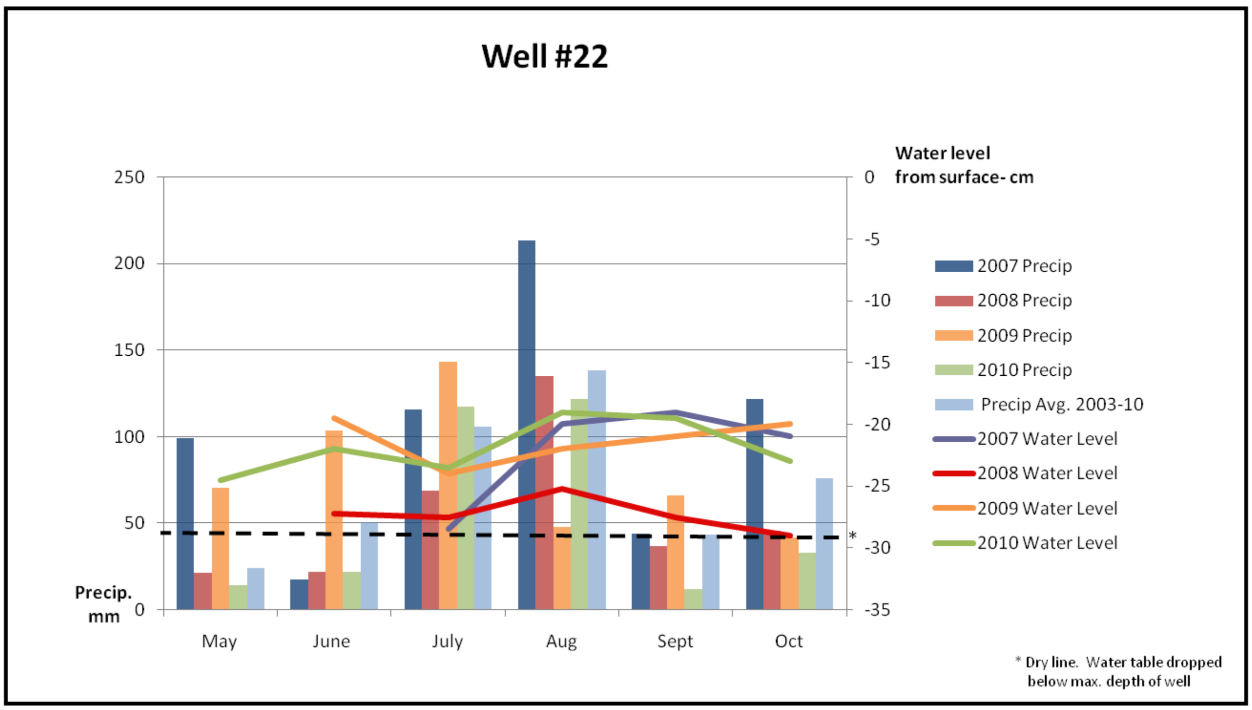
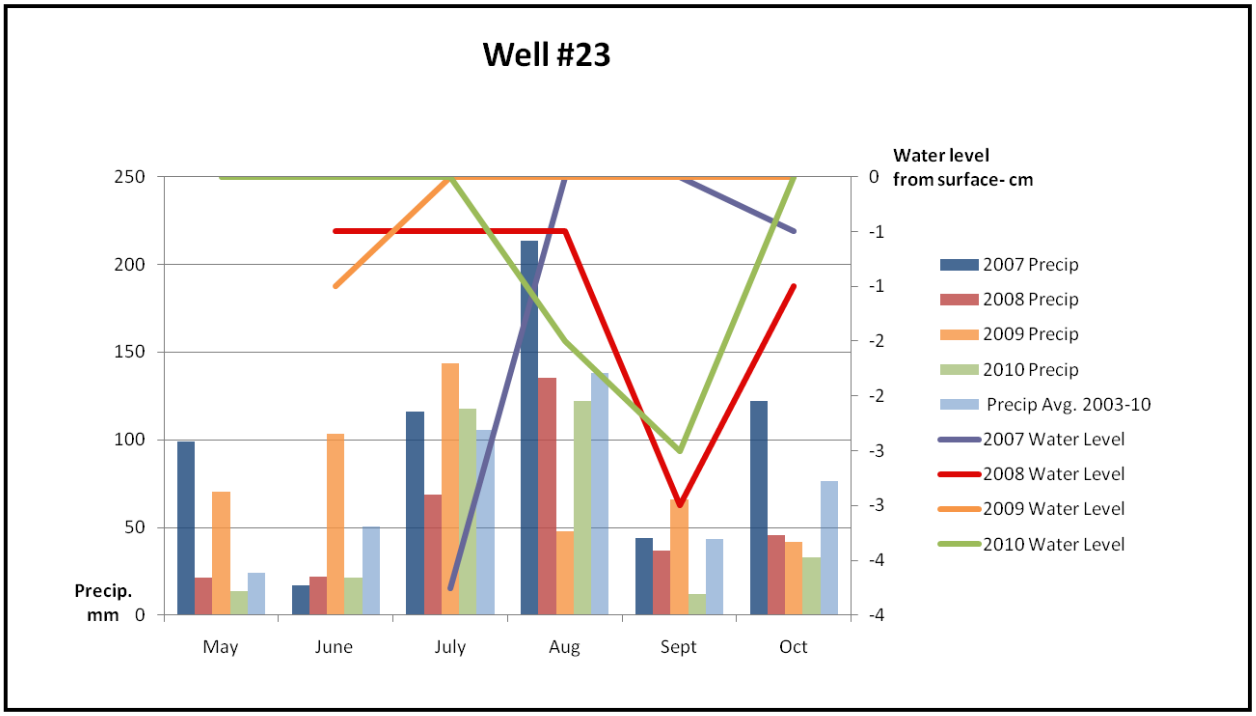
250
200
150
100
50
Precip.
mm
0
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
Water level
from surface- cm
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level

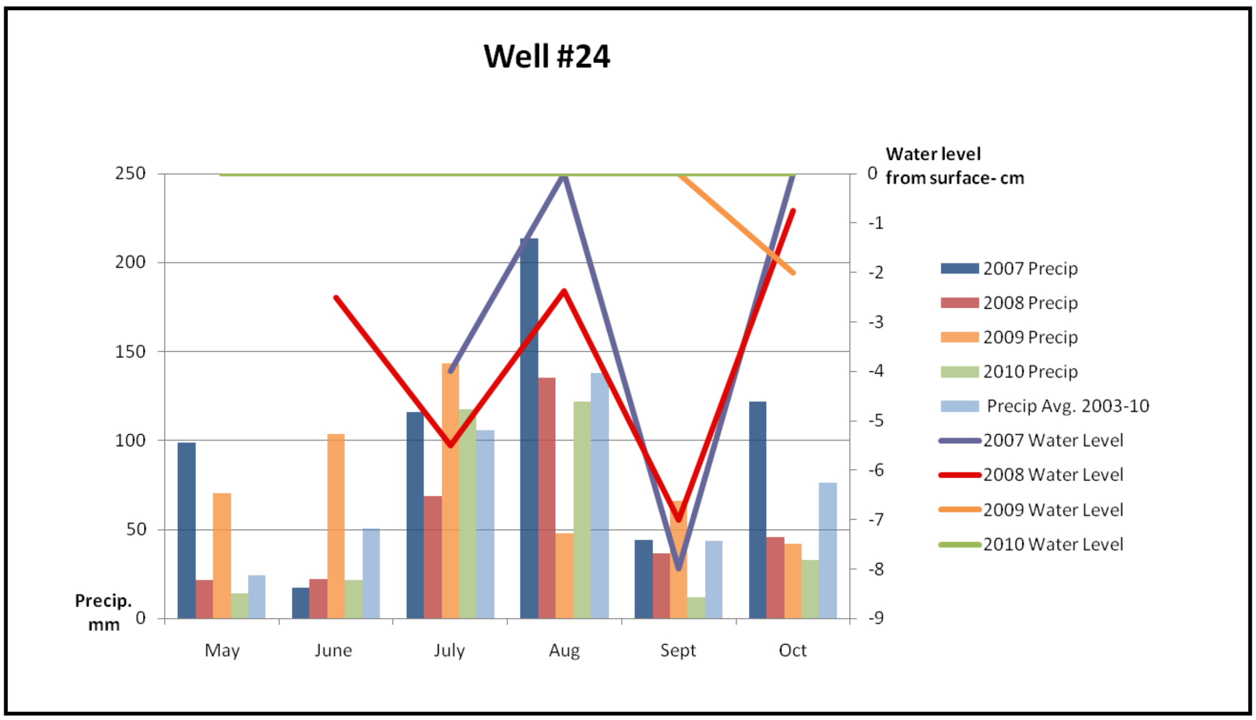

Well #19
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-1
-1
-2
-2
-3
-3
-4
-4
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level

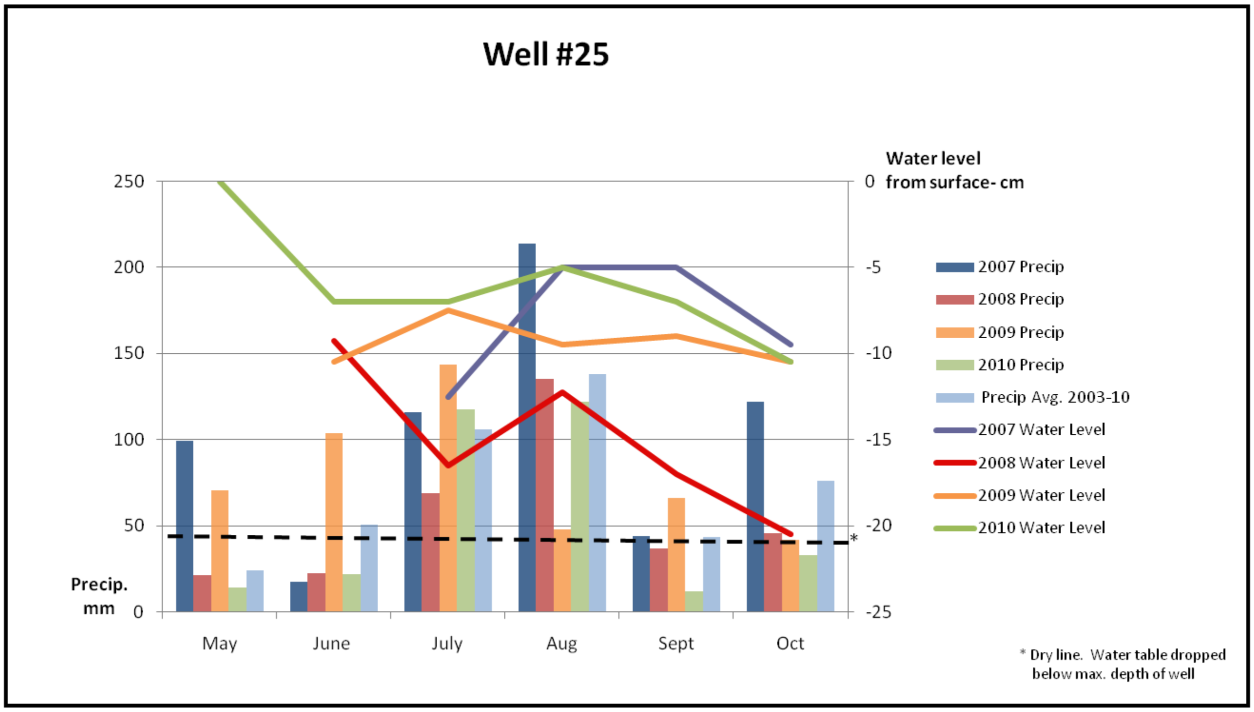

Well #20
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level

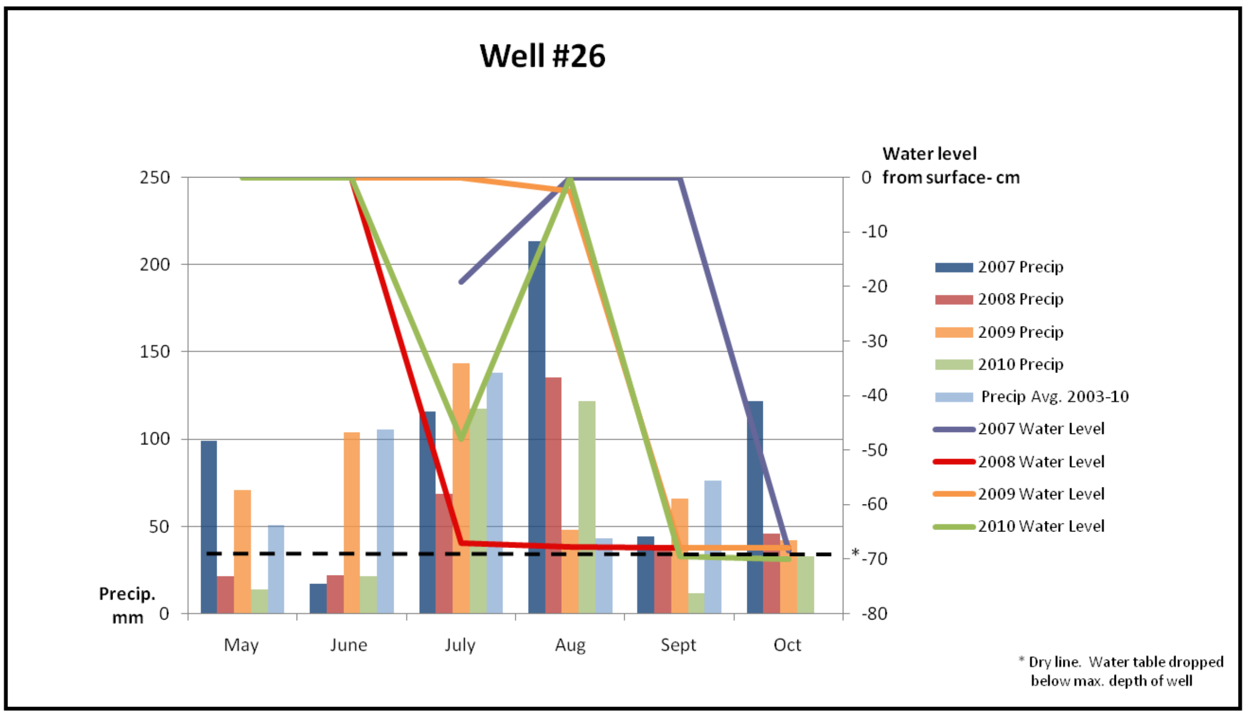

Well #21
Water level from surface- cm
250
200
150
100
50
0
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Precip. mm
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level

