2014

Past, Present, Future: The Evolution of a Wetland Treatment System in Dutchman Canyon on Vermejo Park Ranch

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Past, Present Future: The Evolution of a Wetland Treatment System in Dutchman Canyon on Vermejo Park Ranch

By

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Purpose:

The purpose of this research was to track the evolution of a constructed wetland system through time while taking into consideration anthropogenic perturbations to the system. It was accomplished by reviewing 30 year's-worth of literature associated with the project site, gleaning relevant information, and then synthesizing the information to form a complete evolutionary timeline.

In the mid-1980's, a series of evaporation ponds were built to manage mine effluent originating from three collapsed coal mine adits. The site was revisited in 2009 to conduct an Environmental Assessment (EA) at which time vegetation and basic water quality data were collected. The EA was conducted to establish a baseline habitat and water quality assessment to determine the environmental impact of a large-scale mine reclamation project on the site. Based on the information provided in the EA, the Office of Surface Mining (in coordination with State and Federal agencies) issued a Finding of No Significant Impact (FONSI).

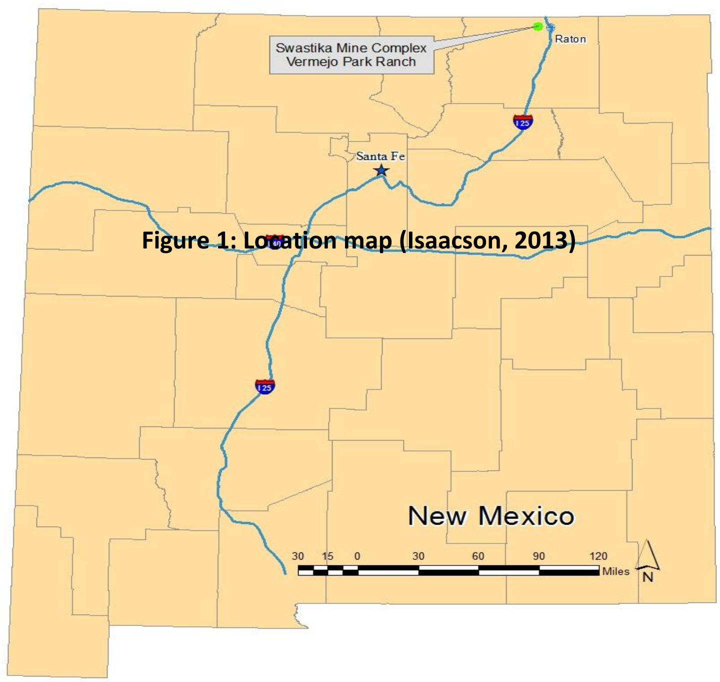


Figure 1: Location map (Isaacson, 2013)

In August 2012 a wetland was constructed using water from the evaporation ponds. The Dutchman Canyon wetland, a continuous flow, free surface wetland, was thus formed. The wetland was intended to passively treat poor-quality mine seepage and impart an improved wetland habitat for a diversity fauna occupying the almost 600,000 acre Vermejo Park Ranch (Ranch) where this system is located (Figure 1). The expanded wetland acreage at Dutchman was also expected to offset wetland losses associated with a large-scale reclamation project within the same mine complex.

Background:

The project area is approximately one mile west of the I-25 corridor near Raton, NM on land owned by the Vermejo Park Ranch, a holding of Ted Turner Enterprises. The entire 600,000 acre ranch lies within the Raton Coal Field. The north-south-trending basin extends into Colorado and is 150 miles long by 120 miles wide. Its southern boundary is near Mora in the Canadian River Valley, and its northern limit is Pueblo, Colorado. The Sangre de Cristo Mountains bound the basin on the west and the High Plains can be thought of as the eastern border. The project area lies in the Raton Mesa group which is

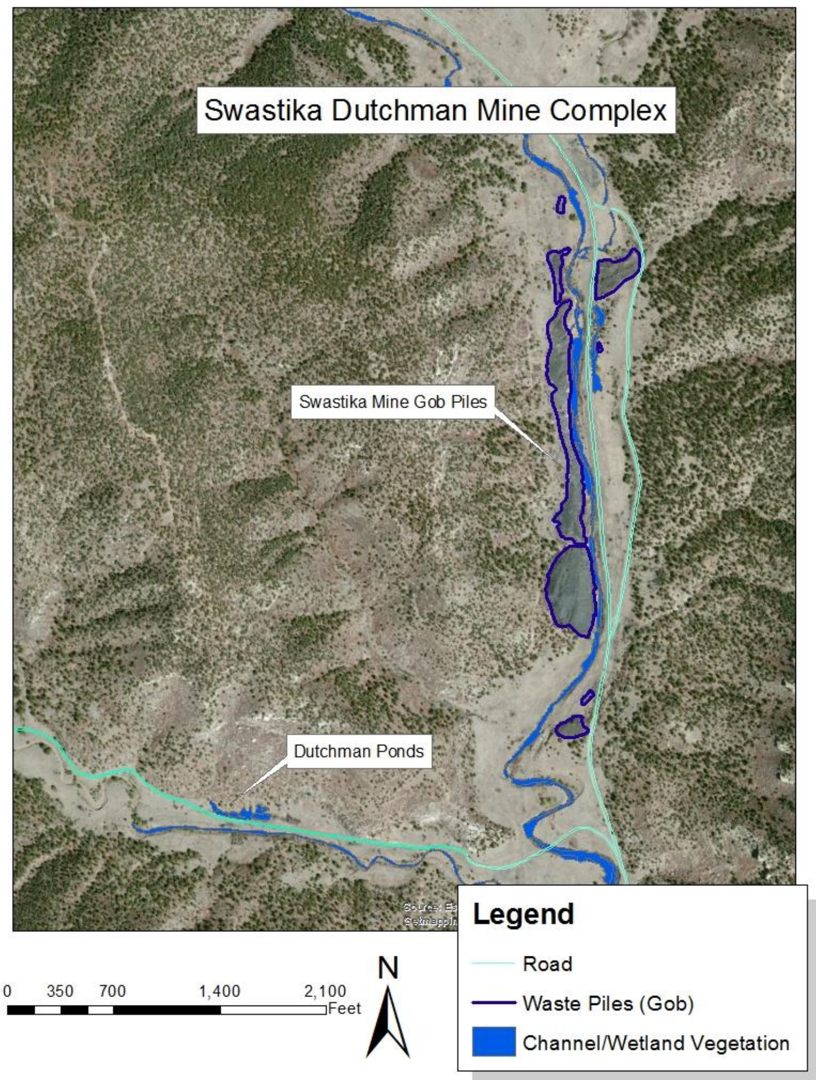


Figure 2: Swastika Dutchman Mine Complex Pre-Reclamation (Isaacson, 2014)

characterized by lava-capped erosional mesas. The Raton Basin exhibits variable physiography, structure, stratigraphy, and petrography, with differences in elevation, climate, vegetation, and land use (Lee 1922).

The Dutchman Canyon Ponds are located within the Swastika Mine Complex in Dillon Canyon on the Ranch. These ponds were constructed in the late 1980's to impound perennial flow from underground mine workings of the Dutchman Canyon Mine. For more information regarding the project location, climate, geology, wildlife uses, and plant community, please see **Appendix 2 : Project Location.**

Permitting:

The wetland creation was authorized by the United States Army Corps of Engineers (USACE) through the issuance of an USACE Nationwide Permit 27 (Aquatic Habitat Restoration, Establishment, and Enhancement Activities) under Section 404 of the Clean Water Act (Ecosphere Environmental Services 2014).

A Preliminary Jurisdictional Determination request and wetland delineation report for the Vermejo Park Ranch Historic Mine Reclamation Project Area, which included the Swastika Mine area and Dillon Canyon drainage, was submitted to the USACE in November 2009 (WET 2009). A wetland mitigation and monitoring plan, Wetland Mitigation Plan for Reclamation and Safeguarding of Abandoned Coal Mine Sites in Dillon Canyon, Colfax County, New Mexico (WET 2010), was also provided to the USACE in March 2010 (Ecosphere Environmental Services 2014). The monitoring plan included special success standards in addition to those outlined in the Nationwide 27 Permit. Success criteria are discussed in greater detail later in this paper.

Wetland Creation:

Phase I: Mine Seepage Management (Construction of Evaporation Ponds- 1986)

In the 1980's, the NM Abandoned Mine Land Program (AMLP) piloted an EA of what is now part of the Ranch in an effort to understand the ecological effects of legacy coal mining. The goal  ultimate was to safeguard mine openings and mitigate water quality impacts related to water seeping from the mines. In the late 70's to early 80's, three adits associated with the Dutchman Mine collapsed, either from natural or human causes. This resulted in water draining from the inner workings of the mine and flowing down the center of the valley. Water quality from the mine drainage is summarized in Table 1.

Figure 3: Mine effluent from upper adit (2009 EA)

The poor quality of the wastewater was a primary concern of the AMLP and was believed to be affecting wildlife and cattle birthing rates:

> "Ranching, mining, and hunting are the prime sources of income in Raton. The acid mine drainage problem that exists in the Raton area is not only a detriment to the environment, but also a threat to the cattle and wildlife in the area. These two commodities can be adversely affected by low birth rates and weights due to the heavy metal contamination of the water resource (New Mexico Abandoned Mine Land Program 1986)."

The 1986 EA goes on to state "…Dutchman Canyon is the site of three abandoned and closed adits. Water flows from each of these adits and into the creek." The water flowing from the adits is mentioned as being "very high in alkalinity" and subsequently contaminates the creek- a main watering source for wildlife and cattle in the area. Exact values or results from water quality testing are below.

1986 Dutchman Canyon Water Quality Report (water samples collected from seepage)		
Analyte	Concentration	Units
pH	8.4	SU
EC @25 °C	3700	uS/cm
TDS	3886	mg/L
HCO_3	2785	mg/L
CO_3	14.7	
Ca	10	mg/L
Mg	2.6	mg/L
K	6.7	mg/L
Na	1030	mg/L
Cl^-	37	mg/L
SO_4^{2-}	ND	mg/L

Table 1: Water Quality Results, Dutchman Mines 1986 (1986 EA)

Ultimately, the main channel flows into the Canadian River and offered potential impacts for downstream users. The preferred alternative to address this issue was to “construct an evaporating pond so that the alkali can be precipitated out prior to the discharge entering the creek and revegetate all areas disturbed (New Mexico Abandoned Mine Land Program 1986).”

The dated EA discusses a second alternative: vegetating the flow area with plant species capable of fixing salts; however, “this would be an expensive means of reclamation. As research into this problem is in its advent and the appropriate plant species for alkaline fixation have not been clearly identified (New Mexico Abandoned Mine Land Program 1986)”. However, vegetation surveys were not conducted for this EA; halophytic vegetation suitable for uptake and bioremediation may have been present on the property at this time. According to the EA, both alternatives would improve riparian and fish habitat along the creek channel in Dutchman Canyon, and the revegetation of disturbed sites would enhance wildlife habitat.

In total, two ponds were built (fall of 1987); an upper, westernmost pond, and a lower, easternmost pond and cattails were planted. However, vegetation in these ponds failed to survive due in part to the salinity of the water. During the initial construction, a culvert was placed at the lower end of the easternmost pond to convey water under the road and into the Dutchman Canyon drainage (the stream) adjacent to ponds. The outfall location of the culvert caused considerable erosion into the stream bank and roadside, while large storm events and periods of high flow would wash the road out entirely. Lack of water quality improvement, road maintenance, culvert degradation, and restrictive access in the rainy season was of concern to the ranch managers and instigated a revisit of the Dutchman Pond sites 20 years later in 2009.

Phase II: Environmental Assessment (2009)

In a field visit in 2009, the ponds were re-visited and the water quality analyzed for pH, Electrical Conductivity (EC) and temperature. The westernmost pond (the upper pond) had a pH of 10.24 and an EC of 3777 μs/cm at 23.6 °C and the easternmost pond (lower pond) tested for pH of 10.04 and an EC of 4184 μs/c at 23.5 °C (cation and anion concentrations were not measured) and discharge into the ponds was estimated to be 30 to 50 gallons per minute. pH and EC values were significantly higher in 2009 than in 1986; reasons for this are unknown.

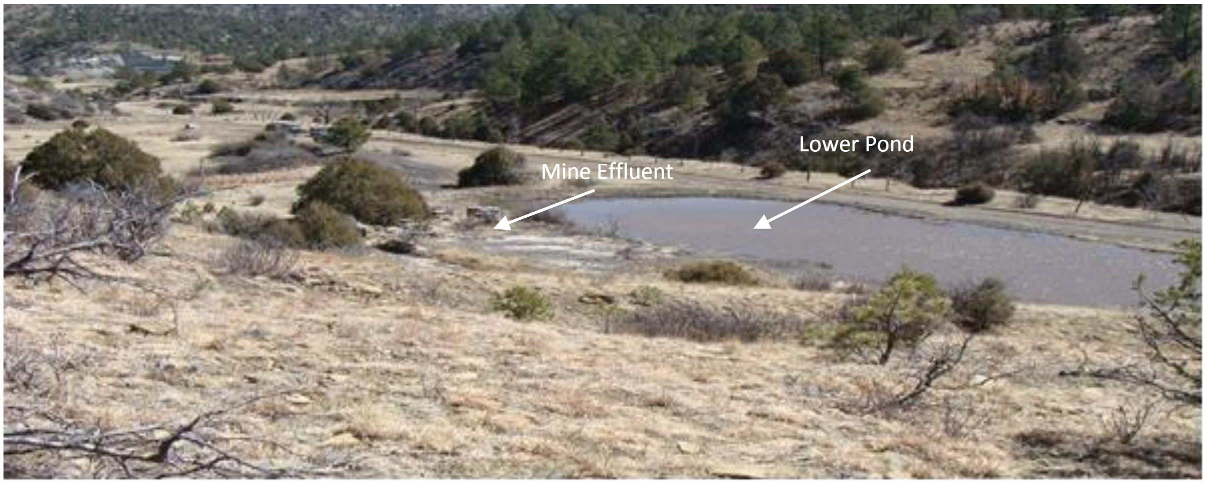


Figure 4: Above lower pond looking southeast (2009 EA)

The areas immediately adjacent to the evaporation ponds and along the path of the mine effluent evolved as emergent marsh wetland zones. In total, 0.49 acres were delineated as part of the wetland delineation required for the EA. 0.28 acres were considered emergent marsh (areas where the vegetation is rooted in saturates soils for much of the growing season), and another 0.01 acre was categorized as wet meadow (lands dominated by wetland vegetation and exhibit indicators of wetland hydrology). According to the 2009 Wetland Delineation, the dominant obligate vegetation in the emergent marsh zone were: mountain rush (*Juncus arcticus*), cosmopolitan bulrush (*Schoenoplecus maritimus*), and common threesquare (*Schoenoplectus pungens*).

Dominant wetland indicatior species for Dutchman Canyon (in 2009) included the following:

Genus	Species	Common Name	Wetland Indicator Status	Emergent Marsh	Upland
Graminoids: Perennial Introduced					
Puccinellia	*distans*	weeping alkaligrass	FACW	D	D
Graminoids: Perennial Native					
Bouteloua	*gracilis*	blue grama	NA		D
Juncus	*arcticus*	mountain rush	OBL	D	
Pascopyrum	*smithii*	western wheatgrass	FAC-		D
Schoenoplectus	*maritimus*	cosmopolitan bulrush	OBL	D	
Schoenoplectus	*pungens*	common threesquare	OBL	D	
Forbs: Annual Introduced					
Kochia	*scoparia*	kochia	FAC		D
Forbs: Perennial Native					
Artemisia	*frigida*	fringed sage	NA		D
Cirsium	*undulatum*	wavyleaf thistle	FAC-		D
Shrubs: Perennial Native					
Gutierrezia	*sarothrae*	snakeweed	NA		D
Rhus	*trilobata*	threeleaf sumac	NI		D

Table 2: Dominant Species in Dutchman Canyon Delineation (HMI Wetland Delineation 2009)

Coal waste, often referred to as gob, littered the canyon near the ponds adding to downstream water quality degradation. The meadow below the ponds contained two gob piles that also needed addressing.   Persistent stream bank erosion, road maintenance, and degradation of downstream waters were considered areas of concern and prompted the 2012 reclamation.

