WETLAND ENHANCEMENT AND CREATION ON RECLAIMED ABANDONED MINED LANDS IN NORTHEAST WYOMING[1]

by

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Abstract. Over 1,200 wetlands have been created in northeast Wyoming as a byproduct of bentonite mining activities. Most of these wetlands were created or enhanced as a result of the reclamation of abandoned bentonite surface mines by the Abandoned Mine Land Division of the Wyoming Department of Environmental Quality (WAML). Beginning in 1985, and eventually using over $40.6 million from fees collected for abandoned mine reclamation under the federal Surface Mining Control and Reclamation Act of 1977 (SMCRA), WAML reclaimed over 3,320 hectares of terrestrial habitat and 180 ha of wetland habitat at 236 AML sites. These reclamation activities included enhancing existing wetlands and creating new wetlands to mitigate for the destruction of jurisdictional (Section 404c of the Clean Water Act) wetlands that were deemed hazardous. Enhancement and creation activities produced small ($\bar{x}$ = 1.2 ha) and shallow (< 2 m deep) wetlands, designed to provide maximum habitat benefits for migrating and breeding waterfowl. We subsequently examined 92 wetlands that had been enhanced or created under WAML. Our objectives were to identify physical variables that were important to waterfowl and could be manipulated during the construction process. In general, waterfowl use wetlands that are > 1.0 ha in size, have abundant emergent and submersed vegetation, and are located within complexes of > 5 wetlands within a 1 km radius. Soil qualities on abandoned bentonite sites are generally heavy clay in texture with high Exchangeable Sodium Percentages and require physical and chemical amendments to facilitate vegetative growth. Wetland plants have been slow to establish at these created wetlands because of the poor soils and a lack of suitable propagules; natural wetlands within this region are almost non-existent and are mostly limited to seasonal playas and small creeks. Ongoing research, including both greenhouse experiments and field trials, has been focused on improving aquatic plant establishment and growth. Techniques to improve bentonite wetlands will be useful not only in future WAML activities, but to bentonite mining companies.

Additional Key Words: reclamation, restoration, waterfowl, wetlands

Introduction

Since the early 1900's, over 1500 wetlands have been created from bentonite mining in northeast Wyoming. These wetlands are created when bentonite, a clay used for many industrial purposes, is mined from shallow outcrops, and the resulting pits fill with runoff or intercept groundwater. Bentonite wetlands are typically small ($\bar{x}$ = 1.2 ha), shallow (< 3 m), unvegetated wetlands with turbid water (Rumble et al. 1985, McKinstry and Anderson 1994a,b) that resemble prairie potholes in structure and function. In 1986, the Wyoming Department of Environmental Quality-Abandoned Mined Lands (WAML) began reclaiming bentonite surface mines in northeastern Wyoming that had been abandoned without adequate reclamation.

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This reclamation was funded and done under the Abandoned Mine Land provisions of Title IV of the federal Surface Mining control Act of 1977 (SMCRA 1977). Reclamation activities included regrading to bury and isolate sodic and/or acid forming materials, to eliminate ponds that presented a "muck" or quicksand-like hazard to livestock and wildlife, and the placing of topsoil materials when available, or amending overburden and mine soils when necessary, to provide a suitable substrate for vegetation establishment.

The initial goal of the WAML reclamation program was to eliminate hazards to public health, safety, and property and to eliminate off-site environmental degradation resulting from these unreclaimed abandoned mines. The early WAML reclamation plans were oriented to re-establish the original pre-mining surface drainage patterns in an effort to maximize hydrologic and erosional stability. Ponds and wetlands resulting from mining were saved only at the request of the landowners, when desirable for hydrologic stability, and/or when they readily fit into the reclamation design (Richmond and Koopman 1990).