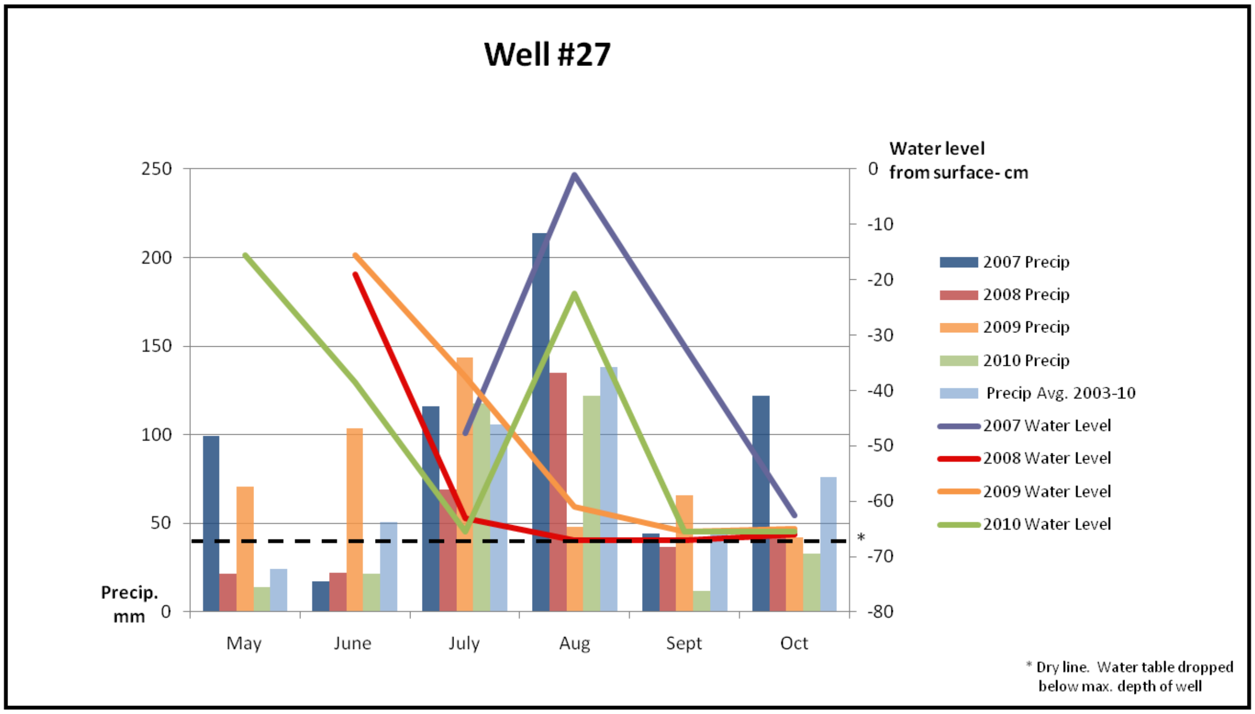

Well #22
Water level from surface- cm
250
200
150
100
50
0
0
-5
-10
-15
-20
-25
-30
-35
Precip. mm
May
June
July
Aug
Sept
Oct
*
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well

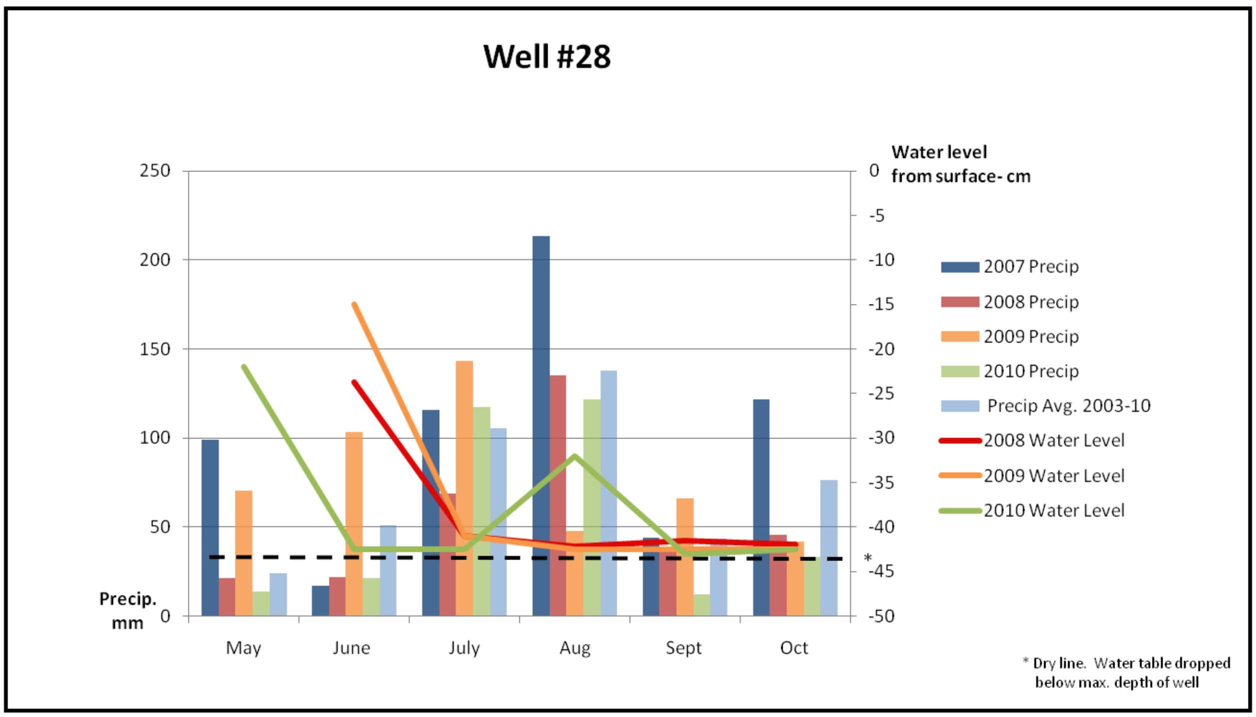

Well #23
Water level from surface- cm
Precip. mm
250
200
150
100
50
0
0
-1
-1
-2
-2
-3
-3
-4
-4
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level

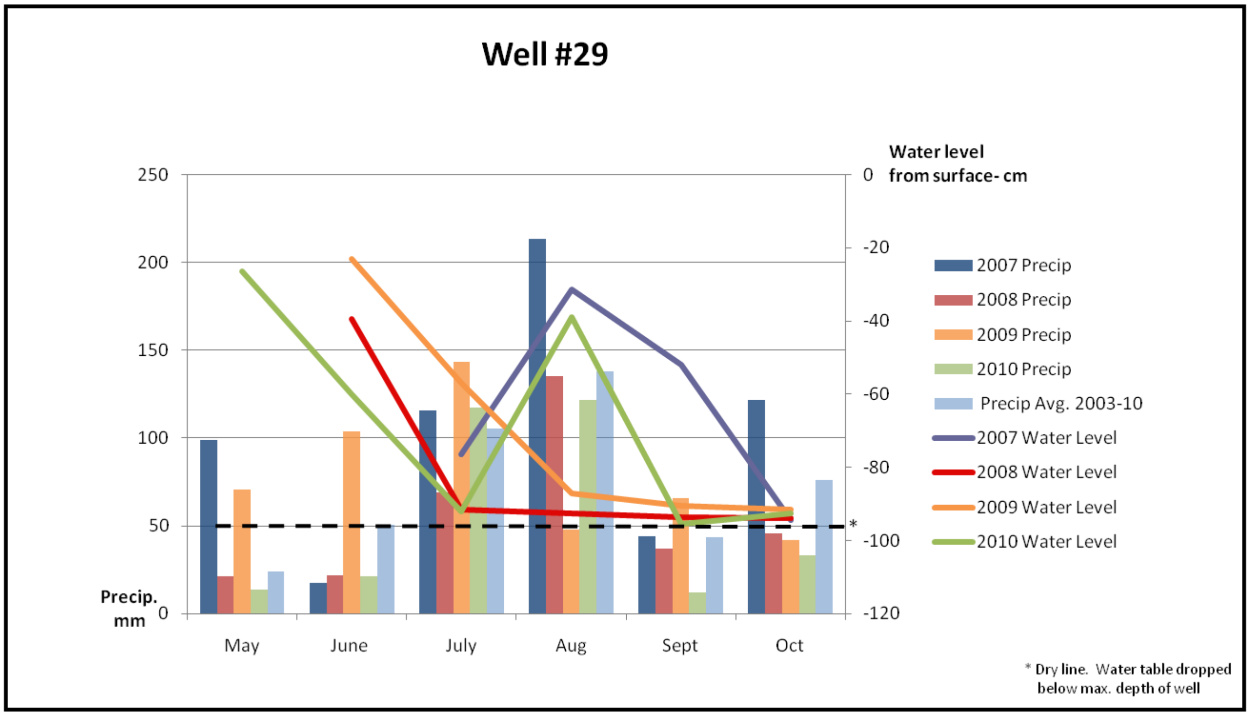

Well #24
Water level from surface- cm
Precip. mm
250
200
150
100
50
0
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level

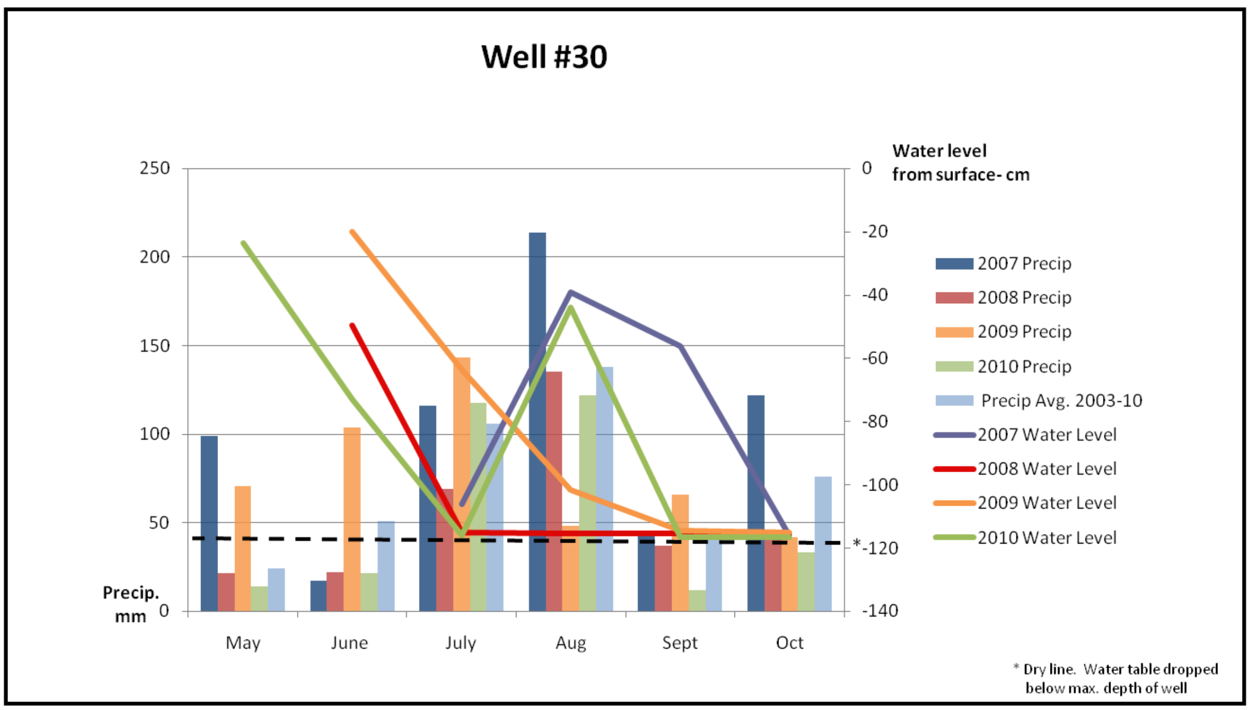

Well #25
Water level
from surface- cm
250
200
150
100
50
0
0
-5
-10
-15
-20
-25
Precip.
mm
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
*
* Dry line. Water table dropped below max. depth of well