Figure 5: Standing at downstream edge of second pond looking east (2009 EA)

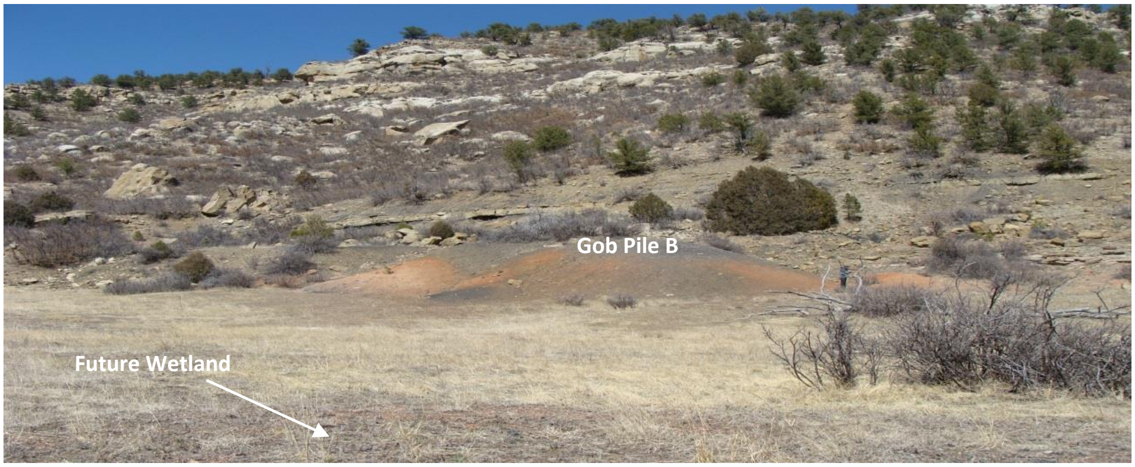


Figure 6: Looking north from road below ponds (2009 EA)

Phase III: Installation of Spillway and Wetland Creation (2012)

The primary objective of the 2012 reclamation was to manage mine effluent in a manner that would reduce erosion of the stream bank and road flanking the pond system while improving water quality. To mitigate the effects of the mine seepage, the culvert was removed and a spillway was excavated in native soil at the downstream end of the last pond, immediately north of a constructed embankment that now forms the south side of the pond system. The spillway is essentially a rock rundown approximately 15 ft. by 4 ft. composed of basalt riprap 8 in. to 10 in. in diameter.

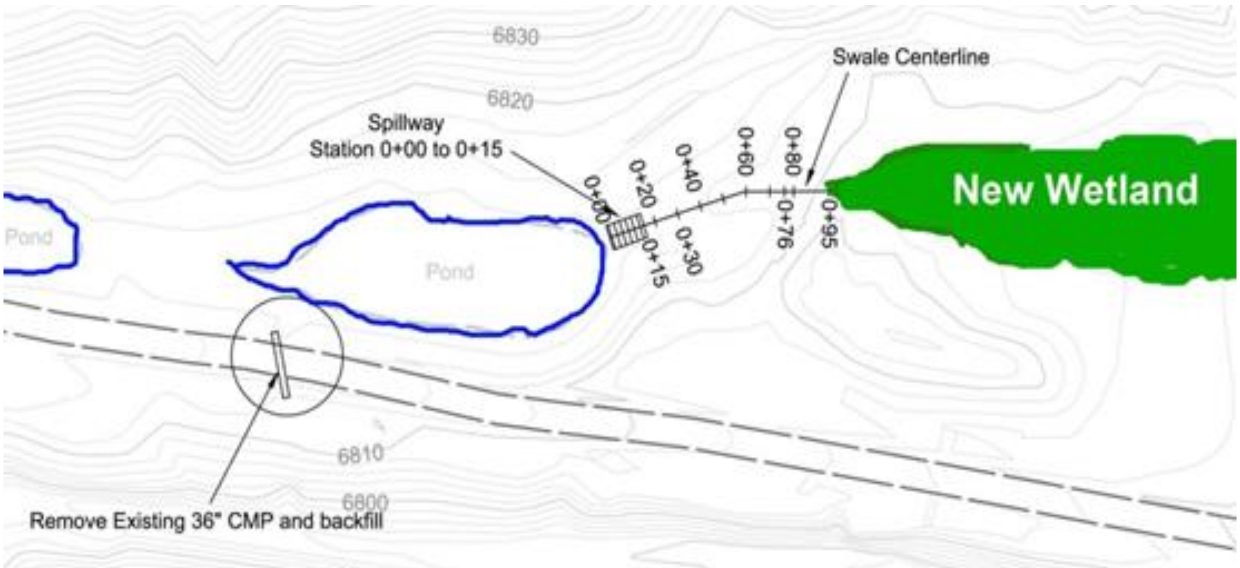


Figure 7: Design specifications of spillway and wetland creation

The spillway slope elevation is approximately one foot below the existing embankment elevation allowing pond outflow to wet the recently reclaimed treatment wetland of roughly 0.66 acres. Suitable freeboard was integrated into the spillway design to ensure that the spillway can pass peak flood flows without overtopping the embankment. The wetland was designed to reduce salinity, alkalinity, and acid levels in mine seepage water through phytoremediation and filtration, while infiltration and evaporation would control water levels in the wetland during most events (Habitat Management Inc. and Water and Earth Technologies). During periods of higher runoff, overflow is conveyed back into the Dutchman Canyon stream channel by a low water crossing on the Dutchman Canyon road downstream. At present, the water drains into a small meadow below the ponds. The road grade flanking the ponds was elevated, and the waste piles surrounding the meadow were reclaimed in-situ. Once the area adjacent to the spillway was deemed sufficiently hydrated, salt tolerant wetland plugs were planted. Willow stakes were also planted in groups at the far end of

Figure 8: Genesis of wetland August, 2012 (Isaacson 2012)

the saturated meadow. The intent is to maintain a mosaic of vegetation by encouraging both wetland grasses and shrub coverage.

The gob piles within the saturated meadow were reclaimed in place by amending the waste material with gypsum and lime. Compost was then ripped to a depth of eight inches. Once the piles were re-graded after ripping with perpendicular furrows, the piles were seeded and covered with wood straw mulch.

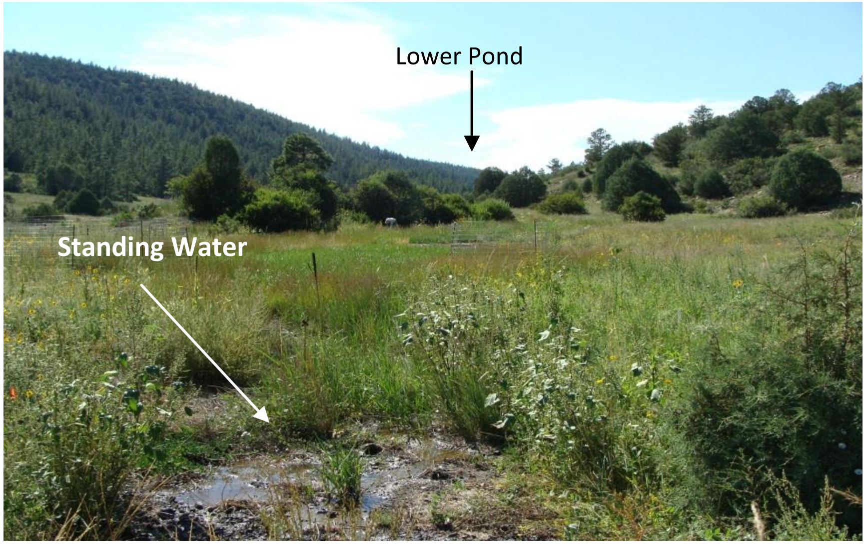


Figure 9: Standing water and wetland vegetation (Isaacson 2013)

Wetland plugs harvested onsite, were planted along the tongue of hydrated soil resulting from the installed spillway. Each of the wetland plugs contained several different plant species and were collected from nearby wetlands. Since the water entering the system has distinct alkaline characteristics, testing the water quality of the effluent leaving the wetland system would help give insight as to whether the salt tolerant plugs were in fact acting as bio-accumulators and naturally treating the water. The entire area was also seeded with mixes specially formulated for this site and referred to as either the Dutchman Wetland Mix (for the low-lying, flat areas within the saturated zone), or the Swastika Upland Mix (for elevated areas above the saturation zone). For seed mixes, refer to Appendix 5.

Black and narrow leaf willows (*Salix nigra* and *Salix exigua*, respectively) were also planted in the wetted meadow. Narrow leaf willow stakes were harvested onsite and the black willow was harvested from the waste water treatment plant in Santa Fe, NM. Black willow tends to have a higher salt tolerance than the narrow leaf. Both willow varieties were planted along the channelized flow and downstream where the water begins fanning out. Three animal exclosures were built surrounding the poles furthest downstream to prevent grazing.

Another important component of wetland ecology is the presence of hydric soils, which by definition is: “a soil that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper 10 inches of soil (Laboratory, 1987).” According to USACE, not all areas containing hydric soils may be considered a wetland; “only when a hydric soil supports hydrophytic vegetation and the area has indicators of wetland hydrology may the soil be referred to as wetland soils (Laboratory, 1987).” Wetland soils take decades to develop, therefore the timing of this project does not allow for the formation of such soils. However, if monitoring and data collection show that this landscape is saturated for seven months during each year, we can be fairly confident that this area could develop into a wetland meeting all the criteria presented by the USACE.

To determine whether the behavior of this man-induced system mimics that of a true wetland, the guidelines and methods set forth in the *Army Corps of Engineers Wetland Delineation Manual* were followed. Vegetation and soil data information was used to help inform hydrologic characteristics.

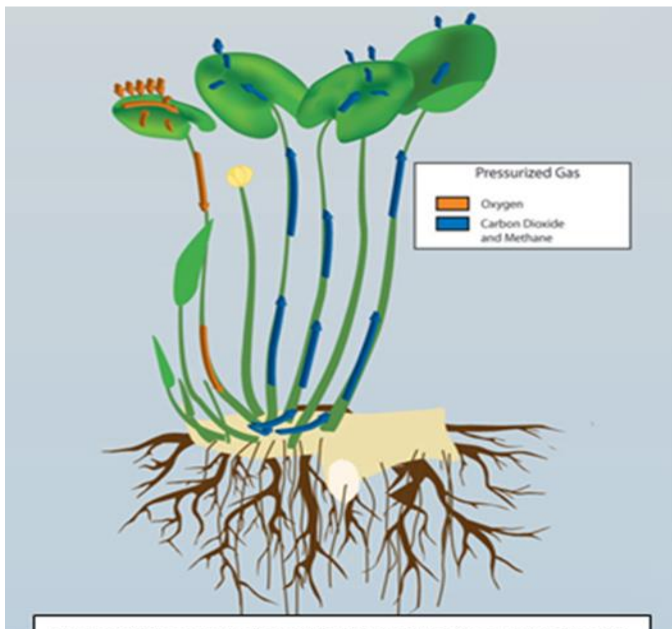
The objective of the reclamation efforts in this canyon was to not only improve water quality, but to do so using a method that would create a wetland habitat. To assess the success of that goal, several items were addressed. For instance, did the area of saturated soil behave like a wetland? If so, what was the effectiveness of the wetland treatment in mitigating the water quality issues at present?

Wetland Function:

In the past 25 years, society has come to understand and appreciate the ecological benefit and economic value of wetlands. For example, federal wetland policy has recently shifted from promoting wetland conversion to encouraging wetland protection and restoration (Ralph E. Heimlich 1998). Wetlands improve and maintain water quality, offer habitat for fish and wildlife, inhibit erosion, attenuate damage caused by flooding, and provide visually pleasing open spaces and recreational opportunities. Wetlands are complex ecosystems that provide many ecological, biological, and hydrologic functions that benefit the overall health of the landscape and enhance quality of life for many.

Ecological Functions:

Wetlands function as living filters by removing nutrients and sediments from surface and ground waters thus maintaining, and at times, improving water quality (Ralph E. Heimlich 1998). Wetlands retain or remove nutrients through uptake by plant life, adsorption into sediments, deposition of organic matter and chemical precipitation. The vegetation and often flat topography associated with wetland systems decreases the velocity of surface waters causing the deposition of sediments in turn, limiting the siltation of streams, rivers, and lakes. Sediment deposited by flood events is often rich in nutrients and can cause spikes in wetland productivity and nutrient cycling.



FigureX: Pressurized gas flow in the floating–leaved water lily, *Nuphar lutea*. (2011 Nature Education, reproduced from Dacey 1981)

In drier, more common upland systems, flooding or significant periods of inundation can be quite stressful for ecosystems not used to such events. However, wetland inhabitants, especially vascular plants, have adapted to deal with these types of stresses. Adaptations including: pressurized gas flow, the creation of oxidized root zones, and anaerobic respiration, allow wetland plants to remain productive in otherwise stressful conditions, making wetlands among the most productive ecosystems in the world (Whittaker 1973). Primary producers support secondary producers that exceed those of terrestrial ecosystems.

Biological Functions:

Wetlands are the most biologically productive ecosystems in temperate regions, rivalling tropical rain forests (Ralph E. Heimlich 1998), and they provide food and habitat for 45 percent of the nation's wildlife (Lawler 2007). Wetland biological productivity stems from their ability to recycle nutrients and energy. Wetlands are habitats for a diverse group of fish and wildlife; some species spend their entire lives in wetlands, while others use them intermittently to mate, feed or rear their young. Most freshwater fish depend on wetlands, however, both fresh and saltwater species feed in wetlands or on food produced in wetlands. Wetlands also serve as nurseries for fauna that use wetlands as safe havens to rear their young, and many species of commercial sport fish use wetlands as spawning grounds. Amphibians and reptiles, which are particularly sensitive to water quality issues, also depend on wetlands for habitat. Over one-third of all bird species in North America depend on wetlands for migratory respites, breeding, feeding, and cover from predation (Ralph E. Heimlich 1998).

Wetlands as Bird Habitats: Wetlands provide exceptional bird habitat. The value of a wetland to a specific bird species is affected by the presence of surface water and the duration and timing of flooding. Some avian species have adapted to wetlands to such an extent that their survival as individual species depends on the availability of certain types of wetlands within their geographic range. While other species use wetlands only intermittently depending on their life stage.

Figure 11: Migratory bird routes of North America (US Geological Survey 1996)

Due to the variety of wetland types, bird adaptation to, and the use of, wetlands varies greatly between species. Birds' utilization of wetlands during breeding cycles ranges widely; birds depend on wetlands for breeding, nesting, feeding and or shelter during the breeding period. Birds that require functional access to wetlands or wetland products during their lifecycle are considered wetland dependent; of the 1,900 bird species in North America, 138 are considered wetland dependent (US Geological Survey 1996).

Hydrologic Functions:

Since wetlands are often found where the water table is close to the surface, the degree of saturation can vary seasonally, especially in dry climates. Wetlands enhance soil accumulation through sediment trapping and reduce erosion by damping wave action and slowing water currents. Wetlands also act as sponges, temporarily storing flood waters and releasing them slowly. This ephemeral loading of water decreases runoff velocity, reduces flood peaks and distributes storm flows over longer time periods causing tributary and main channels to peak at different times. However this is a constructed wetland and its water levels are not determined by an associated creek, so its impact on adjacent stream hydrology is limited.

Wetlands act as natural flood conveyances channeling flood waters form upland areas into receiving waters and attenuating extreme flood events. A strong correlation exists between the size of flood peaks and basin storage. Surface water hydrologists found that basins with 30 percent or more areal coverage by lakes and wetlands have flood peaks that are 60 to 80 percent lower than the peaks in basins with no lake or wetland acreage (US Geological Survey 1996). However, not all wetlands are able to store floodwaters or modify storm runoff; the location and storage capacity of the wetland controls how effective a wetland will be at flood attenuation. In addition, wetlands in basin headwaters are often sources of runoff because they are commonly groundwater discharge zones. For example, wetlands in Alaska that are underlain by permafrost have little to no storage capacity, runoff is therefore rapid and flood peaks tend to be high (US Geological Survey 1996).

Wetlands can also influence local and regional climate regimes. Wetlands tend to temper seasonal temperature variations. During the summer, wetlands maintain lower temperatures because evapotranspiration from the wetland converts latent heat and releases water vapor into the atmosphere. Alternately, in the winter, the warmer water of the wetland prevents fast cooling at night, preventing nearby upland plants from freezing. Wetlands may also alter local atmospheric circulation and so affect moisture convection, cloud formation, thunderstorms, and precipitation patterns (US Geological Survey 1996). When a wetland system or groups of wetlands are drained, changes in local weather systems are not uncommon. Understanding the source and movement of water through a wetland are vital for assessing wetland function and predicting how changes in wetlands will affect the associated basin (Carter 1996).

For a more thorough discussion of wetlands including: national and local trends, classification protocol, the hydrologic process as it pertains to wetlands, and soil and water chemistry, please refer to **Appendix 2: What is a Wetland?**

Monitoring Methods:

Vegetation:

The new wetland area extent was mapped several times a year. Three transects were used for the initial wetland delineation and an additional four transects were installed for future monitoring. In total, seven transects were monitored at the end of each growing season, usually the end of August.

A tape measure was stretched between the permanent markers at the end of each transect. Permanent markers were located using re-bar posts with survey caps placed on top of them to prevent any injury to wildlife. Each transect was also mapped using a GPS with sub-foot accuracy. The approximate location of the boundary between each vegetation community (i.e. upland/wet meadow, wet meadow/emergent marsh, emergent marsh/open water) was recorded along the tape measure. This allowed for determination of changes in wetland characteristics over the monitoring period.

Once the extent of each community was determined on each side of the wetland, a single sample was collected in each community. Communities along a transect, represented multiple times, were sampled each time they were encountered. Upland communities within the reclamation were sampled as well as wetland communities as a measure of reclamation success. Data was collected at the height of the growing season (generally August through early September).