The WAML program became aware of the wetland protection and preservations requirements of Section 404c of the federal Clean Water Act (CWA 1972) in September, 1986. Thereafter, WAML, working with its consultants, the U.S. Army Corps of Engineers, the Wyoming Game and Fish Department, and the affected landowners, developed plans that incorporated the "no net loss" concept for wetlands encountered in the reclamation of abandoned mines. Subsequently, over 3320 ha of abandoned bentonite surface mines have been reclaimed at 236 sites. This includes 180 ha of wetlands resulting from existing ponds left in place, wetlands enhanced by reclamation, or newly constructed wetlands to mitigate for wetlands lost by reclamation.

Prior to 1973 and the promulgation of Wyoming's Land Quality Act of 1973 (WDEQ 2000), surface mining of bentonite and other non-coal minerals did not require reclamation. The overburden piles and the shallow (< 15 m) mine pits often blocked or intercepted drainage channels, creating ephemeral, intermittent, or perennial ponds. Soon, these inundated areas developed the soil and vegetative characteristics of wetlands as defined by the U. S. Army Corps of Engineers (COE 1987).

Laws governing the reclamation of current, and future, bentonite mines in Wyoming are found at Article 4 of the Wyoming Environmental Quality Act, Sections WS 35-11-401 through 35-11-407 (WEQA 2000). The Land Quality Regulations for non-coal mines, Chapters II, and IV, provide for certain stability, grading, and access considerations for permanent water impoundments that may be a part of the reclamation plan. However, there are no specific requirements for wetland habitat considerations for bentonite and other non-coal mineral mines (WLQD 2000). Since these mines occur in isolated dryland country, many landowners welcome the additional wetlands for alternative livestock watering sites and improvements to wildlife habitat.

Bentonite from northeast Wyoming is especially prized for its smectitic structure and ability to absorb water and swell to many times its original size (Edinger 1999). Bentonite is used in many products including foods, cosmetics, and kitty litter; it is also used in many industries including oil and gas drilling, hazardous waste removal, and agriculture. Industry analyses show that Wyoming currently produces almost 80% of the world's sodium bentonite, and the market for bentonite is expected to grow in the future (Casper Star Tribune March 10 1998:C1, August 11 1999:A1) as existing markets expand and new uses for bentonite are discovered.

Bentonite exists as shallow, gently to moderately dipping, deposits across the landscape and often occurs as outcrops due to orogenic and erosive processes (Davis 1963:15, Grim and Guven 1978). The clay beds are generally < 3 m thick (Grim and Guven 1978) and are surface mined using scrapers, bulldozers, and excavating equipment. Since the ore is mined near the surface, overburden is usually nonexistent and shallow depressions eventually develop into wetlands as a result of the mining activity. Approximately 15% of all bentonite mines result in the creation of wetlands (Smith 1984).

Palustrine wetlands (Cowardin et al. 1979) are susceptible to destruction, and creating replacement wetlands is commonly viewed as viable mitigation (Hammer 1992). Wetland creation incidental to mining activity is particularly attractive because of potentially lower construction costs (e.g. reduced excavation costs) and these wetlands can produce valuable habitat for breeding and migrating waterfowl (Uresk and Severson 1988, Nawrot and Klimstra 1989, Rumble 1989, Horstman et al. 1998). Additionally, wetlands created through mining activities are often looked upon as possible replacements for wetlands destroyed in other locations ("wetland banking"). Wetland creation in Wyoming is a valuable management technique and many natural resource agencies use it to improve, create, and mitigate wildlife habitat. Little research has been done on the value of created wetlands for wildlife, and more importantly, on the creation of habitat features that are important to wetland wildlife.

Our objectives are to describe reclamation activities at abandoned bentonite mined lands, review the research on these wetlands, and describe ongoing research that is focused on improving these created wetlands.

Study Area

Most bentonite wetlands in Wyoming are located in the northeastern corner near the towns of Upton and Colony. These areas have high concentrations of bentonite mines (both historic and active) due to the relative accessibility of the ore body. It is widely believed (Grim and Guven 1978, Edinger 1999) that bentonite deposits in Wyoming originated from the caldera explosion of what is now Yellowstone Lake in northwestern Wyoming. Prevailing winds carried volcanic ash from the explosion in an easterly direction, with it eventually settling in the Big Horn Basin of Wyoming and in the tri-state region of Montana, South Dakota, and Wyoming. Eventually a Cretaceous sea inundated the region and sodium bentonite was formed (Hewett 1917, Edinger 1999).