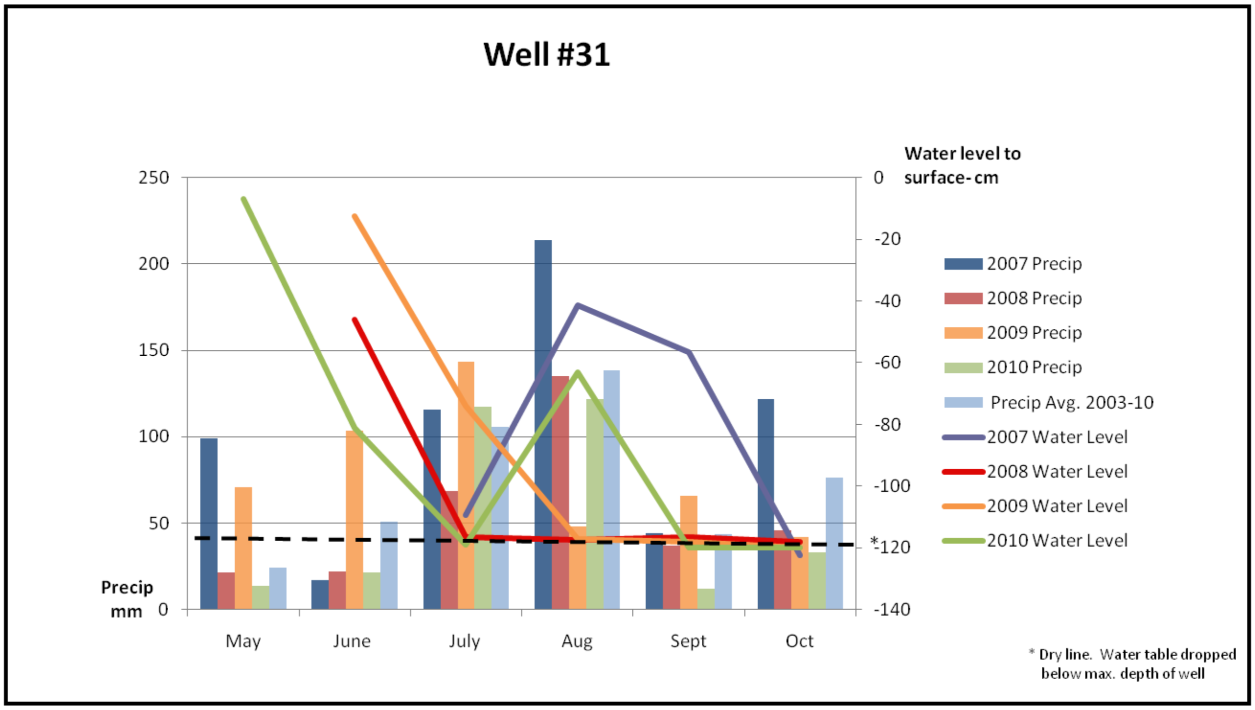

Well #26
Water level
from surface- cm
250
200
150
100
50
0
0
-10
-20
-30
-40
-50
-60
-70
-80
Precip.
mm
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
*
* Dry line. Water table dropped below max. depth of well

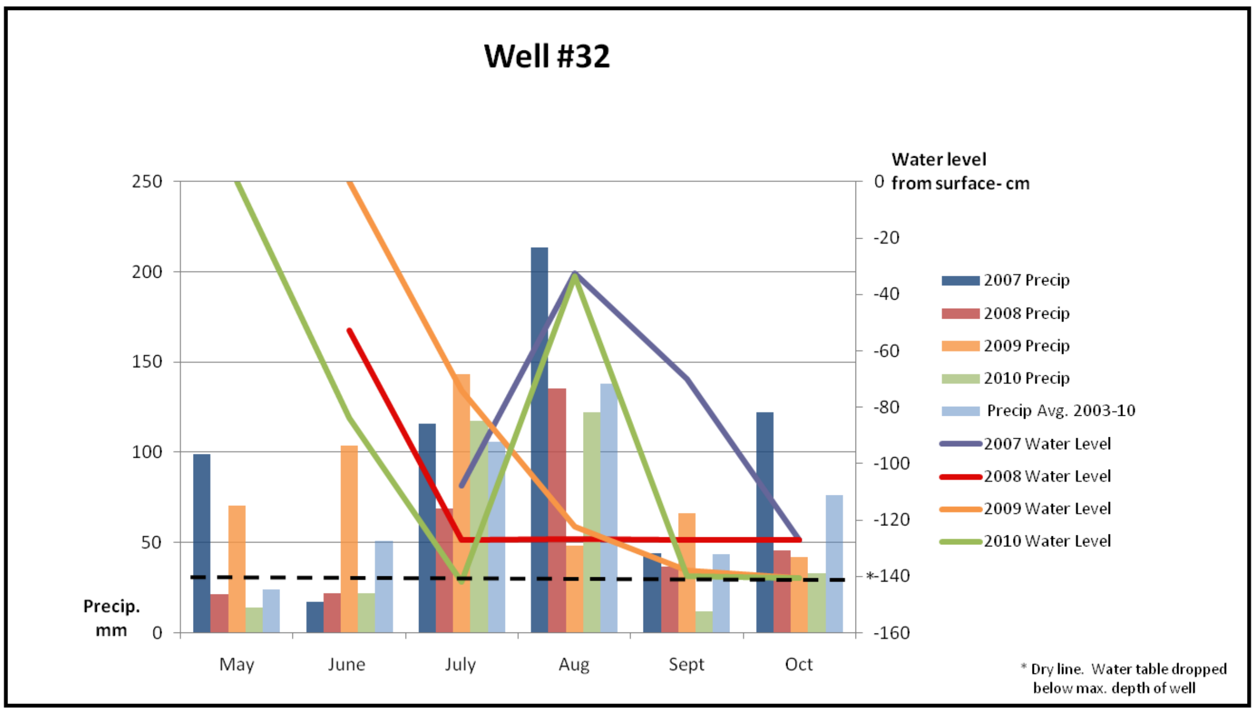

Well #27
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-10
-20
-30
-40
-50
-60
-70
-80
*
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well

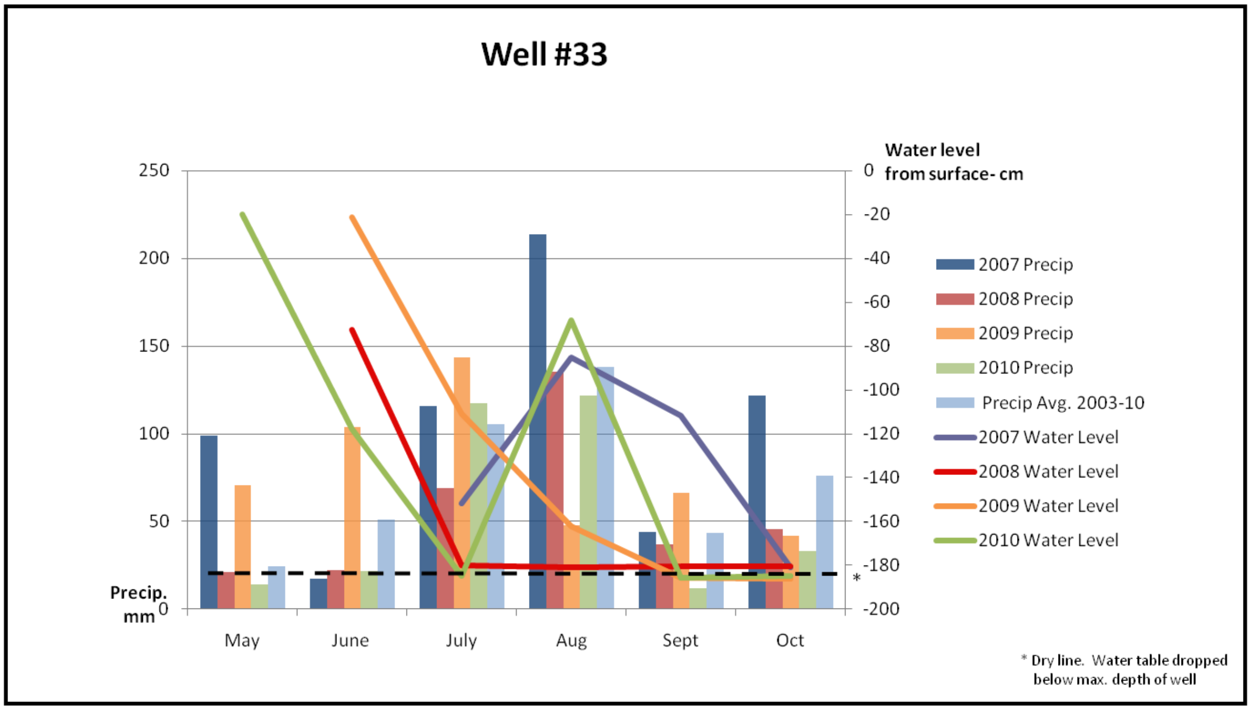

Well #28
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
*
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well

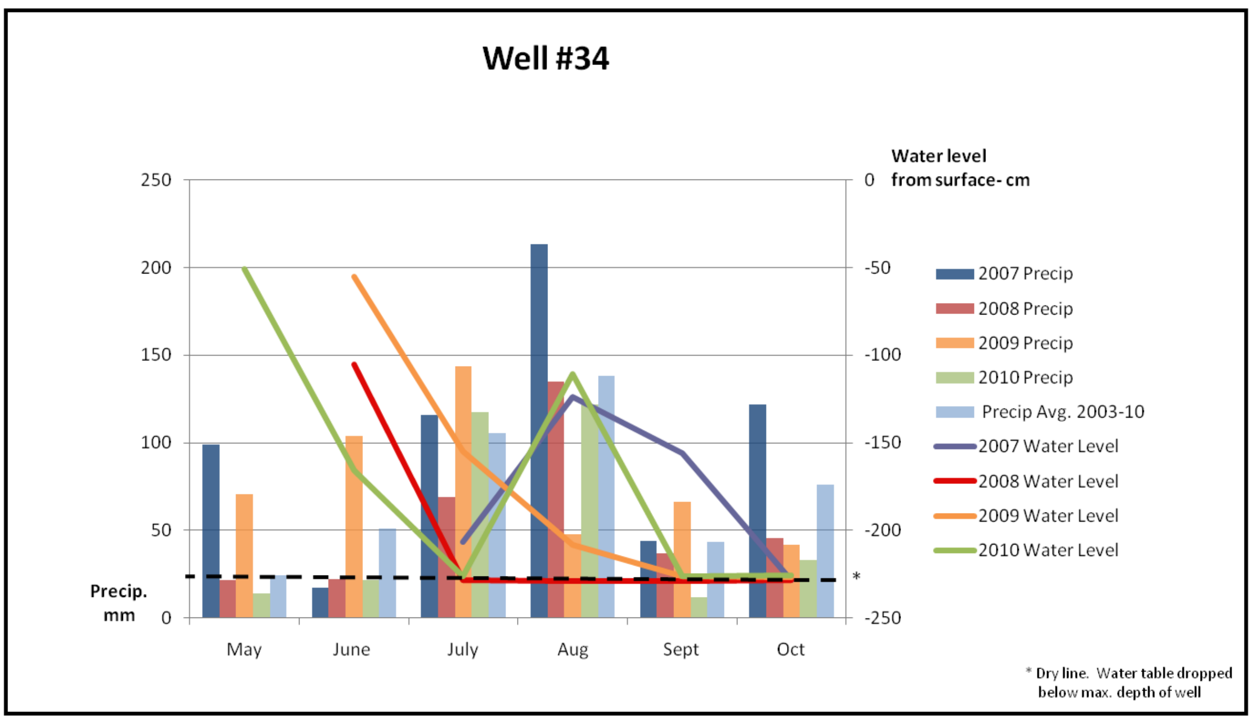

Well #29
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-20
-40
-60
-80
-100
-120
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
*
* Dry line. Water table dropped below max. depth of well


Well #30
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-20
-40
-60
-80
-100
-120
-140
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
*
* Dry line. Water table dropped below max. depth of well