The perimeter of the wetted area was recorded with a GPS multiple times throughout the study. This data, once imported to a map, showed the change of wetland hydration through time and any seasonal trends that have may occurred.

Water Quality:

The constructed wetland is approximately one acre in size, however, only water in the hydrated zones was tested. Water samples collected for analysis by the lab utilized a near-surface grab sample technique where possible. All samples were collected where surface water was present, but not stagnant. Samples were placed in a cooler with ice (to maintain a temperature at or below 6 degrees Celsius), and transported to either the University of New Mexico or Energy Labs in Billings, MT for analysis. Water samples were collected from the lower pond and two downstream locations. The following analytes were measured: pH, EC, Ca Na, Mg, K, CO^3, HCO^3, Cl^-, and $SO_4{}^2$-.

Remote Sensing:

This area is currently being surveyed by aerial photography on a quarterly basis to gather data by remote sensing method. This information can be used in conjunction with visual assessments and transect measurements to measure changes in wetland vegetation through time. However, these results were not available at time of publishing.

The AMLP currently has 2012 (pre-construction) imagery; 2013 and 2014 (post construction) imagery has been gathered, but at this time remains unprocessed. The next step in analyzing this data is to apply a new algorithm to test for wet soils; this has direct implications for ease of measuring wetland extents and changes through time.

Remote sensing data is gathered using the World View 2 mapping technology with eight spectral bands rather than the usual four. The use of eight bands allows for greater resolution regarding vegetation than the color infrared used with four bands. The eight band spectrum utilizes both the near infrared and red edge which provides greater insight into vegetation health and plant discrimination through increased sensitivity to adsorption and reflection of chlorophyll.

The pixel resolution is 0.5 meters meaning it can pick up individual objects 1.5 meters wide; one of the goals of this research was to see if individuals of a community could be identified to the species level.

Reclamation Success Standards:

In addition to the generic standards for success outlined in a basic Nationwide Permit 27, this reclamation included the following conditions based on the 2009 Wetland Delineation:

1. The mitigation and monitoring plan (*Wetland Mitigation Plan for Reclamation and Safeguarding of Abandoned Coal Mine Sites in Dillon Canyon, Colfax County, New Mexico*) submitted in the application will be implemented, including proposed monitoring requirements (Ecosphere Environmental Services 2014).
2. Annual monitoring reports, to include information as described in the permit application shall be due each year on December 31 for a period of not less than five years. After Year 3, should the proposed restoration reach the success criteria in the application, final approval from the USACE may be requested (Ecosphere 2014).

As outlined in the Wetland Mitigation Plan, " … reconstructed wetlands and mitigation areas in the Reclamation Project area will be deemed successful if quantitative vegetation monitoring, photo documentation and post project walkthroughs indicate an establishing riparian community, healthy jurisdictional wetland communities, and functioning stream channels (WET 2010)." Therefore, success for this portion of the greater Swastika Reclamation Project were evaluated on the degree of wetland species establishment. The following goals to determine success for the wetland area were detailed in the Wetland Mitigation Plan (WET 2010):

1. Success criteria shall be evaluated through annual monitoring of the reconstructed channel and wetland functions in the mitigation area for a period of 5 years using methodology identified in the restoration and mitigation plan.

Growing Season	Total Vegetation Cover Goal or Standard (Percent)
1	**10**
2	**15**
3	**30**
4	**60**
5 or	**Standard=80**

Table 3: Vegetation Success Criteria by Year (Ecosphere Environmental Services 2014)

In addition to the total vegetation cover standard, each wetland community (wet meadow and emergent marsh) must meet several additional criteria:

1. Hydrophytic plant species—i.e., Obligate (OBL), Facultative Wet (FACW), or Facultative (FAC)— must represent a minimum of 50 percent of the dominant species present using the "50/20" rule.
2. Indicators of wetland hydrology must be present.
3. Native species must represent a minimum of 50 percent of the dominant species present using the "50/20" rule.
4. A minimum of three plant species shall be classified as dominant in each community using the "50/20" rule.

These vegetation goals and standards were applied for both emergent marsh and wet meadow vegetation communities within the Dutchman wetland mitigation area (Ecosphere Environmental Services 2014, WET 2010)."

Results:

Wetland Extents:

In the 2009 Wetland delineation of Dutchman Canyon, 0.29 acres of wetland community was identified. In 2014, two full growing seasons after the wetland was constructed, 0.34 additional acres of wetland were delineated through vegetation monitoring and GIS mapping. The preexisting wetland habitat remained intact; currently the project site has approximately 0.63 acres of wetland habitat, a 100 percent increase in only two years. Since perennial flow has been documented at this site for almost three decades, one can reasonably conclude that this wetland will likely be sustained through time. However, expansion of the wetland extents seems to have plateaued; several measurements of the wetland area in 2014 showed little or no change in the saturated acreage. Therefore, it is fair to conclude that the wetland area has maxed out; without mechanical intervention to eliminate the topographic limitations of the site, the wetland extents are not likely to increase much beyond the 0.34 acres observed in October 2014.

The total wetland acreage as of October 2014 is 0.63 acres; according to Lawler 2007, an emergent wetland can produce up to 4 pounds of biomass per 10 $ft.^2$ per year, this equates to 10,977 pounds of biomass produced each year by the newly constructed wetland. This has significant impacts on carbon storage, nutrient cycling, and water holding capacity of soils to name a few. Wetlands also provide between 3,000 to 5,000 pounds of forage per acre per year (Zeedyk, 2014). The constructed wetland provides large ungulates and other grazing animals with 1,800 to 3,150 pounds of food mass, not to mention the habitat created for insects and other primary consumers that in-turn provide food for a plethora of wetland-dependent biota.

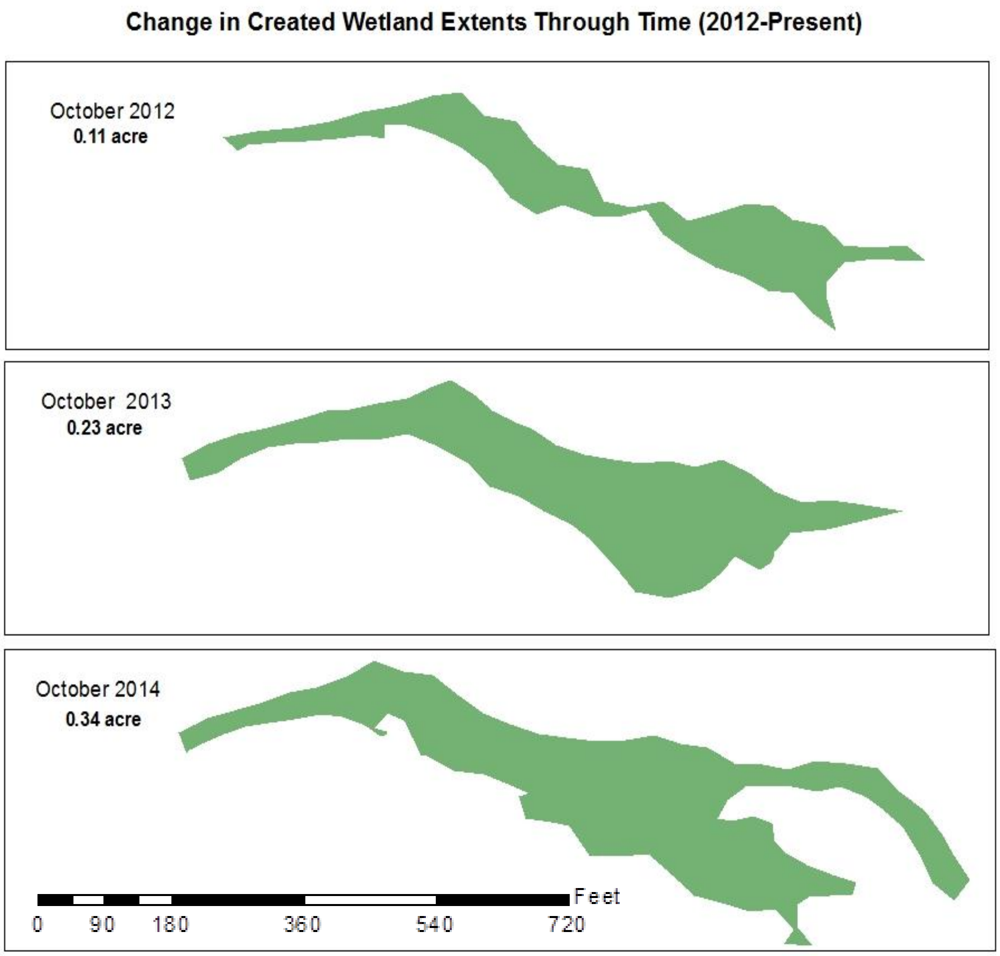


Figure 12: Change in wetland extents through time (Isaacson 2014)

Vegetation:

Vegetation monitoring occurred at seven transects located just upstream of the reclamation area and extended through the most downstream extent. The methods used for measuring vegetative cover and species diversity are described in the monitoring section of this paper. In total, 45 species were identified in both the wetland and upland fringes of the reclamation. Of those, only six are considered wetland obligate or facultative species (Table 4). Four communities were identified based on vegetation cover and type: dry channel (disturbed), emergent marsh, wet meadow and upland.

Dry channels are areas of the study site that exhibit frequent episodes of disturbance and overland flow. These areas contain little vegetation and will not support wetland vegetation due to lack of water and/or poor soil conditions. Dry channels occurred along the roadside and at mine seeps where the water is alkaline and saline. Dry channels accounted for five percent of the total 587 linear feet of delineation.

An area described as an emergent marsh is areas where the vegetation is rooted in saturates soils for much of the growing season; soils in this community were flooded for most of the year. The vegetation is usually dominated by species with an obligate (OBL) or facultative wetland (FACW) wetland indicator status, meaning they can tolerate anaerobic soil conditions resulting from inundation. Of the 11 wetland indicator species found, only three are considered OBL: *Schoenoplectus pungens* (common three square), *Schoenoplectus maritimus* (cosmopolitan bulrush), and *Juncus articus* (mountain rush). Four species in the Ducthman delineation were considered FACW by the USACE: *Puccinellia distans* (weeping alkali grass), *Polygonum aviculare* (prostrate knotweed), *Agrostis gigantean* (redtop), and *Hordeum jubatum* (foxtail barley). Emergent marsh communities accounted for 36 percent of the total delineation.

Wet meadow communities were dominated by wetland vegetation and exhibited indicators of wetland hydrology although, these areas are flooded only part of the year and are therefore inundated for shorter periods than emergent marsh communities and tend to lack saturated surface soils. Wet meadow and upland boundaries were hard to identify due to the abundance of disturbed soils in Dutchman Canyon.

All communities identified as emergent marsh existing in the constructed wetland had a cover of wetland vegetation of 80 percent or greater, with the exception of transect ZI1, which had a cover of less than 10 percent. This may be a function of its proximity to the spillway as well as the vegetative type. In this area, the contractors planted non-halophytic vegetation which may have out-competed the more suitable vegetation, though ultimately dying off once the salinity levels exceeded their tolerances.

The following classification, from the “Handbook of Wetland Vegetation Communities of New Mexico” best describes the current vegetative community at the constructed wetland as Threesquare Bulrush Alliance.

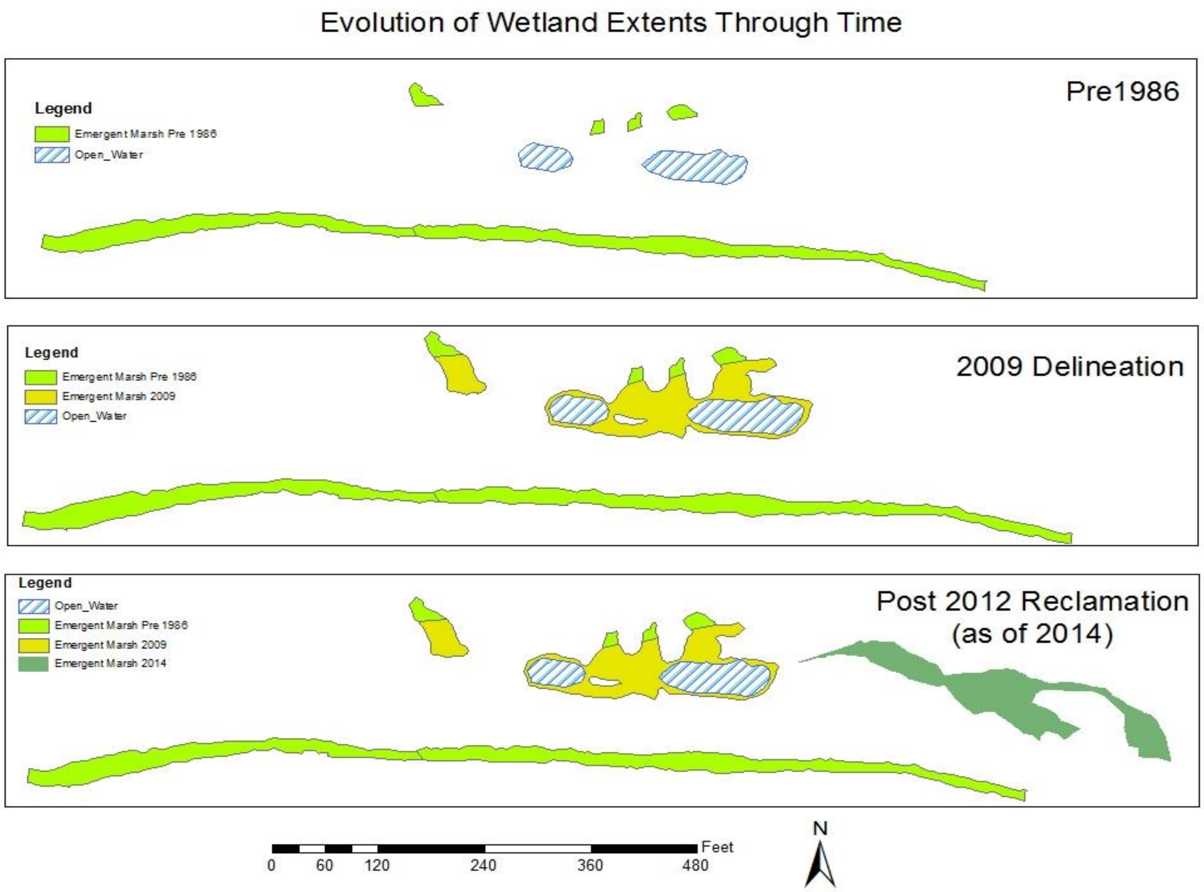


Figure 13: Map depicting wetland changes through time (Isaacson 2014)

<u>Threesquare Bulrush Alliance:</u>

NM Classification: Lowland Western Persistent Emergent Wetland, Semi permanently Flooded.

Distribution: Widespread in the Rocky Mountains and Southwest. In New Mexico it occurs in every major basin of the state including watersheds of the Gila, Pecos, San Juan, Canadian and Rio Grande.

This emergent herbaceous wetland is characterized by the dominance of threesquare bulrush in association with a wide variety of wetland graminoids to form a canopy of 90 percent total cover. Within the wetland extents, current canopy coverage exceeds 80 percent total cover in most areas of saturated soil conditions. However, it will take several years for this wetland to fully develop, therefore at this time, we cannot, determine this wetland's classification. At the end of this multi-year study, researchers hope to establish these wetland characteristics.

Wetland Indicator Species Collected at Dutchman	
Schoenoplectus maritimus (cosmopolitan bulrush)	OBL
Schoenoplectus pungens (common threesquare)	OBL
Agrostis gigantea (redtop)	FACW
Juncus articus (mountain rush)	FACW
Polygonum aviculare (prostrate knotweed)	FACW
Puccinellia distans(weeping alkaligrass)	FACW
Echinochloa colona (jungle rice grass)	FAC
Hordeum jubatum (foxtail barley)	FAC
Kochia scoparia (kochia)	FAC
Pascopyrum smithii (western wheatgrass)	FAC
Portulaca oleracea (common purslane)	FAC

Table 4: Wetland Indicator Species found at Dutchman 2013 Monitoring (Isaacson 2013)

Water Quality:

Guidelines to assess the pre and post wetland creation water quality are outlined in New Mexico Water Quality Standards (20.6.4 NMAC); however, since these ponds are not considered 'navigable waters of the US' these criteria are merely a metric to assess water quality and are not regulated. 20.6.4 NMAC states that the following water quality limits apply to the following waterways, which includes the Dillon Canyon drainage:

(20.6.4.309) CANADIAN RIVER BASIN *- The Mora River and perennial reaches of its tributaries upstream from the state highway 434 bridge in Mora except lakes identified in 20.6.4.313 NMAC, all perennial reaches of tributaries to the Mora River upstream from the USGS gaging station at La Cueva, perennial reaches of Coyote Creek and its tributaries, the Cimarron River and its perennial tributaries above State Highway 21 in Cimarron except Eagle Nest Lake, all perennial reaches of tributaries to the Cimarron River north and northwest of*

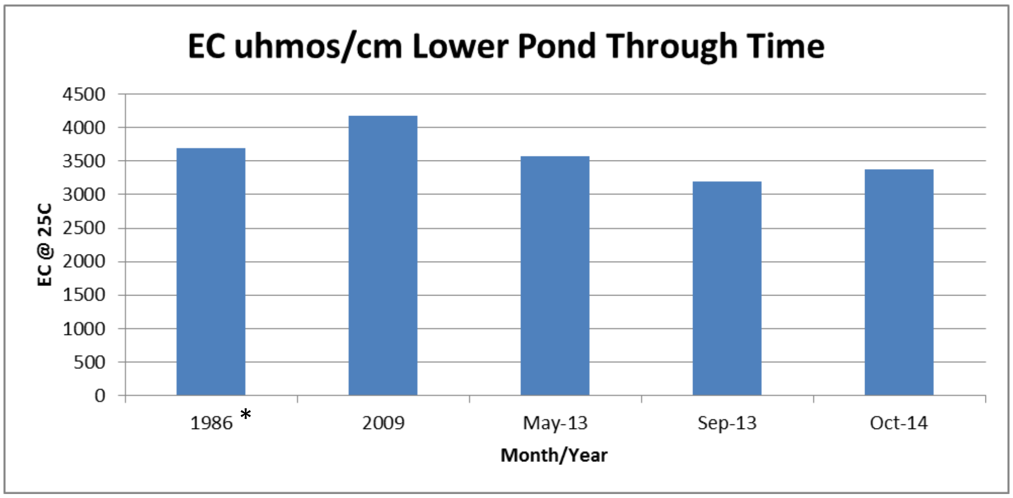
Highway 64 except north and south Shuree Ponds, perennial reaches of Rayado Creek and its tributaries above Miami Lake diversion, Ocate Creek and perennial reaches of its tributaries upstream of Ocate, perennial reaches of the Vermejo River upstream from Rail Canyon and all other perennial reaches of tributaries to the Canadian River northwest and north of U.S. Highway 64 in Colfax County unless included in other segments.

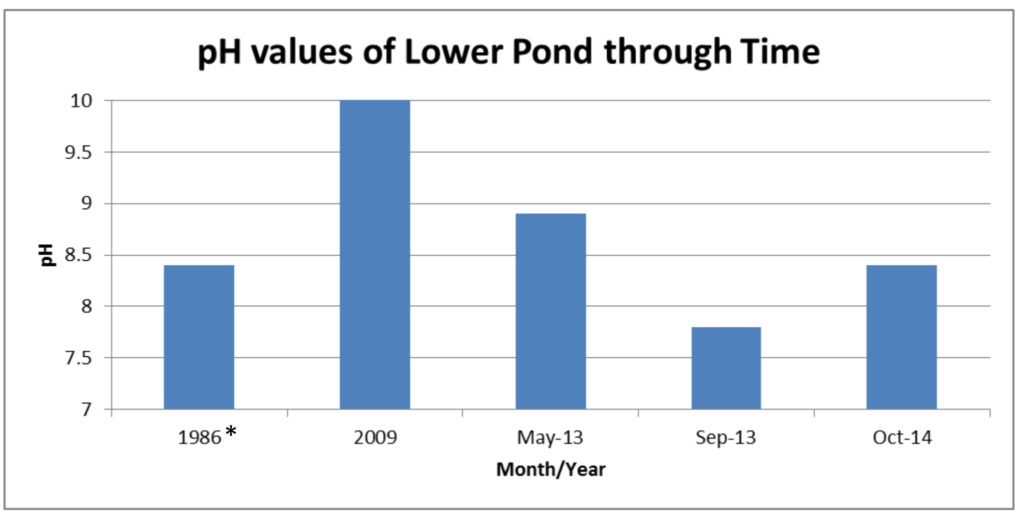
- Limits for pH for Primary Contact are in the range of 6.6 to 9.0;
- Limits for Marginal Warm-water Aquatic Life are Temperature: 32.2^0 C (90^0 F)(maximum) and pH: 6.6 to 9.0;
- Limits for TDS is <3,500mg/l for flows less than 10 cfs;
- Limits for electrical conductivity (EC) or specific conductance 500 µS/cm or less; and
- Standard thresholds or limits for turbidity are not defined in 20.6.4 NMAC.

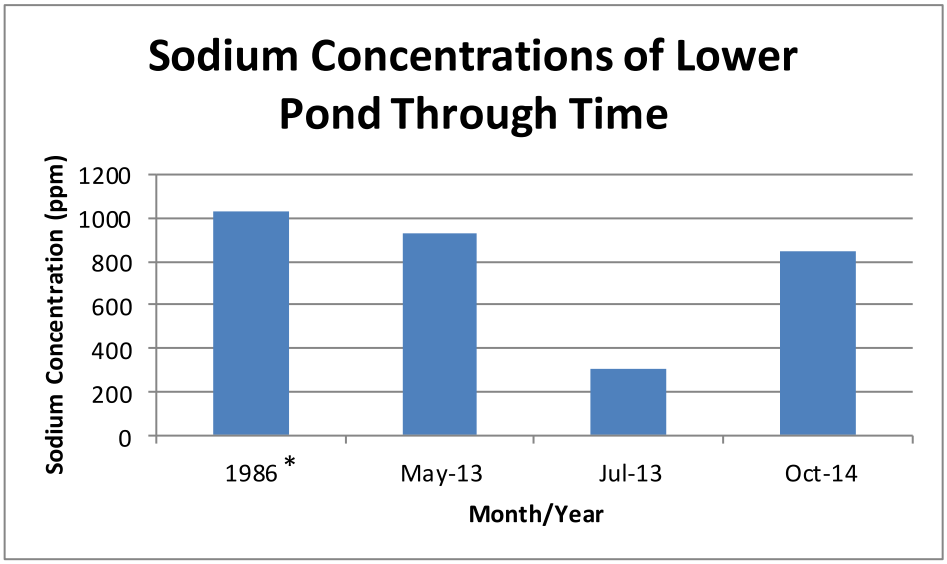
In 2009, prior to initiation of reclamation, The westernmost pond (the upper pond) had a pH of 10.24 and an EC of 3777 µs/cm at 23.6 °C and the easternmost pond (lower pond) tested for pH of 10.04 and an EC of 4184 µs/c at 23.5 °C (cation and anion concentrations were not measured). At the time of sampling, the Dutchman ponds were well above the thresholds of the Surface Water Quality Standards.

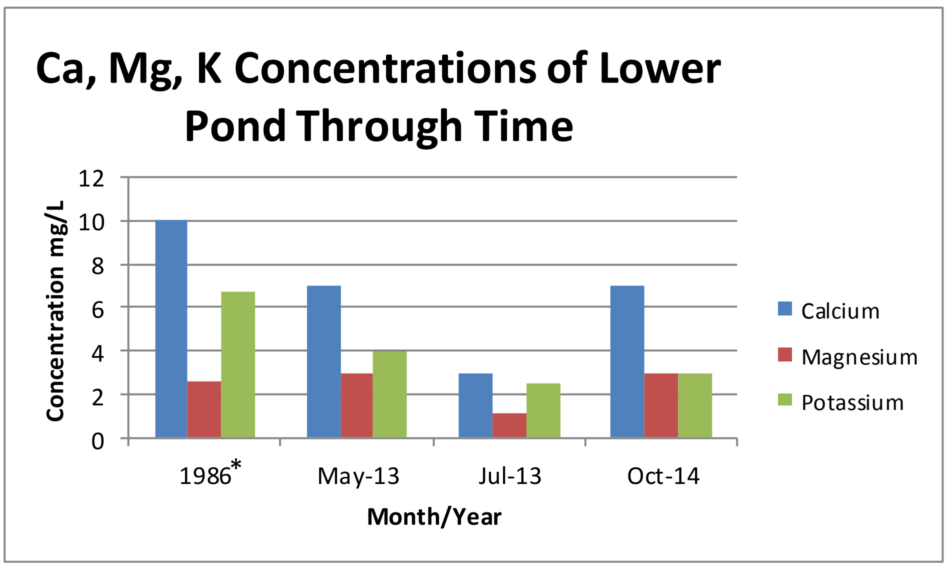
Water in the ponds prior to the construction of the spillway was tested. These tests were basic water tests testing: pH, temperature, EC and turbidity. More recently, unfiltered surface water samples were taken from four locations throughout the project site: from the upper-most adit (believed to be the largest contributor of volume into the ponds), the lower pond, a pool upstream from a sediment long approximately 100 ft. from the spillway, and the most downstream extent. The water samples are being tested for: pH, EC, Ca, Mg, Na, K, CO_3, HCO_3, Cl, and SO_4 . The sample locations are shown on Map 3 in Appendix 4.

Although monitoring water quality is not a requirement of the Nationwide 27 Permit issued by the USACE, it was tested several times over an 18 month period to help evaluate the impacts of a living system on water quality of the mine effluent- water testing proved to be inconclusive: Water temperature never exceeded 90 °F, and therefore met the State's criteria on all sampling dates between 5/21/13 and 10/7/14. However, EC measurements exceeded the State standard on all occasions hitting above 3000 µs/cm often. pH fell below the State standard of 9.0 on all occasions except on testing date 05/21/2013; transect ZI-4 had a pH value of 9.2. All samples indicated that this water was extremely alkaline. Bicarbonate as HCO3 more often than not, exceeded 2000 mg/l. The alkalinity of this water indicates that the water body has a robust capacity to buffer against larger shifts in pH, however, this contradicts the comparison of the 2009 results to the latest 2014 results. This suggests that there was an error in the reports from 2009.









Figures 14, 15, 16, and 17: Analyte concentrations decrease through time; possible correlation with the implementation of wetland (Isaacson 2014)
***Samples taken in 1986 do not have a known month or date of sampling**

The pH, EC, and major inorganic constituents of the lower pond are improving with time which suggests that the actual quality of the mine effluent is improving over time and that the water contributing to our wetland is system is entering the wetland of higher quality than in years previous. However, results of water samples taken throughout the wetland system, did not show any marked improvements in water quality suggesting that the wetland at this time, is not having a significant impact on water quality.

Conclusion:

After two growing seasons, the Dutchman Canyon Constructed Wetland is meeting the requirements of the Nationwide 27 permit. Results from vegetation monitoring and observed soil conditions (saturated soil at depth/ ponding of water at surface greater than 7 months out of the year) prove this wetland has seen a marked increase of wetland vegetation (percent cover exceed the year two threshold of 20 percent) and had positive impacts on the wetland vegetation, no adverse impacts on the system's hydrology. This project has increased the emergent marsh zone of wetland vegetation by almost 100 percent; wetland vegetation now spans over 0.63 acres.

Figures 18, 19, and 20: Photos taken August 2014 from lower pond to downstream extents (Isaacson 2014)

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Appendix 1: Impacts of a September 2014 Flood Event

In September of 2014, the Dutchman Canyon wetland experienced a storm event of unknown size; however, this event was large enough to create alluvial fans along the northern border of the wetland (Figure 20 'sediment deposits'). These sediment flows originated in the foothills flanking the wetland; fine sediment is now confining the wetland expansion to the south and to the east.

Prior to this event, the wetland had established a 0.34 acre area of emergent marsh vegetation. With the sudden deposition of sediment the wetland vegetation has been disturbed- to what degree is unknown. The 2014 monitoring occurred before this event. During a recent walkthrough however, the areas of new deposition were mapped and will be monitored over time. If the wetland vegetation appears to be incapable of rebounding from this event, the AML Program will look into mechanical options for mitigation. This may include, but is not limited to: blading, berming, filling, and possibly excavating to increase slope, remove sediment, and re-contour the hydrated zone to maximize wetland potential.

In addition to the sedimentation of the northern flank, the floodwaters carried a large load of sediment to the southeastern end causing material to berm and slow the movement of water. This caused a new pond to form (Figure 20 'new pond formation'). The pond is adjacent to a breached berm; it is believed that conditions of the flood caused the breach due to overtopping and subsequent erosion, however, the breach has since collapsed on itself, and has arrested the flow of water.

The AML Program will continue to monitor this site. As a proactive measure, they have contacted an engineering firm to develop two possible design scenarios for mitigation at this site. If monitoring reveals unfavorable results, such as failing to meet year three vegetation standards, the AML Program will implement the plans they have solicited.

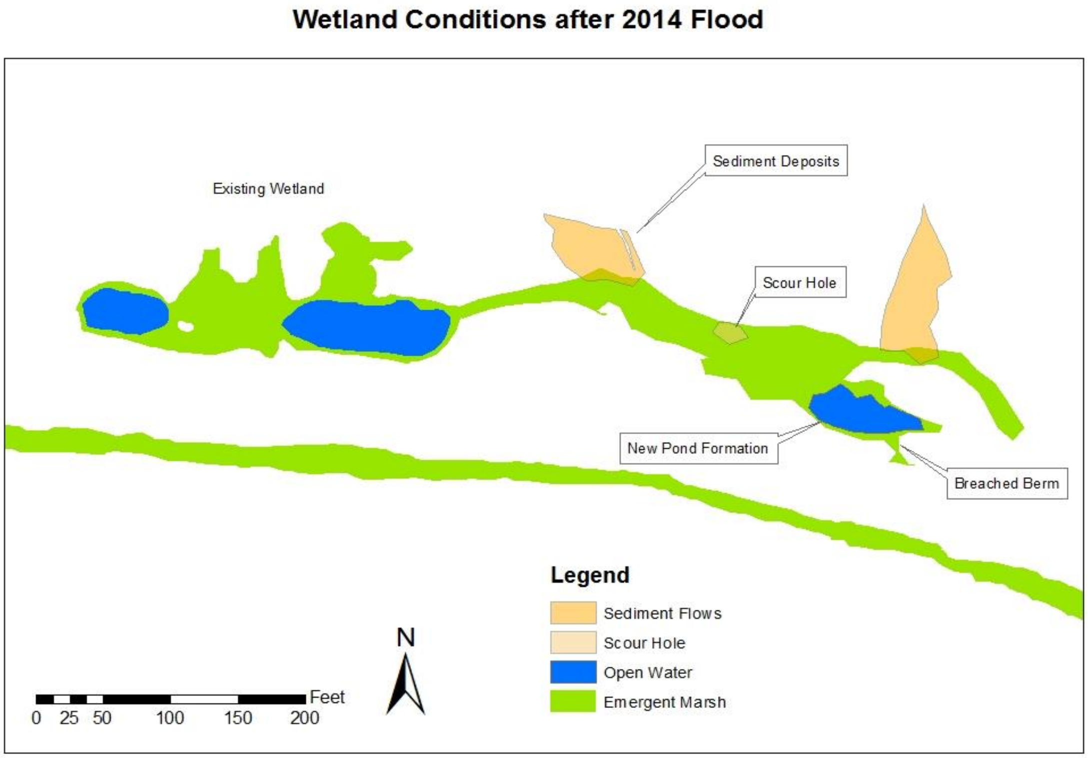


Figure 21: Map showing areas of disturbance caused by flooding (Isaacson 2014)

Figure 22, 23, and 24: Photos of post flood damage (Isaacson 2014)

Appendix 2: Location Information

Climate:

The climate of the project area is described as semiarid. Precipitation mostly takes place during the monsoon season which occurs throughout the months of July and August. Winters are usually dry, but there can be heavy snow accumulations at higher elevations within the watershed. The average annual precipitation is 15 to 16 inches, with up to 22 inches in the high country (Western Regional Climate Center 2010). The mean annual maximum temperature ranges from 55 to 68 ° F with variation caused by elevation changes, slope exposure, and pattern of air drainage. This area of northern New Mexico has an annual average of 273 sunny days including 134 that are frost-free (Water and Earth Team 2009).

Geology:

The Raton Formation (Paleocene and Upper Cretaceous Periods) is the dominant geologic strata of the project area. The formation is located in the eastern Raton Basin and is composed of distal sandstones, mudstones, and thin disconnected coal beds (New Mexico Bureau of Geology and Mineral Resources 2003). Geological materials found in this area are mostly sedimentary formed by residual deposits of a sea that once covered the landscape. Pierre Shale overlays the Niobrara formation and together these marine formations constitute the lower elevations of Dillon Canyon (Lee 1922). While the Niobrara is mostly comprised of lesser valued chalk, limestone, and shale, the overlying Pierre Shale is prized for its oil and natural gas production. At the intersection of these three formations, strata of the Vermejo Formation and Trinidad Sandstone are exposed (New Mexico Bureau of Geology and Mineral Resources 2003).

Beds of high-grade bituminous coal and friable sandstone occur in horizons of the Vermejo Formation. Coal beds can be 15'thick however, most of the formation consists of carbonaceous shale. The quality of the coal varies throughout the coal field but is generally excellent, with no significant faulting (Lee, 1922). Other mineral resources found in the region include graphite, clay, building stone, and oil and gas.

Soils:

Data from the Natural Resource Conservation Service website shows that soils are indicative of both the Deacon-La Brier- Manzano (DR) series and the Midnight-Rombo-Rock outcrop complex (Mn) series. DR soil mapping units are generally level to minimally sloped (0-9 percent), are alluvial in nature, and are associated with canyon bottoms. These soils are derived from igneous and sedimentary rock (USDA 2011).