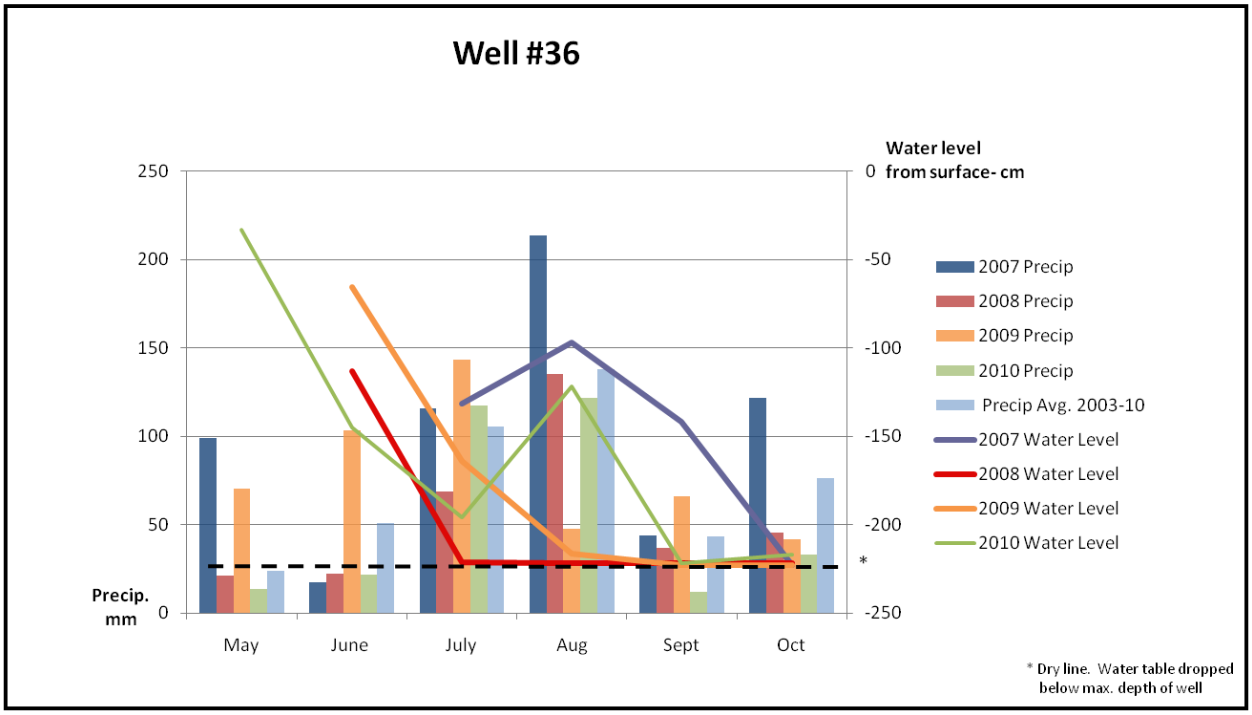

Well #31
Water level to surface- cm
250
200
150
100
50
0
Precip mm
0
-20
-40
-60
-80
-100
*-120
-140
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well

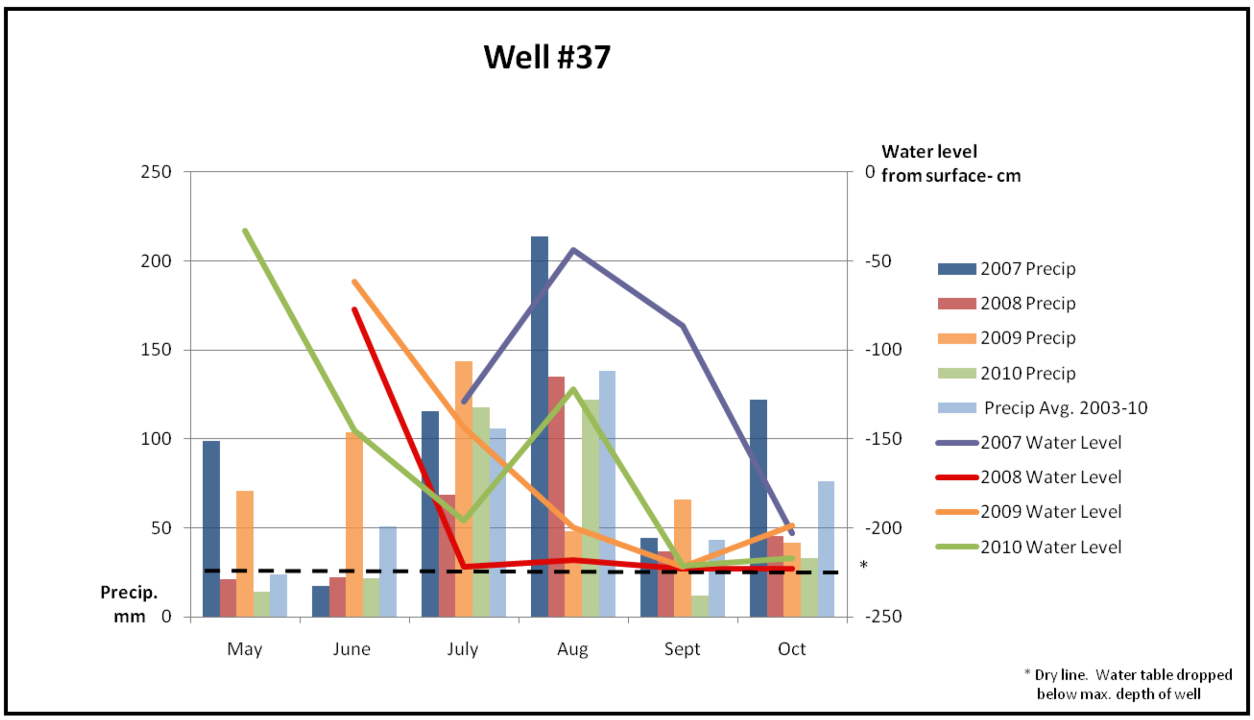

Well #32
Water level from surface- cm
250
200
150
100
50
0
Precip. mm
0
-20
-40
-60
-80
-100
-120
*-140
-160
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level
* Dry line. Water table dropped below max. depth of well



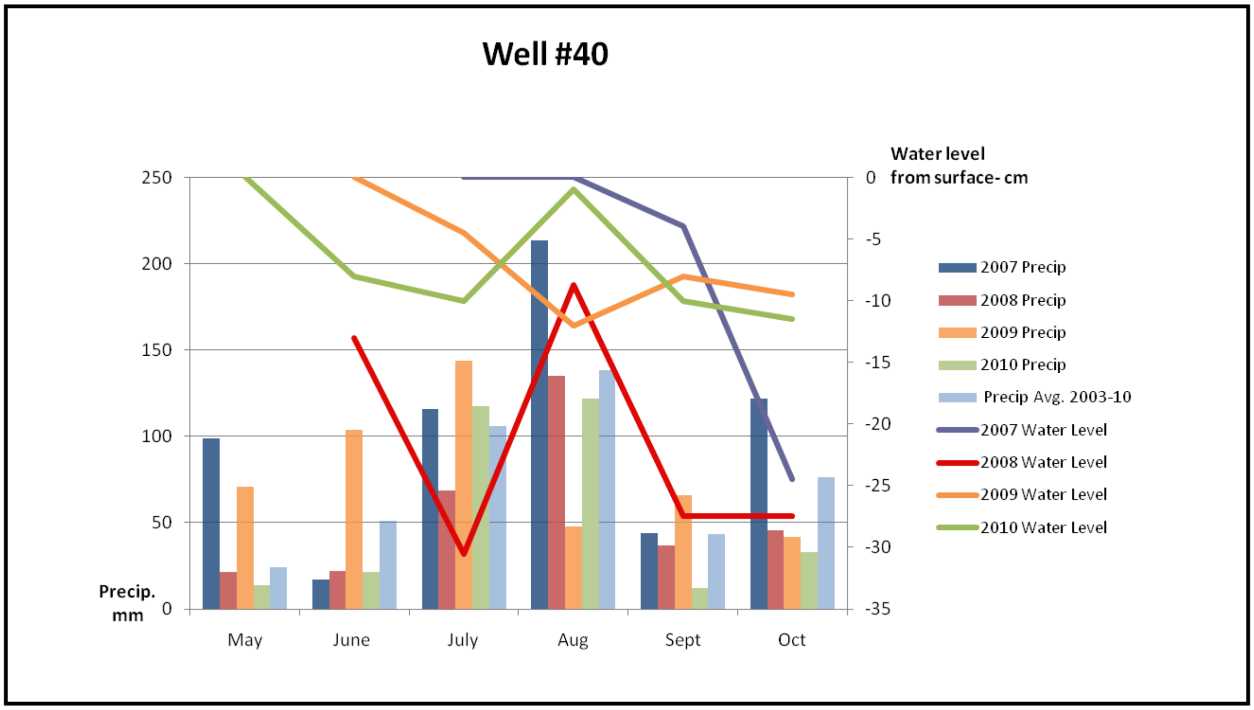


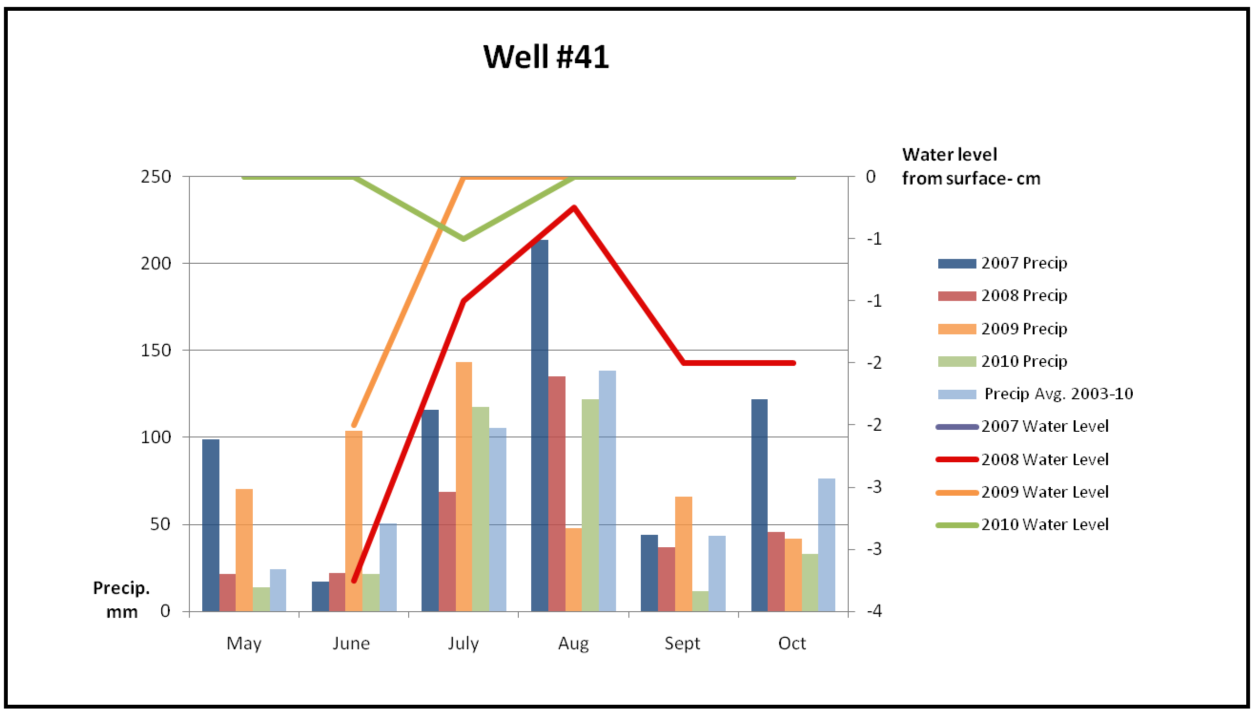
Well #35 was broken and covered by sediment in 2007.