The Mn soils have formed on moderately steep to very steep mountain slopes (25-65 percent) and tend to be located on canyon side slopes and ridges of the project area from elevations of 6,500-9,000 ft. Rombo cobbly silty clay loam has the profile representative of the series; runoff is very rapid and erosion from water is significant, while soil removal by wind is considered only moderate (New Mexico Abandoned Mine Land Program 1986). Both components of this series are formed from alluvium and colluvium derived from sandstone and shale (USDA 2011).

Rock outcrops in the area consist of sandstone and shale.

Hydrology:

The project area consists of steep slopes, relatively shallow soils, and substantial areas of bedrock. In Dutchman Canyon where the Pierre Shale Formation is fairly shallow, the formation acts as an aquitard forcing water to flow horizontally through the more permeable Trinidad Sandstone. During a geotechnical investigation conducted in 2009, groundwater was encountered at depths of eight to10 feet (The Water and Earth Team, 2009).

Groundwater in Dutchman Canyon is also likely fed by groundwater from the bedrock above and behind canyon walls. While ground water elevations in this canyon have not been mapped, perennial flow emanating from the collapsed adits further backs this hypothesis. The presence of seeps at the mine portals indicates that the mines are flooded and are acting as collectors for groundwater percolating through the overlying bedrock (Habitat Management Inc. and Water and Earth Technologies, 2010). Discharge from the seeps is currently contained in two small ponds. Water that leaves the ponds' catchment system either flows into the adjacent stream or soaks into highly permeable alluvial deposits.

Plant Community:

Prior to the installation of evaporation ponds at Dutchman, the area was lacking in emergent marsh communities of any significant size. The straightened stream on the opposite side of the road and the patches of hydrated soil from mine effluent were the only wetland areas near the Dutchman Mine site, however, with the installation of the ponds in 1987, wetland acreage increased significantly. The 2009 EA describes the wetland communities of the 1980's as well as a new acre-sized wetland related to the ponds.

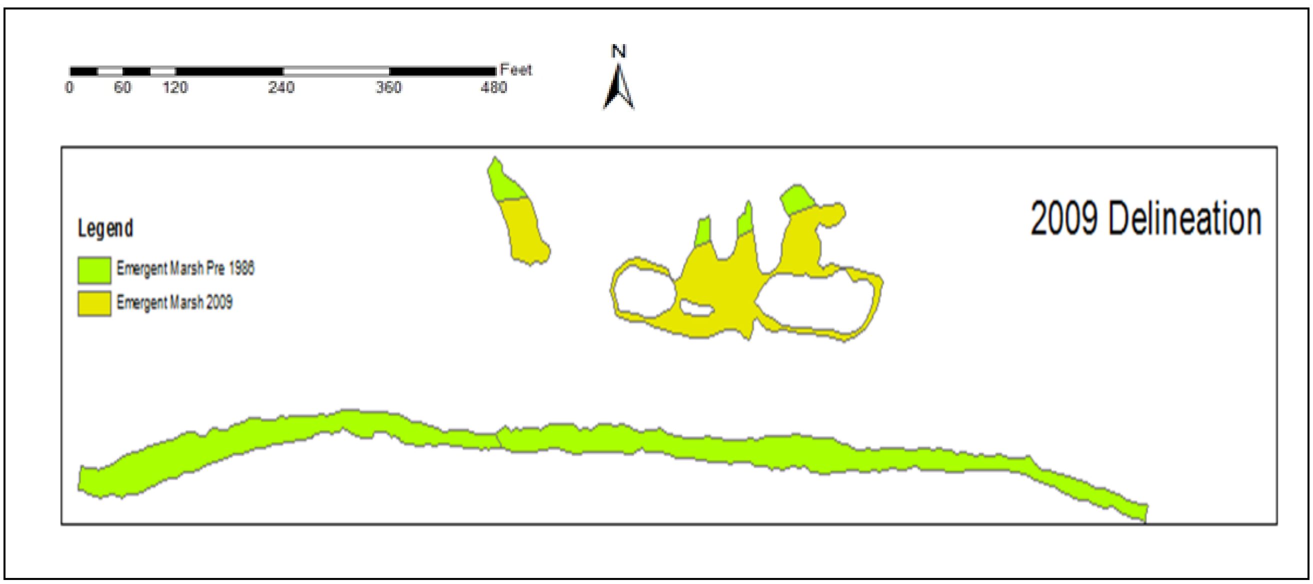


Figure 25: Emergent Marsh coverage after installation of ponds (Isaacson, 2014)

Further east from the ponds and wetland down valley, the plant community transitions from emergent marsh to a mesic grassland dominated by blue grama (Bouteloua gracilis), western wheat grass (Pascopyrum smithii), sideoats grama (Bouteloua curtipendula), and galleta

(Pleuraphis jamesii). In areas that have been disturbed, weedy annual forbs are also dominant (The Water and Earth Team 2009).

Wildlife:

Due to the assortment of habitat types found on the Vermejo Park Ranch, wildlife varies dramatically. Common big game species include: elk (Cervus elaphus nelson), deer (Odocoileus heminus), bear (Ursus americanus) and mountain lion (Felix concolor). Elk and deer populations are abundant in this area. The Raton Basin and Upper Canadian River regions produce the largest population of trophy elk and deer in New Mexico (New Mexico Abandoned Mine Land Program 1986). Elk, bear, buffalo (reintroduced), and mountain lion are the primary objectives of hunters traveling to the Ranch for trophy animals. Other mammals found on the Ranch include: bobcat (Lynx rufus), coyote (canis latrans), raccoon (Procyon lotor), and beaver (Castor canadensis). A wide variety of small rodents and weasels also inhabit the Ranch.

The Raton Basin is home to the largest population of wild turkey in the State; hunters pay substantially to hunt wild turkey on the Ranch. Several non-migratory and migratory bird species live on and around the Ranch or pass through it during their migration. Birds protected under the Migratory Bird Treaty Act (MBTA) found on the Ranch consist primarily of raptors and songbirds. Raptors that nest on the Ranch include: Cooper's hawk (Accipiter cooperii), sharp shinned hawk (Accipiter striatus), golden eagle (Aquila chrysaetos), red-tailed hawk (Buteo jamaicensis), American kestrel (Falco sparverius), and great horned owl (Bubo virginianus). However, Dutchman Canyon lacks the tall trees and high cliffs that are vital for nesting grounds of many of these species (Habitat Management Inc. and Water and Earth Technologies 2010).

A diverse population of songbirds and similar species are associated with the lower elevations of Dutchman Canyon where the ponds and wetland are located. The majority of species occupies the coniferous forests from early spring through fall, and migrates south to winter. A few, however, reside in the canyon fulltime, these include: woodpeckers, jays, chickadees, nuthatches, and finches. The Ranch is also home to birds listed under the Birds of Conservation Concern (BCC) by the US Fish and Wildlife Service (USFWS) for region 16, the Southern Rockies/Colorado Plateau (BCR 16); these include: golden eagle (Aquila chrysaetos), Lewis' woodpecker (Melanerpes lewis), pinyon jay (Gymnorhinus cyanocephalus), Virginia's warbler (Vermivora virginiae), black-throated gray warbler (Dendroica nigrescens) and Grace's warbler (Dendroica dominica) (Habitat Management Inc. and Water and Earth Technologies 2010).

There are several fish species found within the waters of the Ranch, including, the endangered Brook stickleback (Clueae inconstans). Other fish species include members of the Salmonidae family, specifically Cutthroat and Rainbow trout are present in the watershed. These fish are sought after game fish and attract fishermen from all over the Southwest. Although these fish species are found within the Vermejo River system, they are not found in Dutchman Canyon or in close proximity to the project area.

The New Mexico Natural Heritage Program and USFWS list a total of two invertebrate, four fish, 11 bird and three mammal threatened and endangered species for Colfax County, NM; however most of these are not likely to be found in or around Dutchman Canyon or wetland areas (Habitat Management Inc. and Water and Earth Technologies 2010).

Mining History:

Mining in the Colfax County began in 1866 and primarily focused on gold. However, by 1881, coal had become the principal subject of mining activities in the region and in 1909, Colfax County produced 74.8 percent of all coal mined in New Mexico (Oakes, 2010). The Swastika Mine, the mine complex that included the Dutchman Mine was operated by the St. Louis, Rocky Mountain, and Pacific Coal Company. The mine employed 128 men and produced over 19,600 tons of coal (New Mexico Abandoned Mine Land Program 1986).

Coal mining operations were carried out by constructing a horizontal (adit) mine with its entrance at the valley bottom. The adits then connected to the inner workings that spread throughout the formation in multiple levels depending on the coal seam configuration. In general, the mines in Vermejo produced little water and therefore had water systems installed in them for dust abatement and washing of the ore (Oakes 2010).

The Dutchman Mine however, is believed to have contained water and additional piping infrastructure was needed to dewater the inner workings. The water was piped across the small valley (where the present day wetland is located) and allowed to drain to the artificially straightened stream on the opposite side of the valley.

Appendix 3: What is a Wetland?

What is a Wetland?

Most regulatory definitions of wetlands rely on three fundamental environmental parameters: hydrology- the degree of flooding or soil saturation; wetland vegetation (hydrophytes); and presence hydric soils. The USACE and the Environmental Protection Agency (EPA) have jurisdiction over areas regulated by the Clean Water Act; they define a jurisdictional wetland as a specific area that has evidence of all three indicators, whereas the Fish and Wildlife Service (FWS) considers any area with "one or more" of the indictors a wetland. For non-regulators, wetlands are often defined as areas where "water is the primary driver controlling the local environment and associated plant and animal life", with emphasis on either hydrology or botany depending on the discipline of the definer (Kercher 2005). Wetlands are transitional zones between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. They usually lie in depressions or form along rivers and coastal waters where the landscape is vulnerable periodic flooding (Fish and Wildlife Service 1984).

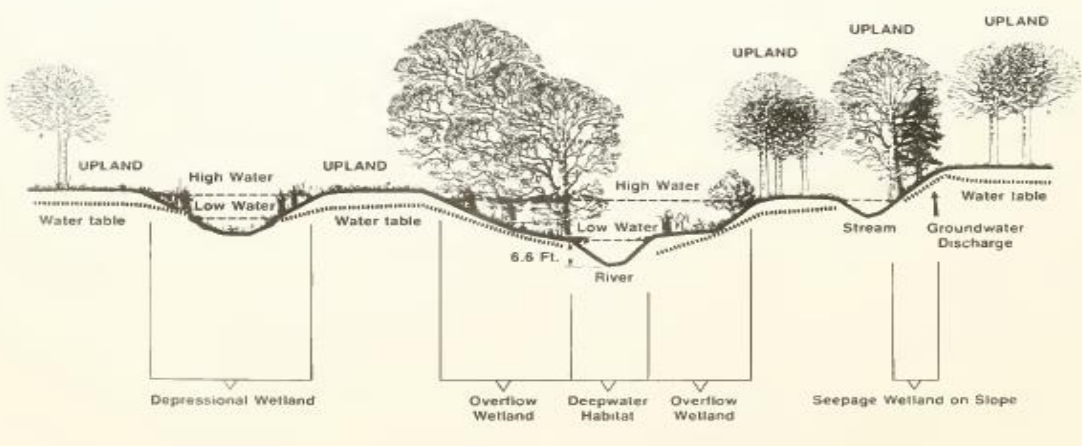


Fig. 1. Schematic diagram showing wetlands, deepwater habitats, and uplands on landscape. Note differences in wetlands due to hydrology and topographic location.

Figure 26: Schematic of wetland locations on landscape (Fish and Wildlife Service 1984)

Wetland Trends:

Based on historical evidence and anecdotal data, it is estimated that about half of the world's wetlands have been lost over the past two centuries. Much of the loss occurred in northern countries during the first half of the twentieth century, however, increasing need for agricultural lands and housing in tropical and subtropical regions has accelerated wetland loss since the 1950's (Kercher 2005). Wetlands are lost mainly due to draining for agricultural purposes, reduced inflows and siltation, and encroachment. It has been estimated that 26 percent of the global wetland area have been dewatered for intensive agricultural purposes since 1985. Land reclaimed for agricultural use has been the primary cause of wetland destruction. Today, wetlands cover less than nine percent of global land area.

It is estimated that of the available wetland area in North America, 27 percent has been replaced by irrigable acreage or dried as a result of diverting water from wetlands to commercial farmland. In the 48 contiguous states of the United States, 53 percent of wetlands were lost from 1780-1985 however, the annual rate of loss is currently 80 percent lower than the previous 200 years. The lower 48 states contained an estimated 103.3 million acres of wetlands in the mid-1980's compared to an estimated 220 million acres found over the same region in 1600's (US Department of the Interior 2009). In New Mexico alone, it is assumed that nearly 36 percent of orginal wetland acreage has been lost (Yuhas 1996). In the United States, freshwater forested wetlands have experienced the greatest loss in area, and total wetland acreage is declining despite the wetland policy reform efforts of several administrations (Kercher 2005).

Marine intertidal	—1.7
Estuarine intertidal nonvegetated	—0.1
Estuarine intertidal vegetated	—0.2
Freshwater nonvegetated	12.6
Freshwater vegetated	—1.4
Freshwater emergent	—4.6
Freshwater forested	—2.3
Freshwater shrub	6.6
All freshwater wetlands	—0.6
Lacustrine habitats	0.8
Riverine habitats	—0.6
Estuarine subtidal habitats	0.1

Figure 27: Percent change in wetland area for selected wetland and deep-water categories in the United States, 1986-1997 (Kercher, 2005)

According to the *2004 -2009 Wetland Status and Trends report to Congress*, wetland area declined by 62,300 acres during the five year reporting period. Collectively, marine and estuarine intertidal wetlands declined and forested wetlands sustained their largest losses since the 1974-1985 monitoring period. The report claims that the decline in marine and estuarine wetlands reflects damages caused by storms and rising sea levels along coastal regions. Forest wetlands were lost, however, due to competing land uses and commercial development interests. Overall, freshwater wetlands experienced a slight increase in area during this period, but these increases are negated once declines in forested wetlands are considered. Between 2004 and 2009, 489,600 acres of former upland area was reclassified as wetlands (US Department of the Interior 2009); the Dutchman Canyon constructed wetland would be included in this category.

The Wetland Status and Trends report cites that aggregate effects of reductions in freshwater wetland systems have had fracturing effects on hydrologic and ecosystem connectivity. In certain regions, profound drops in wetland extent have resulted "in habitat loss, fragmentation and limited opportunities for reestablishment and watershed rehabilitation (US Department of the Interior 2009)."

In New Mexico wetlands cover 0.6 percent of New Mexico (about 482,00 acres), a reduction of about 33 percent from the wetland acreage thet existed 200 years ago (US Department of the Interior 2009). New Mexico (NM) is 34th in total wetland acreage among the 48 continous States. Wetlands not only provide important wildlife habitat, but they provide scenic beauty and recreational opportunities that generate income for the State making them both an environmental and economic commodity. For instance, in the Rio Grande Valley, wetlands offer habitat for 246 bird species, 10 species amphibians, 28 reptiles, and 60 species of mammals, as well as, stoppover, feeding, and breeding grounds for migratory fowl (US Fish and Wildlife Service 1990).

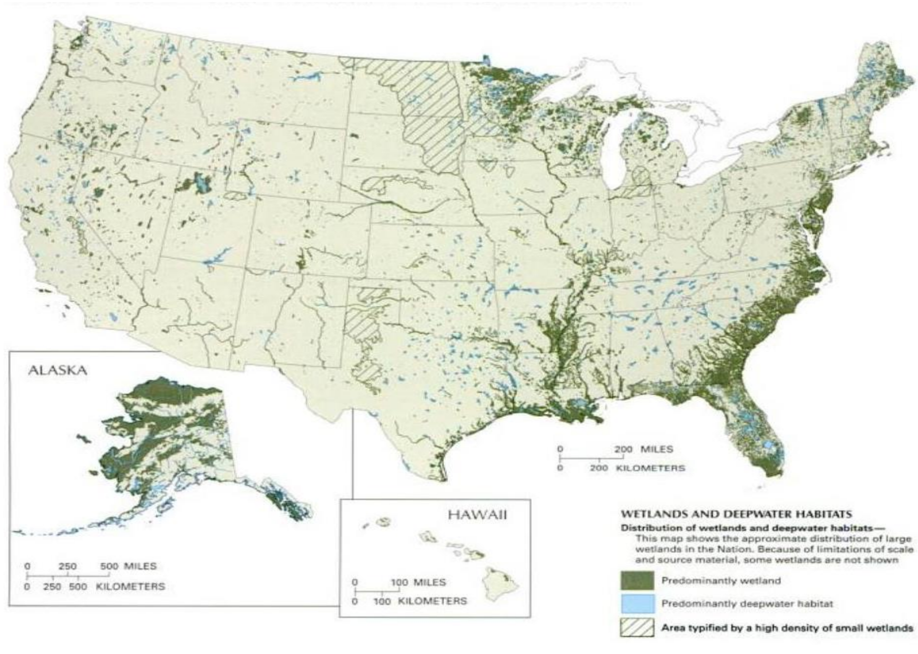


Figure 28: Wetland and deep-water habitats of the US (US Department of the Interior, 2009)

Wetlands occur in all regions of NM, however, they are most prevelant in the eastern and northern areas of the state. In the Southern Rocky Mountains, wetlands are most common in high elevation valleys and intermountain basins. In the Eastern Plains, wetlands occur along flood plains of the Canadian and Pecos Rivers and are associated with playa lakes (US Geological Survey 1996). In the Basin Range and Colorado Plateau regions, wetlands are sparsely distributed (with exception of those associated with the Gila, San Francisco and San Juan Rivers).

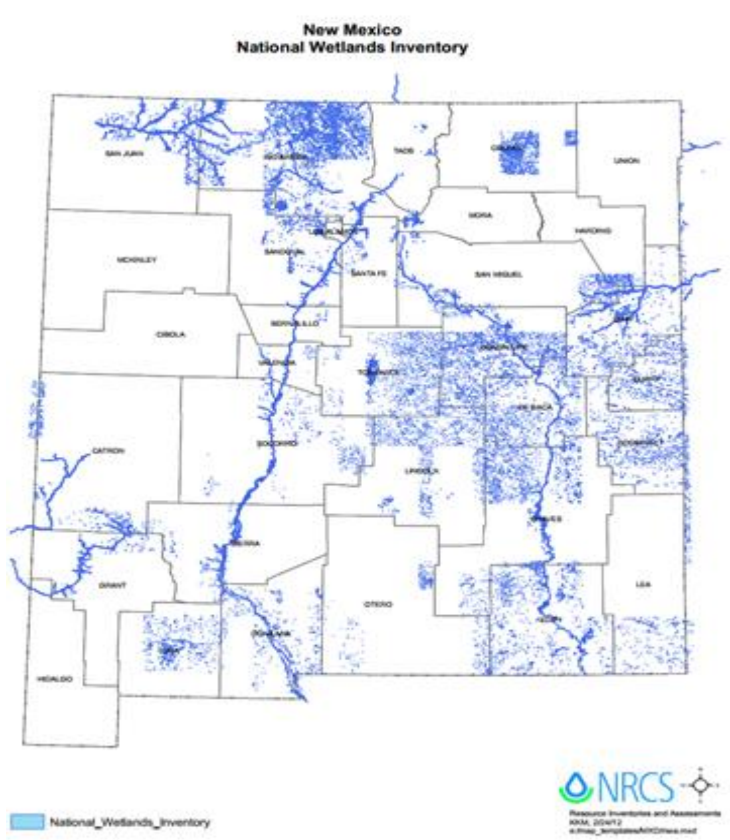


Figure 29: Wetland areas of New Mexico (US Fish and Wildlife Service, 1990)

The Bosque del Apache National Wildlife Refuge is one of the most well known riparian wetlands in NM. The refuge is approximately 57,191 acres lying along a nine mile stretch of the Rio Grande in south-central NM. Marshes within the refuge are the ultimate winter habitat for migrating birds including: ducks, geese, sandhill cranes, and the endagered whooping crane and (southwestern) willow flycatcher. Currently the Bosque is undergoing a reclamation campaign to restore cottonwood and willow habitat that was loss during the expansion of water infrastructure projects in the first half of the 20th century (US Geological Survey 1996). However, streamflow regimes in the area were greatly altered allowing the colonization of exotic species such as the Russian olive and salt cedar.

Types of Wetlands:

The term wetland is a generic descriptor that is used to describe a variety of saturated zones; all wetlands fall into one of five categories: 1) areas with hydrophytes and hydric soils (marshes, bogs, and swamps); 2) areas devoid of hydrophytes but contain hydric soils (for instance, areas with poor water quality that prevent the growth of hydrophytes); 3) areas with hydrophytes but non-hydric soils (newly developed wetlands where hydric soils have yet to develop); 4) areas without soils but provide hydrophytes (seaweed-covered rocky shores); and 5) wetlands without soil and without hydrophytes (gravely beaches or rocky shores with vegetation) (Cowardin 1971).

There are five major systems of wetlands: marine, estuarine, riverine, lacustrine, and palustrine; which, can further be broken down into subsystems: tidal, sub tidal and intertidal, lower perennial, upper perennial, intermittent, limnetic, and littoral (palustrine does not include a subsystem). These are then described in terms of classes (Figure14, Cowardin 1971).

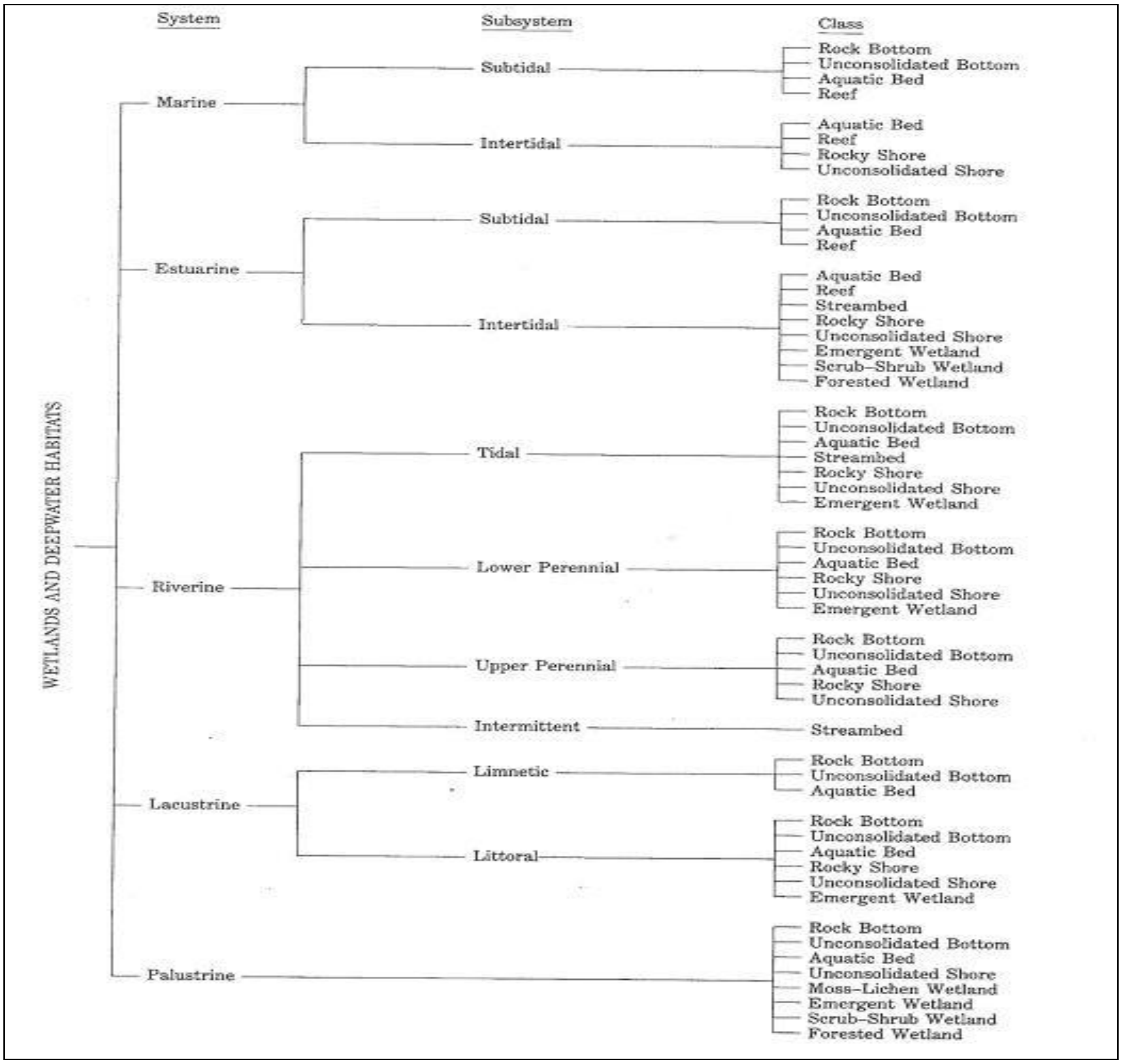


Figure 30: Hierarchy of wetland systems (Cowardin 1971)

Although there are many categories of wetlands throughout the world, non-tidal marshes are the most prevalent type of wetland in North America. Differentiations in wetland type are caused by variations in soil, landscape, climate, water regime, chemistry, vegetation, and human disturbance (Environmental Protection Agency 2001).

System:

In New Mexico, there are three systems present: Palustrine, Lacustrine, and Riverine. Palustrine systems only include wetlands whereas other systems comprise wetlands and deep water habitats. The term Palustrine encompasses all non-tidal wetlands dominated by trees, shrubs, persistent emergent vegetation, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity is below 0.5percent. These systems also include wetlands lacking this vegetation, but encompasses all of the following four characteristics: area less than 20 acres, active wave-formed or bedrock shoreline feature is missing, water depth in the deepest part of the basin is less than 2m at low water, and salinity due to ocean-derived salts is less than 0.5percent (Cowardin 1971). Palustrine wetlands often occur in the vicinity of springs, flowing wells, and in this case, seeps. They may also be found on floodplains of riparian systems, around the shores of some lakes, and reservoirs (EcologyDictionary.org 2008). The wetland in Dutchman Canyon is consistent with the description of Palustrine wetlands.

Class:

The Emergent Wetland Class is characterized by erect, rooted, herbaceous hydrophytes, excluding lichens and mosses. The vegetation is persistent throughout the growing season most years and is predominantly composed of perennial species. All water regimes are included with the exception of sub tidal and irregularly exposed (Cowardin 1971). In areas where climatic regimes are relatively stable, such as the Vermejo Park Ranch, emergent wetlands remain constant in appearance year after year. However, in areas that have violent climatic events, emergent wetlands can revert to open water systems in some years. Emergent wetlands occur throughout the United States and are present in all systems except the Marine. Emergent wetlands are often referred to as marshes, fens, prairie potholes, and sloughs (Cowardin 1971).

Subclass:

The subclass Persistent simply means that the wetland is dominated by species that persist, or remain standing until the beginning of the next growing season if not longer. Palustrine persistent emergent wetlands often contain an array of grass like plants such as those seen in Dutchman: redtop, western wheatgrass, alkali weeping grass, bulrush and others. The constructed wetland in Dutchman Canyon qualifies; it is permanently flooded, is primarily dominated by erect, rooted, hydrophytes that are well suited for anaerobic soil conditions. The emergent vegetation adjacent to rivers and lakes is often referred to as the “shore zone” or “zone of emergent vegetation”.

***Dutchman Classification**:* Emergent Wetland, Saturated/Permanently Flooded, Mixosaline

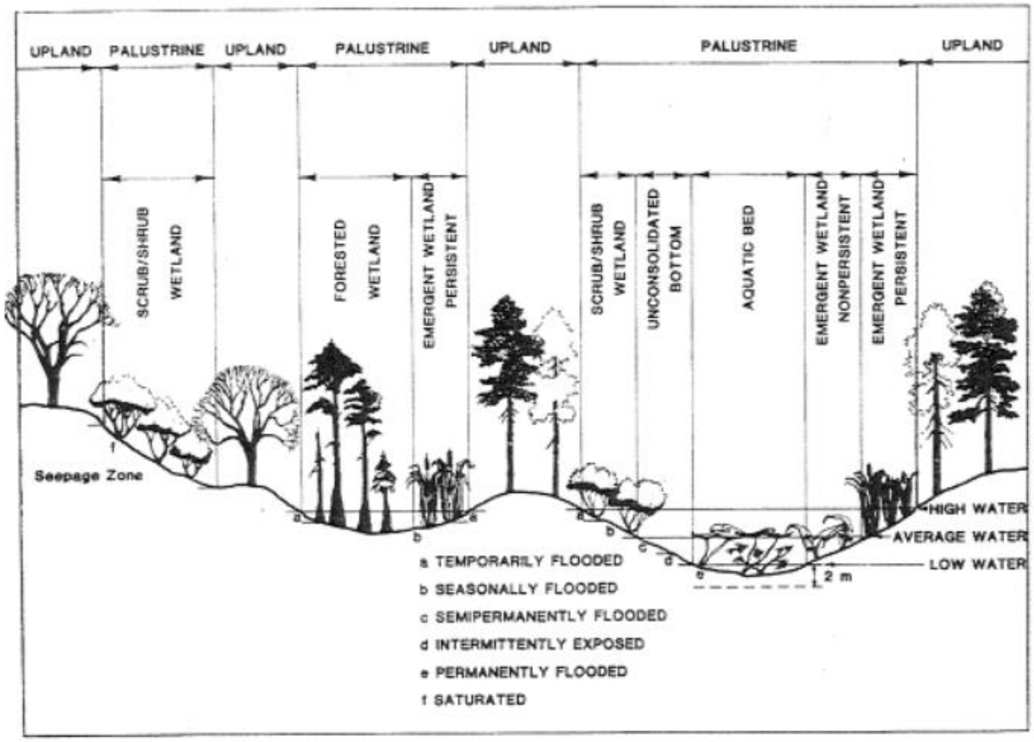


Figure 31: Distinguishing features and examples of habitats in the Palustrine System (Cowardin, 1971)

The Hydrologic Impacts or Benefits of Wetlands:

The formation, persistence, size, and function of wetlands are controlled by the hydrologic process (Carter 1996). Differences in wetlands are also determined by the movement of water through or within the wetland, water quality, and the degree of natural or manmade disturbance. The roles wetlands play in changing the quantity and quality of water moving through them are related to the wetland's physical setting.

Hydrologic processes that happen in wetland systems are the same processes that take place outside of wetlands and are collectively referred to as the hydrologic cycle; major components include: precipation, evapotranspiration (ET), storage and surface and ground water flow into, or out of, the system. Favorable subsurface geology and adequate water supply are necessary for the existence of wetlands (Carter 1996).

Water budgets help provide a basis for understanding hydrologic processes of a wetland (Carter 1996). A wetland's water budget is the sum of all the inflows and outflows of the system. The addition of all the inflows minus the all of the outflow components is the change in storage. The significance of each component's role in maintaining wetlands varies both spatially and temporally, however, all of these factors work in tandem to create the unique hydrology of a wetland. The hydrology of a wetland system is largely responsible for the vegetative communities present at that wetland. The type of vegetation that occurs in and around a wetland greatly affects the quality of the the wetland as habitat and the value of the wetland as an economic boon (Carter 1996).

The movement, distribution and quality of water are the primary factors influencing wetland structure and function. Water regimes can greatly differ in regard to timing and duration of surface water inundation as well as the seasonality of such patterns (Cherry 2012). Inland wetlands, which are free of diurnal tidal fluxes, can be permanently flooded or intermittently flooded with fluctuations occurring on a seasonal scale. In most wetland systems, the inflow sources and outflow mechanisms change with time; therefore, the hydrologic scenario is rarely stable and often goes through periods of hydrologic pulses. Pulses can cause the system to become unbalanced as these influxes of surface water can introduce sediment and nutrients or they can act as cleansing episodes by increasing productivity thus removing waste materials and toxins (Cherry 2012).

Figure 32: Hydrologic process of wetlands (Carter, 1996)

Hydrologic pulses can drive system productivity by influencing species richness and increasing rates of Organic Matter (OM) production in a wetland, whereas, permanent flooding can actually cause a system to stall. Studies have shown the primary productivity and species richness increase with in periods of flux and tend to stagnate in areas that are perennially flooded or, in contrast, drained. Anaerobic conditions can limit decomposition rates, causing OM accumulation, and can alter reduction-oxidation reactions controlling nutrient transformations in wetland soils. Although scientists understand flooding tolerances of many plants species, the effect of saturated soil conditions on root zone productivity is less known (Carter 1996). Golet and Lowry (1987) found that surface flooding and duration of saturation within the root zone accounted for as much as 50 percent of the variation in growth of some plants. Plant distribution is also closely related to water chemistry: wetlands can be fresh or saline, acidic or basic and contain high levels of nutrient loading depending on their location within the landscape.

Water Chemistry:

The water chemistry of a wetland is largely a result of the geologic setting, water balance, quality of inflowing water, soil type, surrounding vegetation and local human activity (Carter 1996). Wetlands that have limited outflow lose water primarily to ET, have a high concentration of chemicals and tend to have brackish or saline water. Dissimilarly, wetlands that depend on precipitation as a primary input of water, and lose water to surface water outflows or ground seepage, tend to have lower concentrations of chemicals. In the case of the Dutchman ponds, the wetland receives water primarily from precipitation and mine seepage. Often, plants serve as indicators of wetland chemistry. In freshwater wetlands pH, mineral and nutrient composition influence plant abundance and species diversity (Carter 1996).

pH Modifiers:

Acidic waters are characterized by high concentrations of chloride and/or sulfate and have comparatively low concentrations of other ions (some very soft waters may have neutral pH levels). Some studies suggest that acidity may not be the primary constituent controlling the presence or absence of specific plants or animals Cowardin 1971). However, in systems where, for example, a peat layer isolates overlying plant roots from the mineral substrate, the availability of minerals in the root zone strongly influences the type of plant communities that occupy the site. Therefore, rather than using plant and animal populations as indicators for pH levels, scientist have used mineral rich and mineral poor categories to instead describe hydrogen ion concentrations. The Dutchman system is very much in the Alkaline (>7.4) pH modifier category.