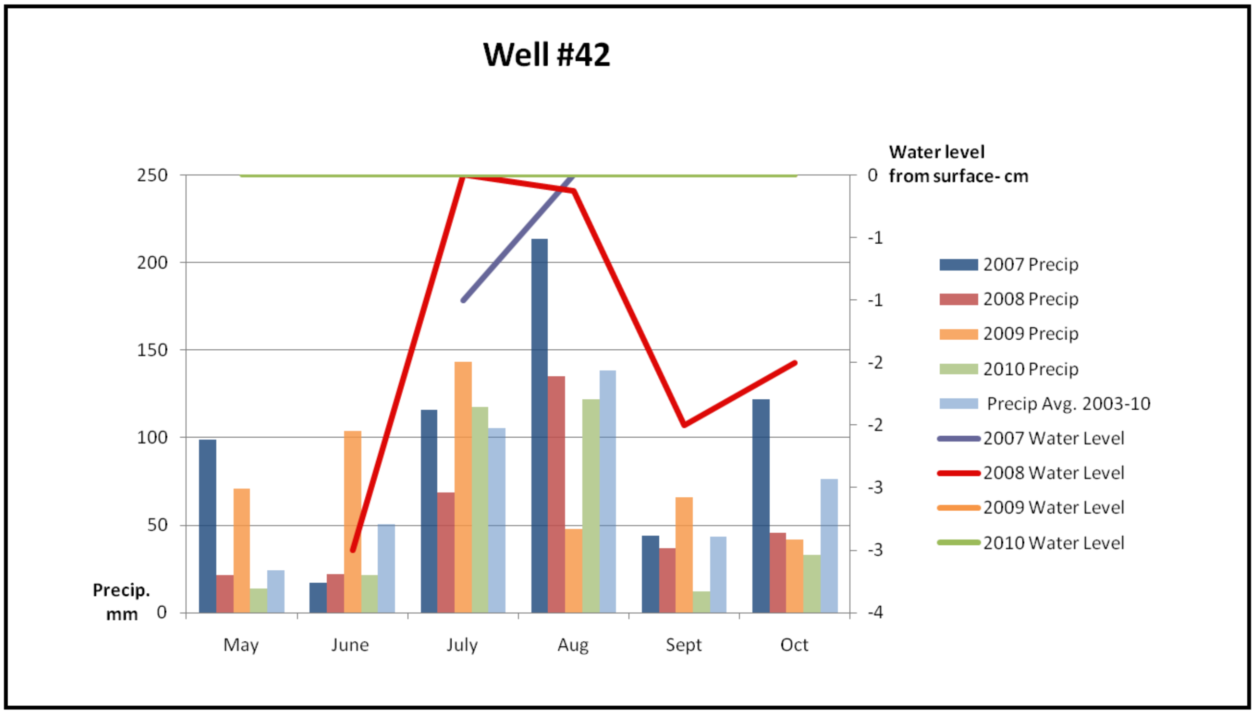


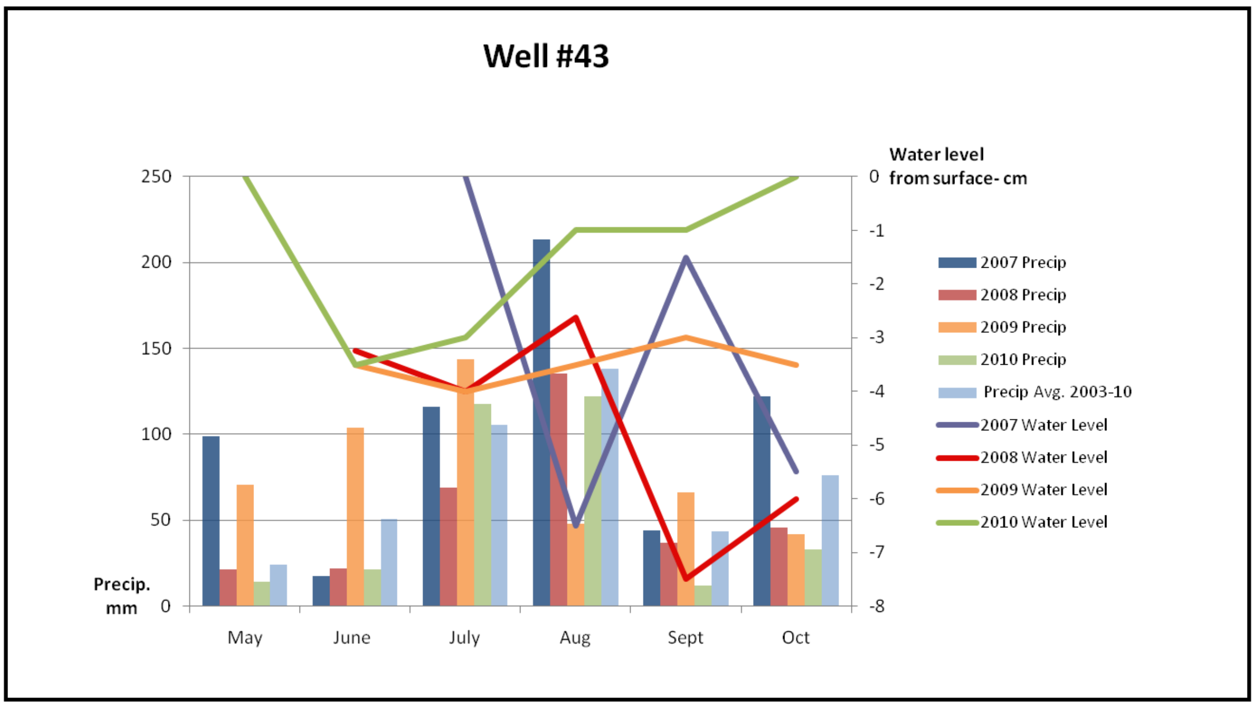


Wells 38 and 39 filled with sediment or were inoperable after 2007.

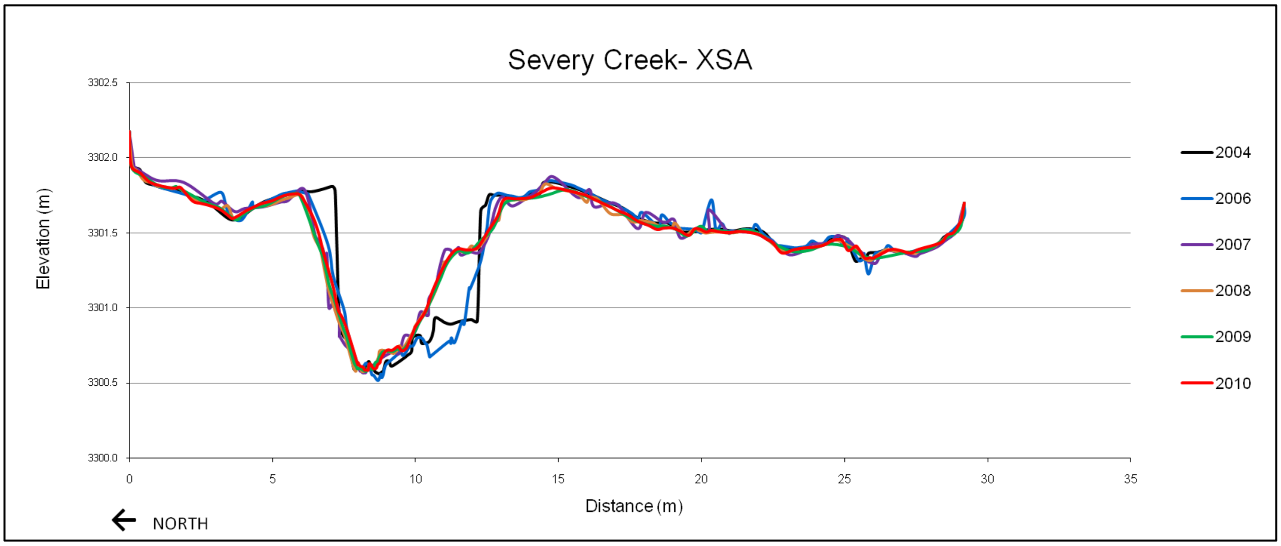

Well #40
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-5
-10
-15
-20
-25
-30
-35
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level

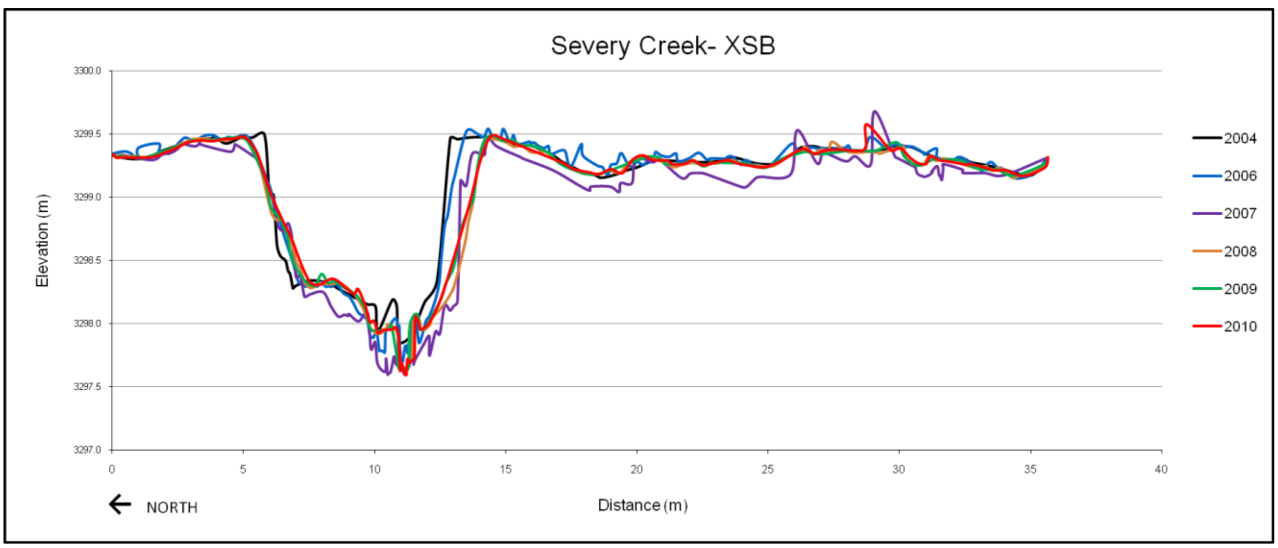

Well #41
Water level
from surface- cm
250
200
150
100
50
0
Precip.
mm
0
-1
-1
-2
-2
-3
-3
-4
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level

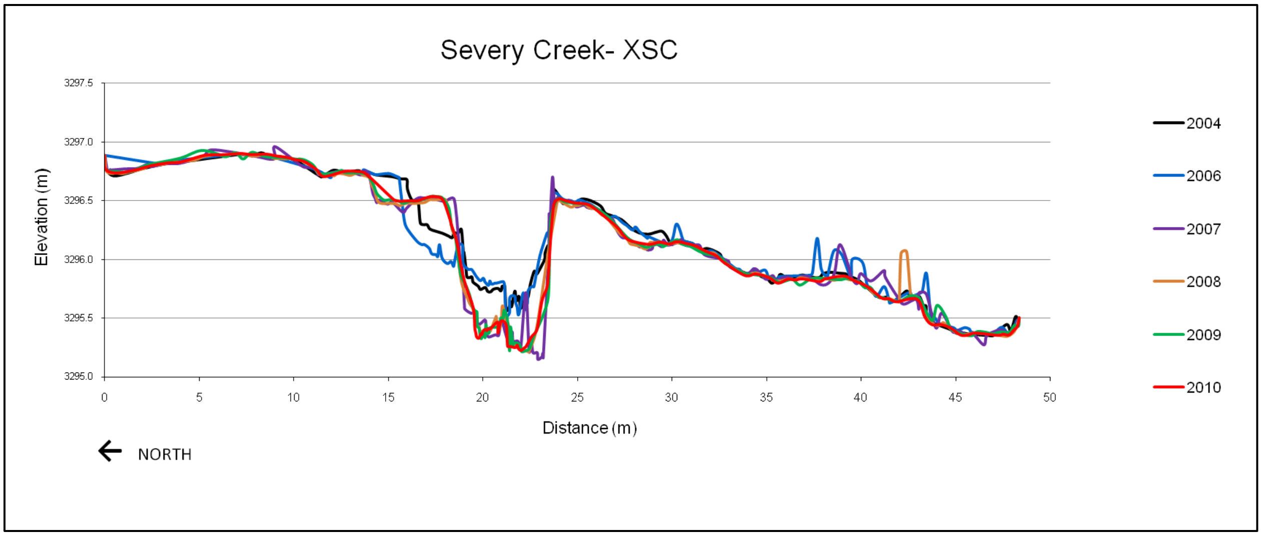

Well #42
Water level from surface- cm
Precip. mm
250
200
150
100
50
0
0
-1
-1
-2
-2
-3
-3
-4
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level

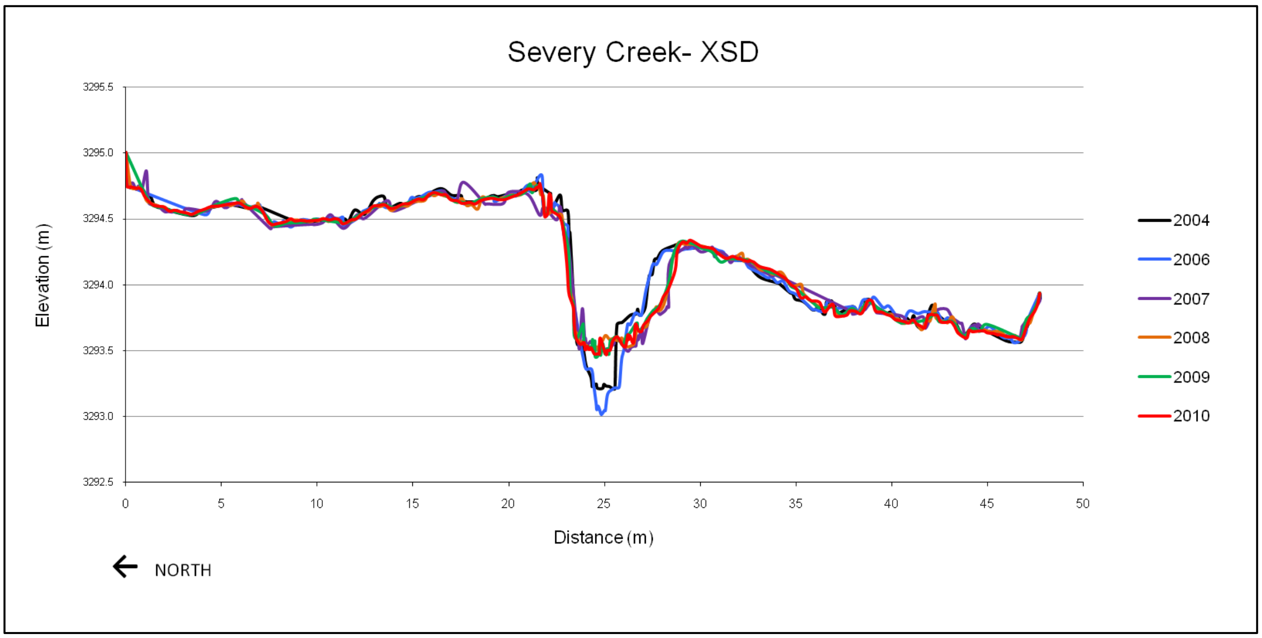

Well #43
Water level from surface- cm
Precip. mm
250
200
150
100
50
0
0
-1
-2
-3
-4
-5
-6
-7
-8
May
June
July
Aug
Sept
Oct
2007 Precip
2008 Precip
2009 Precip
2010 Precip
Precip Avg. 2003-10
2007 Water Level
2008 Water Level
2009 Water Level
2010 Water Level