Salinity Modifiers:

Salinity refers to the Total Dissolved Solid (TDS) concentration in water. Brackish water is used to describe waters with a TDS >1000 mg/L while saline is most often used to describe TDS measurements above 35,000 mg/L, such as ocean or sea water. In a wetland system, salinity is dictated by the interactions between precipitation, surface runoff, groundwater flow, and evaporation and or transpiration. In inland wetlands, high soil salinities control the invasion or establishment of many plants. These salinities are expressed in units of specific conductance as well as percent salt. Measuring water's electrical conductivity (EC) is also an indirect measurement of TDS. High EC measurements are correlated to high concentrations of the following ions: cations including calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K); and three major anions: carbonate (CO3), sulfate (SO4) and chloride (Cl) (Wetzel 1975).

Submerged Soil: Chemistry and Behavior

Hydric Soils:

According to the US USACE, a hydric soil is a soil that is formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation (US Army Corps of Engineers 1995)**.** Hydric soils develop under anoxic conditions and several biogeochemical transformations take place shortly after the available oxygen is depleted, including nitrate reduction to nitrogen gas, sulfur reduction to hydrogen sulfide, carbon reduction to methane, and increased solubility (depending on soil pH and redox potential), (Kercher 2005).

Submerging a soil generates an assortment of electrochemical alterations, including: a decrease in redox potential, an increase in pH of acid soils and a decrease in pH of alkaline soils, shifts in conductance and ionic strength, changes in mineral equilibria, cation and anion exchange interactions, and sorption/desorption of ions (Ponnamperuma 1972). The most significant chemical difference between submerged soils and well drained soils is that submerged soils are at a reduced state. Submerged soils tend to be a greenish grey hue and have a low oxidation - reduction potential. Reduction of the soil is a result of anaerobic respiration by soil microbes.

During anaerobic respiration, OM is oxidized and soil components are reduced (Ponnamperuma 1972). Oxidation-reduction is a chemical reaction where electrons are transferred from a donor to an electron acceptor. The electron donor releases electrons and is oxidized; the receiver gains electrons and is reduced. The source of electrons for most biological reduction is OM. The amount of energy available to an organism depends on the electron acceptor. For biological reactions oxygen provides the greatest amount of energy and all higher life forms, including most graduate students, require an aerobic environment in which oxygen is present. The state of a soil can be defined quantitatively by measuring the intensity (redox potential) or capacity (total concentration of reduction products) (Ponnamperuma 1972).

Soils at Dutchman are, at this time, on a trajectory to becoming marsh soils. Marsh soils are defined as soils that are more or less permanently inundated (Cowardin 1971). Freshwater marsh soils tend to be located on the edges of lakes and stream networks that are capable of producing a constant source of submergence. There are also saltwater marshes and these often occur near estuaries, tidal flats, and deltas (Ponnamperuma 1972).

Oxygen Availability:

The formation of anaerobic conditions in wetland soils occurs due to the fact that oxygen is depleted faster than it can be replenished through diffusion. The rate of oxygen depletion varies depending on factors such as: soil temperature, soil structure, the degree microbial respiration and vegetative cover. Oxygen and other atmospheric gases can pass into the soil through molecular diffusion in interstitial waters only (Ponnamperuma 1972); therefore, the oxygen diffusion rate drastically decreases when a soil becomes inundated. Within a few hours, microorganisms use up the oxygen in both the water and soil pore space and effectively render the soil devoid of molecular oxygen (Ponnamperuma 1972). Scientists Evans and Scott (1955) found that the concentration of oxygen in the water used to submerge soil decreased to one-hundredth of its original value within 75 minutes (Ponnamperuma 1972).

Submerged soils are not uniformly devoid of oxygen (Ponnamperuma 1972). Oxygen concentrations may be high in surface layers where there is contact with oxygenated water; these layers are usually a few millimeters thick. In most wetlands, limited areas of oxidized soils persist near the surface or surrounding the roots of vascular plants; generally however, anaerobic or reduced conditions are found prominently throughout wetland systems (Cherry 2012). Howeler and Bouldin (1971) found that submerged soils and lake muds are anoxic below the soil water interface. These anaerobic soil conditions, or lack of molecular oxygen, are a key identifier of wetland systems.

The existence of an oxygenated surface layer in wetland systems is important from an ecological stand point; these muds act as sinks for phosphate and other vital plant nutrients (Ponnamperuma 1972). The mud acts as a chemical barrier to the exchange of certain plant nutrients from the soil to the water body. The surface layer must have access to oxygenated water; this occurs through turbulence from wind or by thermal movements (Ponnamperuma 1972). When this occurs, oxygen availability exceeds the demand at the mud/water interface. By contrast, if the surface utilizes the oxygen faster than it can be supplied, the surface will undergo reduction and release large stores of nutrients from the mud into the water (Ponnamperuma 1972).

Submerging soils impedes the diffusion of oxygen to deeper zones. Aerobic organisms in the soil become quiescent or die, while, the facultative and obligate anaerobes flourish. These organisms proliferate using carbon compounds as substrate and oxidized soil components and dissimilation products of organic matter as electron acceptors in respiration (Ponnamperuma 1972); the shift from aerobic to anaerobic respiration occurs at oxygen levels of 3×10^{-6} M or lower (Ponnamperuma 1972). In the absence of oxygen, facultative and obligate anaerobes us NO_3^-, Mn(IV), Fe(III), SO_4^{2-}, dissimilation compounds of organic matter, CO_2, N_2 and H^+ ions as electron acceptors in their respiration reducing NO_3^- to N_2, Mn(IV) to Mn(II), Fe(III) to Fe(II), SO_4^{2-}, to H_2S, CO_2, to CH_1, N_2 to NH_3 and H^+ to H_2 (Ponnamperuma 1972). Anaerobic respiration also produces chemically reducing by-products; therefore, switching from aerobic to anaerobic respiration ignites the reduction of submerged soils. Soil reduction requires several components: the absence of oxygen, presence of decomposable organic matter, and the proliferation of anaerobic soil microbes. The path, rate, and level of reduction are dependent on factors such as: pH, temperature, percent OM, and the nature and content of electron receptors (Ponnamperuma 1972).

pH:

When an aerobic soil is submerged, as is the case at Dutchman Canyon, its pH decreases during the initial days, arrives at a minimum, and then increases asymptotically to a somewhat stable value of 6.7-7.2 with a few weeks (Ponnamperuma 1972). Generally, submerging soils increases pH of acid soils and depresses the pH of sodic and calcareous soils and converges around a pH of 7. However, according to Ponnamperuma (1972), even though submerged soils exhibit changes in pH, soil properties and temperature markedly influence the pattern of said changes. For example, soils high in organic matter and reducible iron attain a pH of 6.5 after only a few weeks of submergence. However, acid soils low in organic matter or active iron may not reach a pH of 5 or higher even after a few months of submergence. The presence of organic matter can amplify the decreases in pH of sodic and calcareous soils while, low temperature or the presence of nitrate retards the increase in pH of acidic soils (Ponnamperuma 1972).

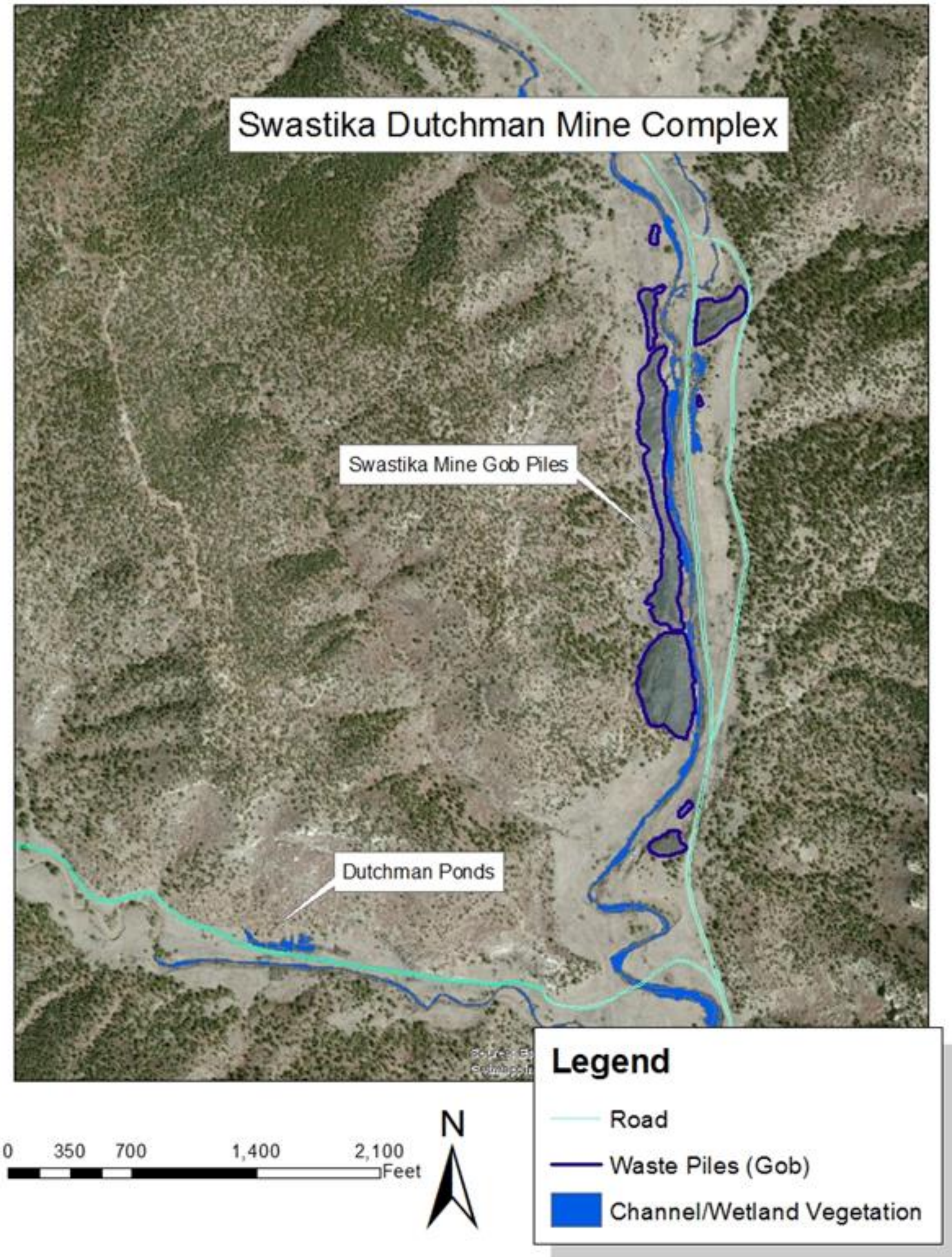
pH values can radically affect hydroxide, carbonate, sulfide, phosphate, and silicate equilibria in saturated soils. These equilibria control the precipitation and dissolution of solids, the sorption and desorption of ions, and the concentrations of nutritionally significant ions or compounds such as Al^{3+}, Fe^{2+}, H_2S, H_2CO_3 and un-disassociated organic acids (Ponnamperuma 1972).

Carbon:

Organic matter decomposition in saturated soils contrasts with decomposition in well drained soils in two ways: breakdown of organic materials is slower, and the end product is very different. In porous or well drained soils, plant matter is decomposed by a large assembly of microorganisms. Due to the elevated energy release associated with aerobic respiration, decomposition occurs rapidly.

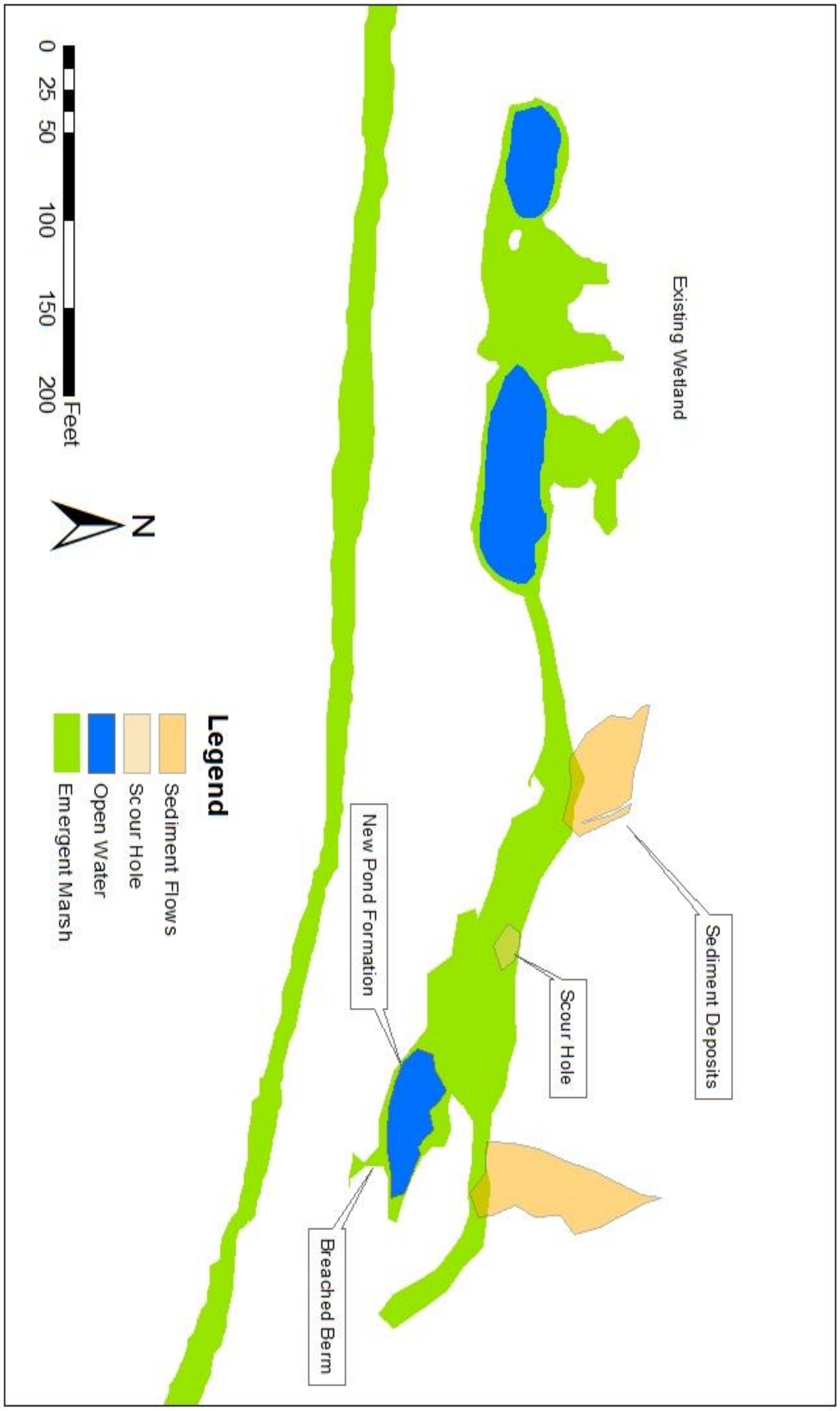
Appendix 4: Site Maps

Site Location Map (Isaacson, 2013)



The Swastika Mine Complex (Isaacson, 2014)

Sample Locations (Isaacson, 2014)



Flood Damage (Isaacson 2014)

Appendix 5: Seed Mixes

Dutchman Wetland Seed Mix:

Percent of Mix	Species	Common Name
8.26	*Beckmannia syzigachne*	American Sloughgrass
9.75	*Distichlis stricta*	Inland Saltgrass
1.72	*Juncus balticus*	Baltic Rush
3.52	*Muhlenbergia asperifolia*	Scratchgrass
13.00	*Panicum virgatum*	Switchgrass
8.52	*Phalaris arundinacea*	Reed Canarygrass
1.65	*Puccinellia airoides*	Nuttall's Alkaligrass
19.89	*Scirpus maritimus*	Alkali Bulrush
29.56	*Pascopyrum smithii*	Western Wheatgrass, var. Arriba

Application Rate: 6 LBS PLS per acre

Swastika Upland Seed Mix:

Percent of Mix	Species	Common Name
4.62	Oryzopsis hymenoides	Indian Ricegrass
5.49	Bouteloua curtipedula	Side-oats Grama
2.29	Bouteloua gracilis	Blue Grama
3.45	Bromus ciliates	Fringed Brome
12.31	Elymus trachycaulus	Slender Wheatgrass
9.84	Stipa viridula	Green Needlegrass

14.92	Pascopyrum smithii	Western Wheatgrass
5.45	Hilaria jamesii	Galleta
3.44	Schizachyrium scoparium	Little Bluestem
0.30	Sporobolus cryptandrus	Sand Dropseed
0.19	Artemsia frigida	Fringed Sage
0.27	Artemesia ludoviciana	Prairie Sage
1.09	Dalea purpurea	Purple Prairie Clover
10.52	Helianthus annus	Annual Sunflower
1.05	Sphaeralcea coccinea	Scarlet Globemallow
1.11	Ratibida columnifera	Prairie Coneflower
3.74	Ceratoides lanata	Winterfat
7.10	Rhus trilobata	Skunkbrush Sumac
3.95	Rosa Woodsii	Wood’s Rose

Application Rate: 11.41 LBS PLS per Acre

Apendix 6: Water Quality Reports

1986: Dutchman Mines

KRAMER & ASSOCIATES

LABORATORY: 125 EUBANK N.E.
ALBUQUERQUE, NM 87123
505-292-4004

SURFACE WATER SAMPLE ANALYSIS REPORT

YORK CANYON MINE
KAISER STEEL CORPORATION

SAMPLE IS OLD PORTAL MINE
**** ALL UNITS ARE MG/L **** Dutchman Canyon

DATE SAMPLED: 11 / 26 / 86

DATE ANALYSED: 12 / 9 / 86

TOTAL SUSP. SOLIDS = 5.6	PH = 8.40	ARSENIC = <0.[illegible]
TOTAL DISS. SOLIDS = 3886	CARBONATE = 14.7	
CONDUCTIVITY (UMHOS) = 3700	BICARBONATE = 2785	BORON = 0.[illegible]
ADJUSTED SAR = 158.3	ALKALINITY = 2252	CADMIUM = [illegible]
HARDNESS AS CACO3 = 36	P. ALKALINITY = 24	COPPER = [illegible]
CALCIUM = 10	SULFATE = 0	LEAD = [illegible]
MAGNESIUM = 2.6	ACIDITY = 0	
SODIUM = 1030	T. PHOSPHATE = --	
POTASSIUM = 6.7	O. PHOSPHATE = --	
TOTAL IRON = 0.47	CHLORIDE = 37	
TOTAL MANGANESE = 0.08	CYANIDE = <0.005	ION BALANCE,% = [illegible]
	NITRATE AS N = --	
	AMMONIA AS N = --	
	FLUORIDE = --	

Date: 5/15/2013 Lab: Energy Laboratories Billings, MT

	Sample ID			
Analyte (mg/L)	Upper Adit	Lower Pond	ZI-1	ZI-4
Al 396.153	NA	NA	NA	NA
As 188.979	NA	NA	NA	NA
B 249.772	NA	NA	NA	NA
Ba 455.403	NA	NA	NA	NA
Be 313.107	NA	NA	NA	NA
Ca 317.933	7	7	7	8
Cd 228.802	NA	NA	NA	NA
Co 228.616	NA	NA	NA	NA
Cr 267.716	NA	NA	NA	NA
Cu 324.752	NA	NA	NA	NA
Fe 259.939	NA	NA	NA	NA
K 766.490	4	4	5	3
Li 610.362	NA	NA	NA	NA
Mg 280.271	2	3	3	3
Mn 257.610	NA	NA	NA	NA
Mo 202.031	NA	NA	NA	NA
Na 589.592	895	932	961	1060
Ni 231.604	NA	NA	NA	NA
Pb 220.353	NA	NA	NA	NA
Se 196.026	NA	NA	NA	NA
Si 251.611	NA	NA	NA	NA
Sr 421.552	NA	NA	NA	NA
V 310.230	NA	NA	NA	NA
Zn 213.857	NA	NA	NA	NA
pH	8	8.9	8.9	9.2
EC	3310	3580	3550	4030
TDS	NA	NA	NA	NA
HCO_3	2370	2240	2220	2190
CO_3	ND	127	142	314
Cl^-	35	37	38	42
SO_4^{2-}	ND	ND	ND	ND

Date: 7/31/2014 Lab: UNM

	Sample ID		
Analyte (mg/L)	Lower Pond	Well 4	Well 5
Al 396.154	31.864	35.512	39.16
As 188.980	-0.0716667	-0.0741667	-0.0766667
B 249.773	0.5523333	0.5878333	0.6233333
Ba 455.404	0.7713333	0.8888333	1.0063333
Be 313.108	-0.0403333	-0.0398333	-0.0393333
Ca 317.934	27.380667	29.038167	30.695667
Cd 228.803	-0.0103333	-0.0103333	-0.0103333
Co 228.617	-0.0166667	-0.0136667	-0.0106667
Cr 267.717	0.004	0.0055	0.007
Cu 324.753	0.0923333	0.1033333	0.1143333
Fe 259.940	24.778	28.598	32.418
K 766.491	10.02	11.062	12.104
Li 610.363	0.09	0.093	0.096
Mg 280.272	10.193333	11.019833	11.846333
Mn 257.611	0.4356667	0.5046667	0.5736667
Mo 202.032	-0.023	-0.023	-0.023
Na 589.593	311.83333	314.48333	317.13333
Ni 231.605	0.013	0.015	0.017
Pb 220.354	0.1903333	0.2543333	0.3183333
Se 196.027	-0.3113333	-0.3468333	-0.3823333
Si 251.612	22.657333	27.062833	31.468333
Sr 421.553	0.709	0.7805	0.852
V 310.231	0.081	0.091	0.101
Zn 213.858	0.1683333	0.1978333	0.2273333
pH	NA	NA	NA
EC	NA	NA	NA
TDS	NA	NA	NA
HCO_3	NA	NA	NA
CO_3	NA	NA	NA
Cl^-	NA	NA	NA
SO_4^{2-}	NA	NA	NA

Date: 4/2/2014 Lab: Energy Laboratories Billings, MT

	Sample ID			
Analyte (mg/L)	Lower Pond	ZI-1	ZI-2	ZI-4
Al 396.154	NA	NA	NA	NA
As 188.980	NA	NA	NA	NA
B 249.773	NA	NA	NA	NA
Ba 455.404	NA	NA	NA	NA
Be 313.108	NA	NA	NA	NA
Ca 317.934	6	6	6	5
Cd 228.803	NA	NA	NA	NA
Co 228.617	NA	NA	NA	NA
Cr 267.717	NA	NA	NA	NA
Cu 324.753	NA	NA	NA	NA
Fe 259.940	NA	NA	NA	NA
K 766.491	4	4	4	4
Li 610.363	NA	NA	NA	NA
Mg 280.272	2	2	2	2
Mn 257.611	NA	NA	NA	NA
Mo 202.032	NA	NA	NA	NA
Na 589.593	876	926	900	856
Ni 231.605	NA	NA	NA	NA
Pb 220.354	NA	NA	NA	NA
Se 196.027	NA	NA	NA	NA
Si 251.612	NA	NA	NA	NA
Sr 421.553	NA	NA	NA	NA
V 310.231	NA	NA	NA	NA
Zn 213.858	NA	NA	NA	NA
pH	8.7	8.7	8.8	9
EC	3370	3380	3400	3330
TDS	NA	NA	NA	NA
HCO_3	2250	2210	2210	2030
CO_3	123	143	151	209
Cl^-	35	35	35	35
SO_4^{2-}	ND	ND	ND	ND

Date: 10/15/2014 Lab: Energy Laboratories Billings, MT

	Sample ID		
Analyte (mg/L)	Lower Pond	ZI-1	ZI-3
Al 396.154	NA	NA	NA
As 188.980	NA	NA	NA
B 249.773	NA	NA	NA
Ba 455.404	NA	NA	NA
Be 313.108	NA	NA	NA
Ca 317.934	7	8	9
Cd 228.803	NA	NA	NA
Co 228.617	NA	NA	NA
Cr 267.717	NA	NA	NA
Cu 324.753	NA	NA	NA
Fe 259.940	NA	NA	NA
K 766.491	3	2	2
Li 610.363	NA	NA	NA
Mg 280.272	3	3	3
Mn 257.611	NA	NA	NA
Mo 202.032	NA	NA	NA
Na 589.593	844	894	896
Ni 231.605	NA	NA	NA
Pb 220.354	NA	NA	NA
Se 196.027	NA	NA	NA
Si 251.612	NA	NA	NA
Sr 421.553	NA	NA	NA
V 310.231	NA	NA	NA
Zn 213.858	NA	NA	NA
pH	8.7	8.7	8.9
EC	3370	3370	3270
TDS	2160	2170	2150
HCO_3	2130	2130	2040
CO_3	137	137	175
Cl^-	35	35	33
SO_4^{2-}	1	1	1

Water Quality Results (5/15/2012-10/15/201

		Sample ID			
	Analyte (mg/L)	**DM3**	**DM2**	**ZI-2**	**ZI-3**
Date: 7/31/2013 Lab: UNM	Al 396.153	304.7	344.1	295.7	243.2
	As 188.979	-0.262	-0.159	-0.131	-0.149
	B 249.772	3.895	2.828	2.324	1.941
	Ba 455.403	8.104	8.373	7.015	5.626
	Be 313.107	-0.01	-0.01	-0.015	-0.02
	Ca 317.933	92.08	151.1	105.3	96.32
	Cd 228.802	0.005	0.006	0.004	0.001
	Co 228.616	0.271	0.303	0.246	0.196
	Cr 267.716	0.307	0.239	0.303	0.14
	Cu 324.752	0.699	1.043	0.719	0.518
	Fe 259.939	552	459.2	393.4	340.3
	K 766.490	69.63	82.8	68.32	46.29
	Li 610.362	0.31	0.31	0.314	0.363
	Mg 280.271	62.03	63.08	61.79	42.9
	Mn 257.610	41.57	11.3	9.672	5.074
	Mo 202.031	-0.105	-0.079	-0.068	-0.053
	Na 589.592	95.36	7.521	96.97	150.7
	Ni 231.604	0.375	0.361	0.366	0.227
	Pb 220.353	0.508	0.533	0.376	0.367
	Se 196.026	-9.191	-6.598	-5.114	-4.193
	Si 251.611	0.214	0.557	0.609	0.656
	Sr 421.552	2.678	3.514	1.946	3.184
	V 310.230	0.801	0.675	0.657	0.532
	Zn 213.857	1.983	2.148	1.812	1.518

Soil Samples (7/31/2013)

Date: 11/4/2013 Lab: UNM (ROOTS)

	Sample ID						
Analyte (mg/L)	DM3	DM2	DM1	ZI-1	ZI-2	ZI-3	ZI-4
Al 396.153	33.81	50.36	41.9	63.38	44.22	17.62	74.67
As 188.979	-0.075	-0.025	-0.056	-0.061	-0.021	-0.052	-0.046
B 249.772	0.407	0.67	0.738	0.593	0.547	0.269	0.445
Ba 455.403	3.731	6.169	7.611	3.34	2.961	1.548	2.529
Be 313.107	-0.036	-0.033	-0.033	-0.034	-0.034	-0.037	-0.034
Ca 317.933	58.46	97.03	95.11	44.81	32.45	23.44	64.42
Cd 228.802	-0.024	-0.026	-0.027	-0.028	-0.025	-0.026	-0.026
Co 228.616	0.005	0.048	0.053	0.032	0.022	0.01	0.027
Cr 267.716	0.127	0.055	0.078	0.085	0.092	0.182	0.068
Cu 324.752	0.543	0.267	0.287	0.284	0.247	0.182	0.324
Fe 259.939	38.85	125.6	177.2	108.7	82.57	45.95	92.19
K 766.490	0.329	0.095	0.11	0.155	0.183	0.384	0.255
Li 610.362	0.051	0.058	0.057	0.074	0.076	0.05	0.064
Mg 280.271	16.96	18.11	16.19	13.84	15.44	11.56	17.97
Mn 257.610	2.323	2.253	2.437	2.429	1.793	1.321	3.321
Mo 202.031	0.012	0.005	0.004	0.01	0.008	0.016	0.003
Na 589.592	115.1	151.8	79.97	77.32	156.1	84.98	86.14
Ni 231.604	0.078	0.066	0.074	0.078	0.047	0.07	0.051
Pb 220.353	0.009	0.102	0.183	0.082	0.039	0.014	0.177
Se 196.026	-0.065	-0.174	-0.259	-0.171	-0.133	-0.078	-0.14
Si 251.611	5.864	4.42	2.191	0.938	0.363	1.946	2.255
Sr 421.552	4.672	6.59	6.08	2.771	2.709	1.245	2.358
V 310.230	0.081	0.228	0.222	0.124	0.058	0	0.133
Zn 213.857	0.827	0.551	0.524	0.743	0.511	0.441	0.656

Date:11/4/2014 Lab:UNM (STEMS)

	Sample ID						
Analyte (mg/L)	DM3	DM2	DM1	ZI-1	ZI-2	ZI-3	ZI-4
Al 396.153	3.362	16.1	2.106	17.37	45.51	7.362	NA
As 188.979	-0.076	-0.06	-0.069	-0.066	-0.071	-0.065	NA
B 249.772	0.207	0.316	0.2	1.007	0.321	0.181	NA
Ba 455.403	1.706	2.189	1.32	1.729	2.091	0.605	NA
Be 313.107	-0.037	-0.037	-0.037	-0.037	-0.036	-0.037	NA
Ca 317.933	115.1	26.93	18	30.75	31.52	11.29	NA
Cd 228.802	-0.026	-0.027	-0.026	-0.026	-0.026	-0.025	NA
Co 228.616	-0.024	-0.015	-0.024	-0.015	-0.007	-0.017	NA
Cr 267.716	0.048	0.042	0.03	0.032	0.051	0.024	NA
Cu 324.752	0.141	0.146	0.057	0.117	0.138	0.092	NA
Fe 259.939	3.671	17.83	3.153	13.35	33.06	6.828	NA
K 766.490	0.279	0.182	0.218	0.263	0.643	0.391	NA
Li 610.362	0.02	0.057	0.055	0.053	0.08	0.052	NA
Mg 280.271	18.93	15.3	12.82	9.582	18.47	6.437	NA
Mn 257.610	4.349	2.253	2.027	1.74	2.326	1.723	NA
Mo 202.031	0.024	0.037	0.099	0.019	0.035	0.048	NA
Na 589.592	97.54	339.7	329.3	116.7	276.1	170.4	NA
Ni 231.604	0.017	0.017	0.005	0.018	0.029	0.008	NA
Pb 220.353	-0.017	0.002	0.018	-0.004	0.015	-0.009	NA
Se 196.026	-0.023	-0.054	-0.011	-0.05	-0.078	-0.036	NA
Si 251.611	0.867	0.96	2.204	0.572	0.391	0.561	NA
Sr 421.552	7.7	2.397	1.777	2.154	2.69	0.733	NA
V 310.230	0.007	0.068	0.008	0	0.037	-0.031	NA
Zn 213.857	0.381	0.624	0.382	0.472	0.537	0.255	NA

Date:11/4/2014 Lab:UNM (LEAVES)

	Sample ID						
Analyte (mg/L)	DM3	DM2	DM1	ZI-1	ZI-2	ZI-3	ZI-4
Al 396.153	30.47	9.922	3.649	17.24	9.953	13.59	NA
As 188.979	-0.082	-0.07	-0.081	-0.072	-0.07	-0.08	NA
B 249.772	0.273	0.356	0.273	0.266	0.308	0.251	NA
Ba 455.403	2.7	2.15	2.855	1.615	1.073	1.134	NA
Be 313.107	-0.037	-0.037	-0.037	-0.037	-0.037	-0.04	NA
Ca 317.933	135.9	30.88	42.19	28.92	26.76	30.74	NA
Cd 228.802	-0.027	-0.021	-0.026	-0.023	-0.025	-0.03	NA
Co 228.616	-0.014	-0.02	-0.019	-0.014	-0.019	-0.02	NA
Cr 267.716	0.032	0.037	0.039	0.031	0.096	0.032	NA
Cu 324.752	0.256	0.142	0.097	0.144	0.14	0.106	NA
Fe 259.939	22.97	10.99	7.149	15.2	8.812	10.57	NA
K 766.490	0.158	0.089	0.198	0.087	0.406	0.29	NA
Li 610.362	0.025	0.049	0.047	0.049	0.063	0.05	NA
Mg 280.271	21.88	16	17.27	9.763	19.6	17.19	NA
Mn 257.610	3.255	1.379	1.589	1.747	1.71	1.788	NA
Mo 202.031	0.046	0.089	0.113	0.042	0.161	0.243	NA
Na 589.592	48.15	110.8	167.5	63.52	159.6	124	NA
Ni 231.604	0.013	0.012	0.044	0.026	0.044	0.013	NA
Pb 220.353	-0.002	-0.01	-0.009	0.002	-0.008	-0.01	NA
Se 196.026	-0.033	-0.036	-0.01	-0.049	-0.037	-0.03	NA
Si 251.611	3.376	0.695	1.857	1.208	0.383	0.785	NA
Sr 421.552	9.526	2.486	3.22	1.952	2.126	1.61	NA
V 310.230	0.014	0.048	0.016	0.003	-0.013	-0.02	NA
Zn 213.857	0.595	0.394	0.373	0.494	0.597	0.366	NA

Vegetation ICP Data (11/4/2013)