Appendix C. USFS (SC XSA-E) Cross-section Data



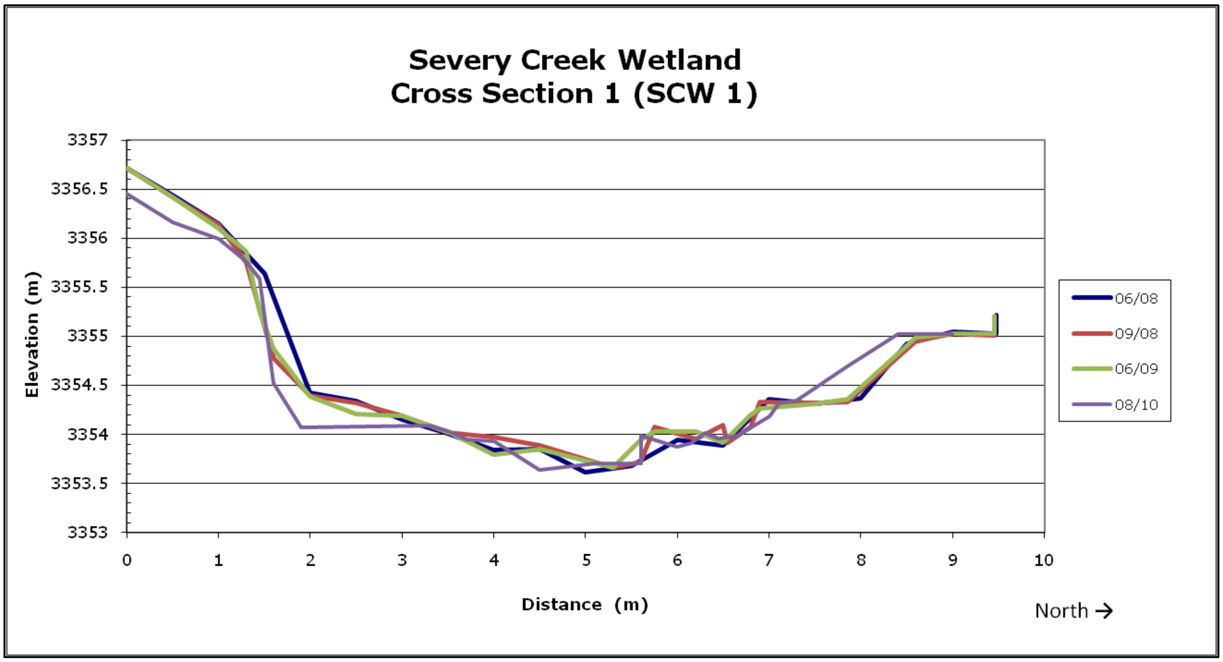


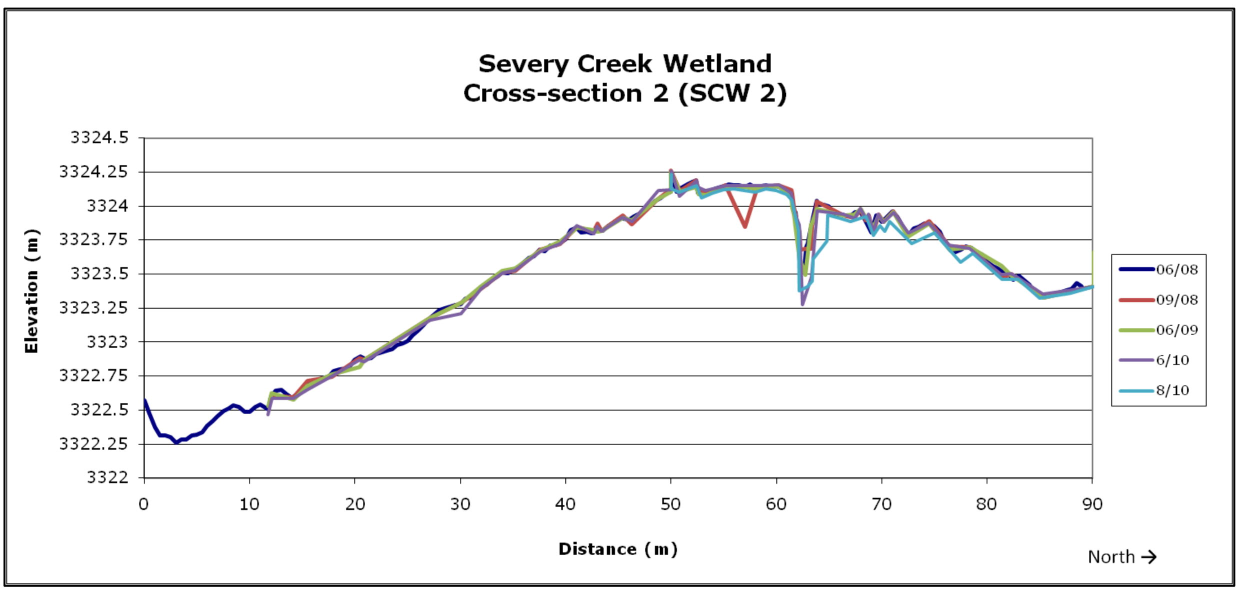

Severy Creek- XSC
3297.5
3297.0
3296.5
3296.0
3295.5
3295.0
Elevation (m)
0
5
10
15
20
25
30
35
40
45
50
Distance (m)
NORTH
2004
2006
2007
2008
2009
2010

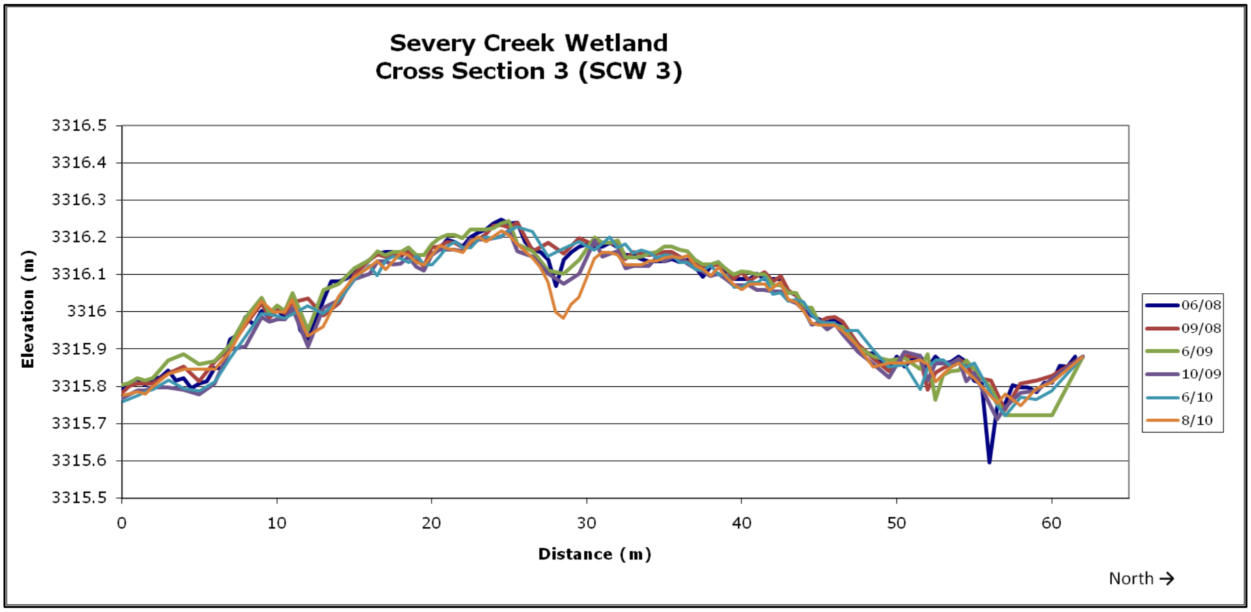

Severy Creek- XSD
3295.5
3295.0
3294.5
3294.0
3293.5
3293.0
3292.5
Elevation (m)
0
5
10
15
20
25
30
35
40
45
50
Distance (m)
NORTH
2004
2006
2007
2008
2009
2010

Severy Creek- XSE
3292.5
3292.0
3291.5
3291.0
3290.5
3290.0
Elevation (m)
0
10
20
30
40
50
60
70
Distance (m)
NORTH
2004
2006
2007
2008
2009
2010

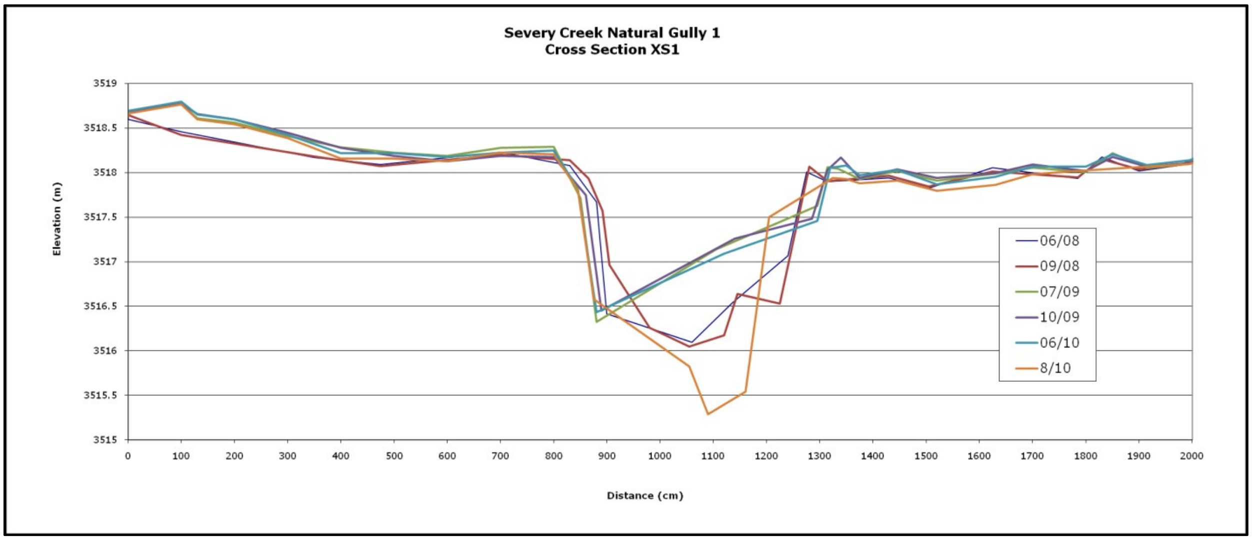
Appendix D. RMFI (SCW 1-3) Cross-section Data

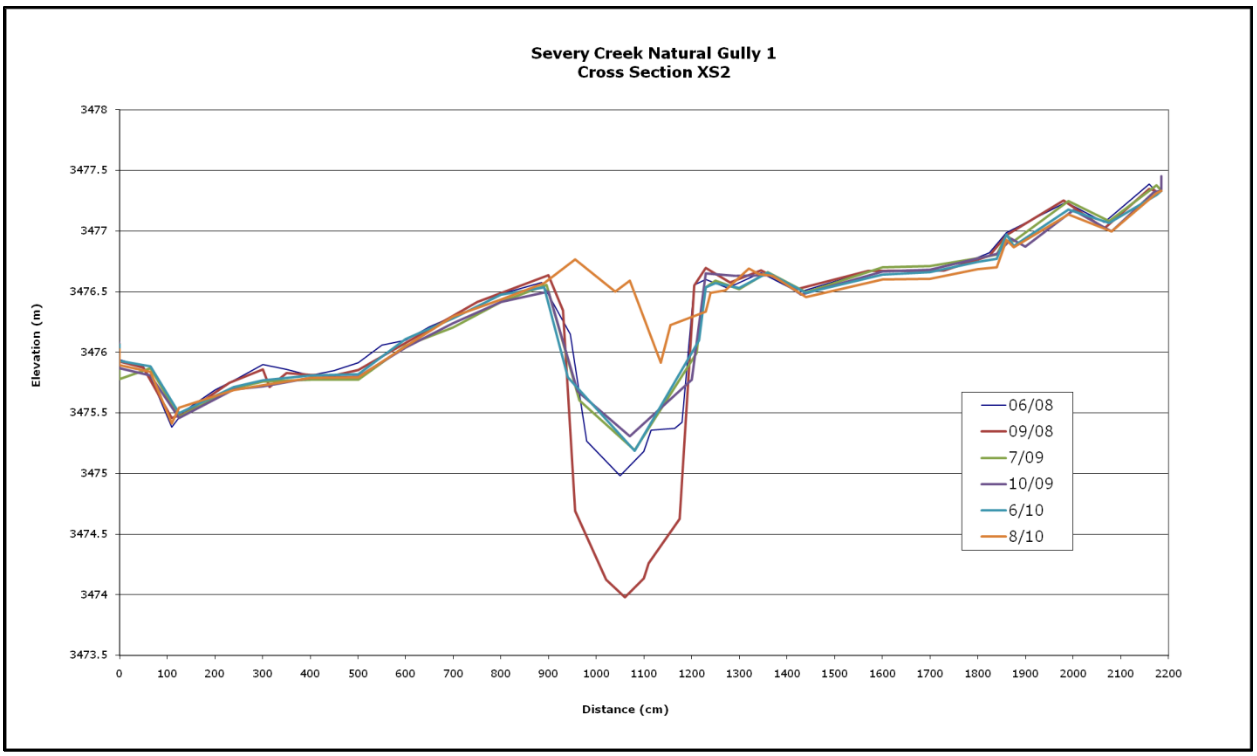


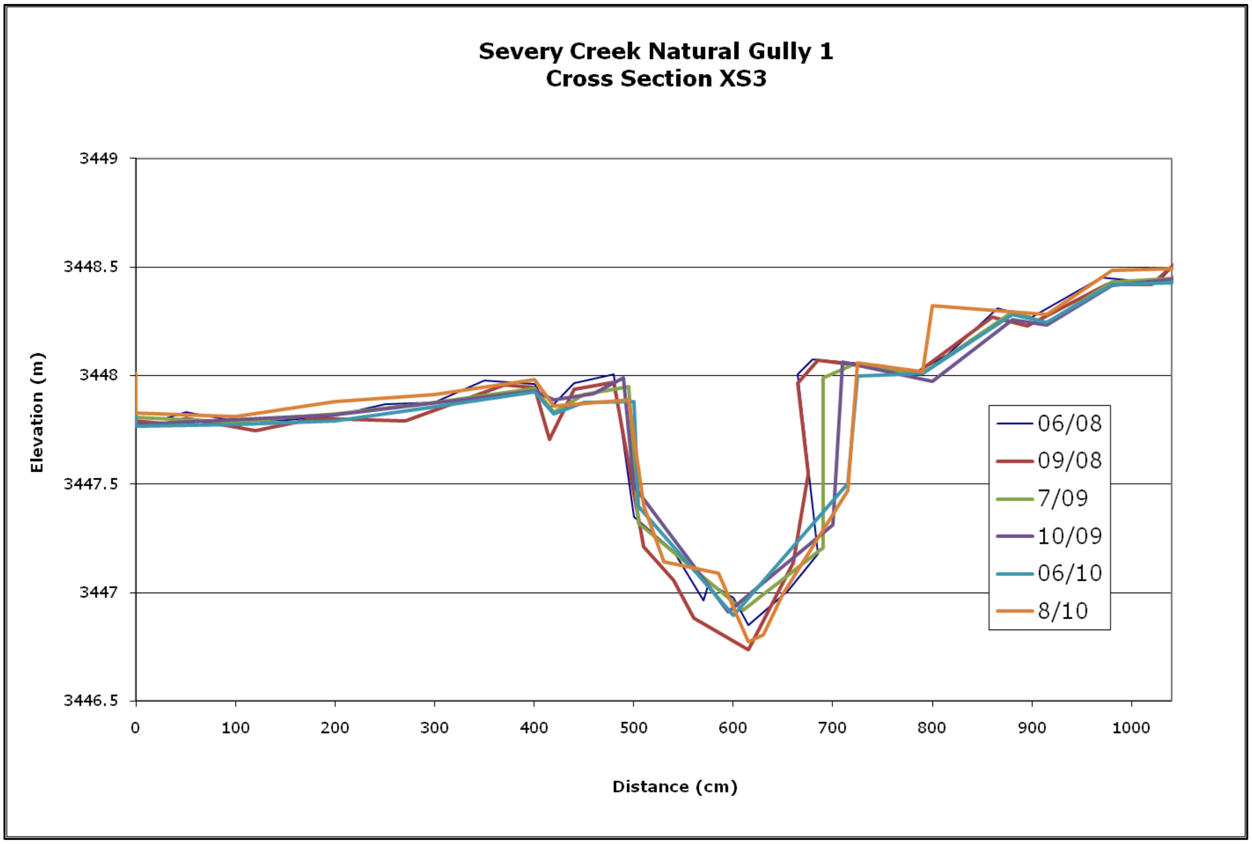


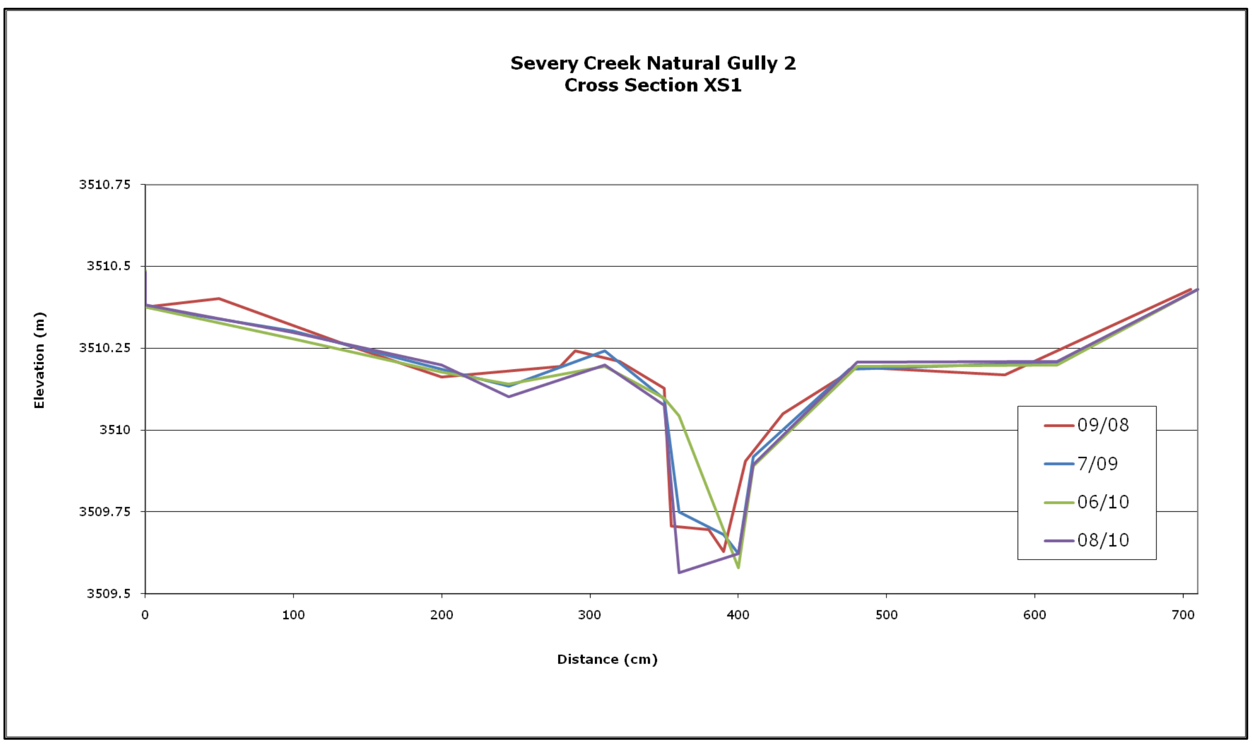

Severy Creek Wetland
Cross Section 3 (SCW 3)
Elevation (m)
3316.5
3316.4
3316.3
3316.2
3316.1
3316
3315.9
3315.8
3315.7
3315.6
3315.5
0
10
20
30
40
50
60
Distance (m)
06/08
09/08
6/09
10/09
6/10
8/10
North →

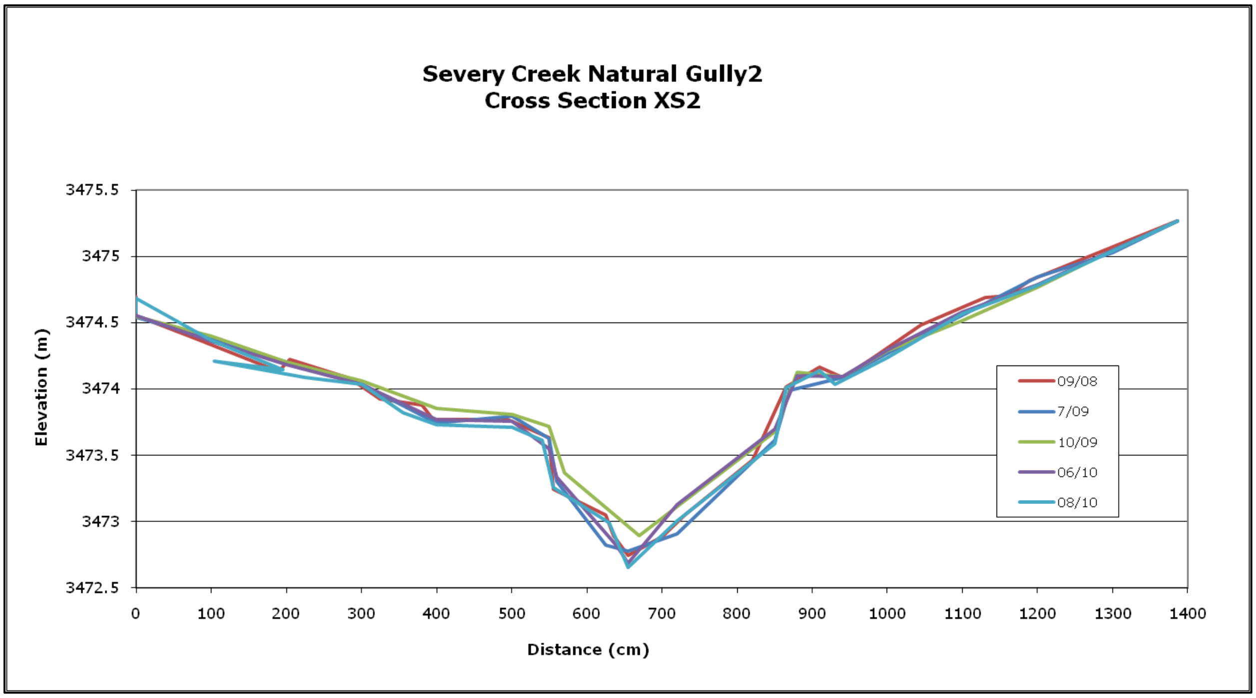
Appendix E. RMFI Cross-section Data NG1 XSC 1-3 and NG2 XSC 1-3

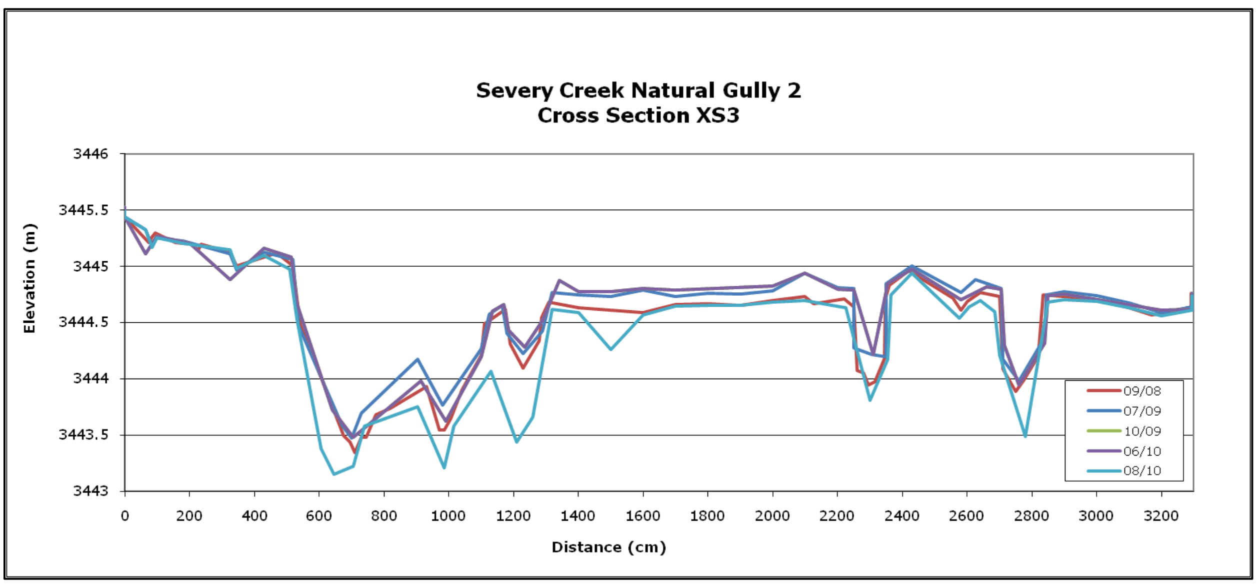




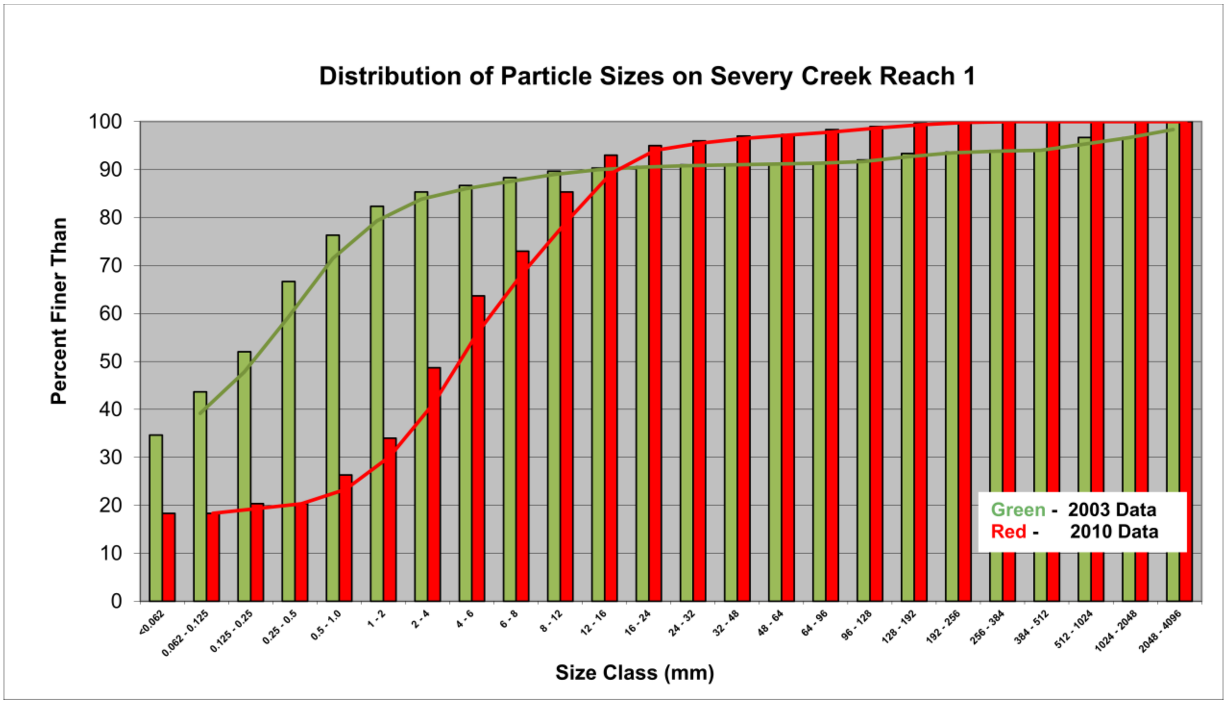

Severy Creek Natural Gully 1
Cross Section XS3
3449
3448.5
3448
3447.5
3447
3446.5
Elevation (m)
0
100
200
300
400
500
600
700
800
900
1000
Distance (cm)
06/08
09/08
7/09
10/09
06/10
8/10

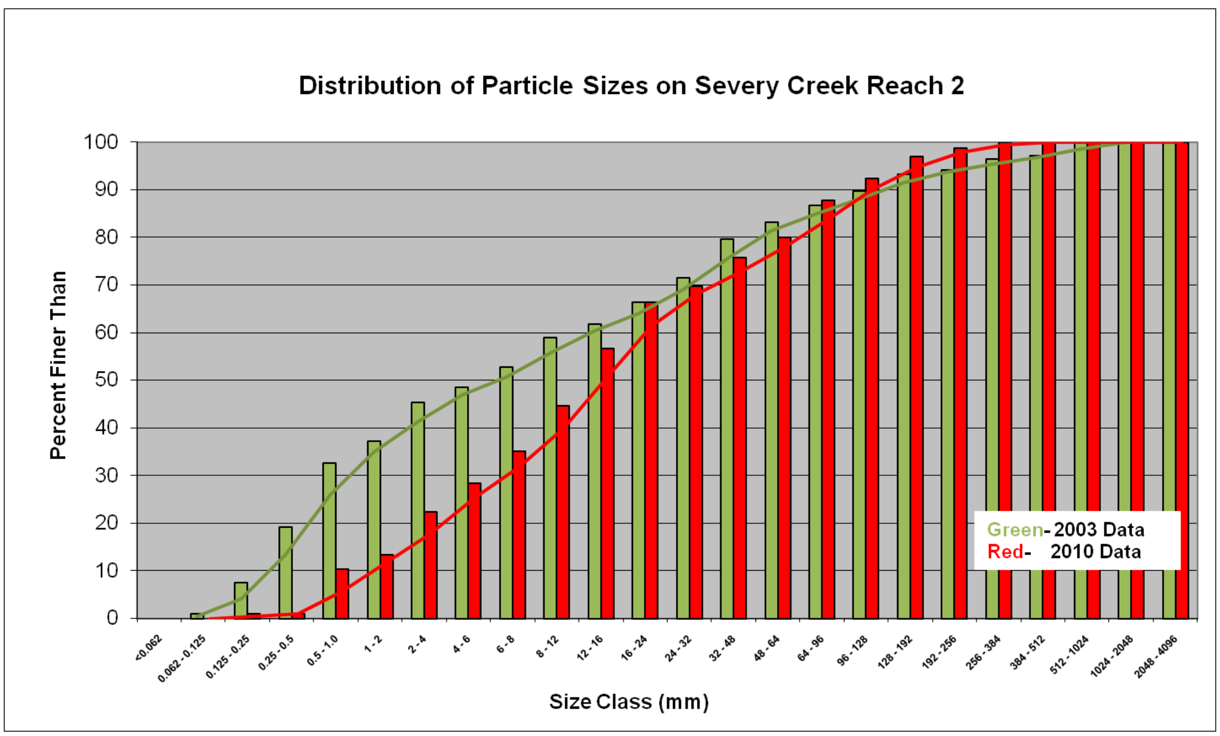

Severy Creek Natural Gully 2
Cross Section XS1
3510.75
3510.5
3510.25
3510
3509.75
3509.5
Elevation (m)
0
100
200
300
400
500
600
700
Distance (cm)
09/08
7/09
06/10
08/10

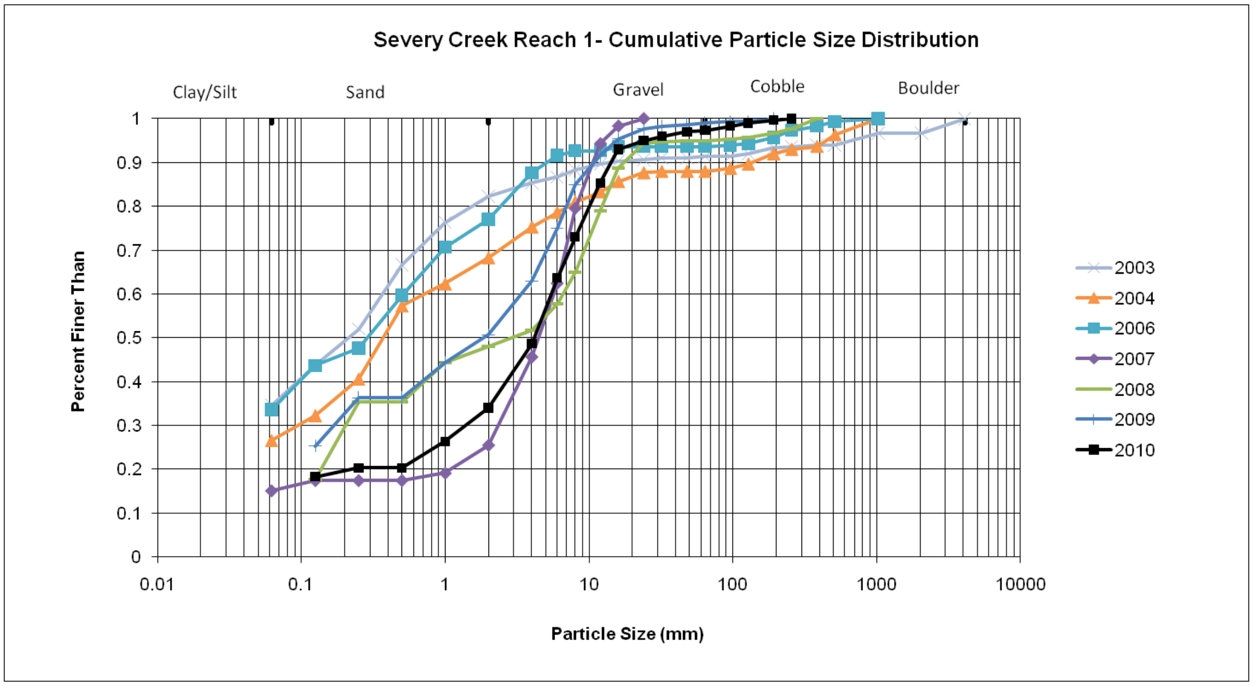

Severy Creek Natural Gully2
Cross Section XS2
3475.5
3475
3474.5
3474
3473.5
3473
3472.5
Elevation (m)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
Distance (cm)
09/08
7/09
10/09
06/10
08/10


Severy Creek Natural Gully 2
Cross Section XS3
3446
3445.5
3445
3444.5
3444
3443.5
3443
Elevation (m)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
Distance (cm)
09/08
07/09
10/09
06/10
08/10

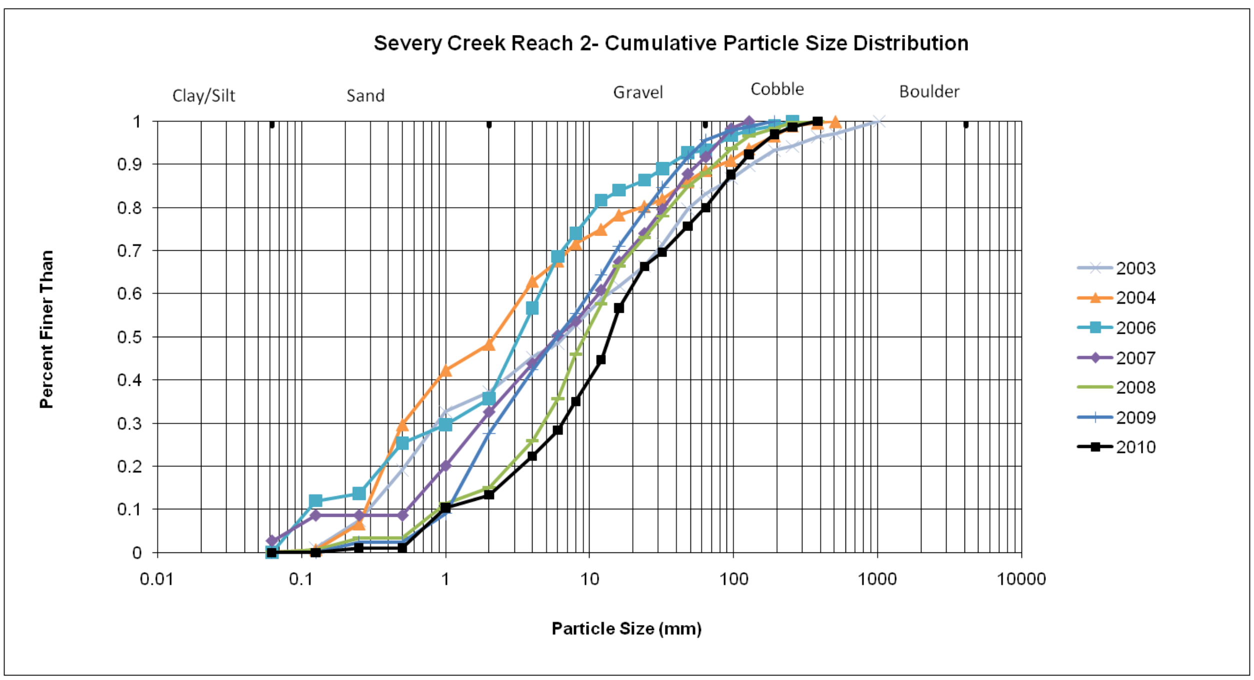
Appendix F. Pebble Count Data for Severy Creek Reach 1 and 2







Severy Creek Reach 1- Cumulative Particle Size Distribution
Clay/Silt
Sand
Gravel
Cobble
Boulder
Percent Finer Than
Particle Size (mm)
0.01
0.1
1
10
100
1000
10000
2003
2004
2006
2007
2008
2009
2010



Severy Creek Reach 2- Cumulative Particle Size Distribution
Clay/Silt
Sand
Gravel
Cobble
Boulder
Percent Finer Than
Particle Size (mm)
0.01
0.1
1
10
100
1000
10000
2003
2004
2006
2007
2008
2009
2010