The bentonite region of northeastern Wyoming can be described as a high elevation (>1,500 m), sagebrush (*Artemisia* spp.)/grassland community interspersed with fragments of Ponderosa pine (*Pinus ponderosa*), with a rolling topography. Snow can occur in any month of the year but primarily occurs between November and April. Average precipitation is 35-40 cm/yr and occurs primarily as rainfall in May, June, and July. Bentonite wetlands are filled almost exclusively from surface waters since groundwater depths are usually > 200 m and bentonite acts as a barrier to most water movement. Soils of the area generally contain little organic matter, are fine grained, alkaline, highly sodic, and poorly drained due to the high clay content (Lowry and Wilson 1986).

Three types of wetlands were left after reclamation activities by WAML: (1) wetlands newly created to mitigate for wetland losses elsewhere; (2) wetlands completely reclaimed by excavating and stabilizing the wetland basin, reducing highwalls, recontouring the surrounding uplands, and revegetating the surrounding watershed; and (3) wetlands where the basin was left undisturbed but the surrounding uplands were recontoured and terrestrial vegetation was restored. Research that we discuss was conducted on a sample of wetlands that represented a combination of all three types of wetlands. Further wetland descriptions can be found in McKinstry and Anderson (1994a,b, 2001).

Natural wetlands in northeast Wyoming are scarce and generally restricted to seasonal playas or small rivers and streams (Brewster et al. 1976, Evans and Kerbs 1977), thus these bentonite wetlands account for a majority of the wetlands within the region. Stock ponds and other impoundments created by mining (coal) are the only other wetlands present and can be important habitat for migrating and breeding waterfowl (Uresk and Severson 1988, Rumble 1989, Svingen and Anderson 1998, Ball et al. 1995), although few exist in this area.

Review of Past Research

In 1990, the Wyoming Game and Fish Department (WG&FD) became interested in the value that wetlands created through bentonite mining provided to migrating and breeding waterfowl. Wyoming is ranked sixth of the 50 states in waterfowl production (Kelly et al. 1995), and it was/is felt that bentonite wetlands play a substantial role in providing waterfowl habitat. As a result of this interest several projects were initiated with the objectives of 1) quantifying waterfowl use at constructed wetlands, 2) identifying variables that were important to migrating and breeding waterfowl and that could be manipulated during the construction/reclamation stage, 3) evaluating the predictability of wetland creation within this landscape, and 4) providing management recommendations concerning future wetland creation. Detailed results of this research are found in McKinstry and Anderson (1994a, b, 2001) and Anderson et al. (1994), and we review it here.

Waterfowl Use

Bentonite wetlands are used primarily by Canada geese (*Branta canadensis*) and dabbling ducks during spring and fall migration and for breeding. Diving ducks use these wetlands during migration but few have been observed using them during breeding season. Species composition of breeding waterfowl is dominated by mallards (*Anas platyrhynchos*) and blue-winged teal (*Anas discors*), which are predominant on stock ponds in South Dakota (Rumble and Flake 1983), Montana (Ball et al. 1995), and North Dakota (Lokemoen 1973). Mallards have large home ranges and can effectively use dispersed wetlands like the scattered wetlands in Wyoming and western South Dakota (Lokemoen 1973, Nudds and Ankney 1982). Canada geese are not usually found in association with smaller wetlands like stock ponds but many of these created wetlands are large (e.g. > 2 ha) and can provide the types of habitat geese need for breeding (Naugle et al. 1997).

Generally, waterfowl are found on bentonite wetlands that are > 1.0 ha, have abundant submersed and emergent vegetation, and are located within complexes of > 5 wetlands within 1 km. The role of complexes is especially important since wetlands of different sizes, depths and types can be incorporated during mining activities to meet the needs of different species of animals. Wetland complexes can provide alternative sites when birds are disturbed; a greater probability of water availability throughout brood rearing and molting seasons; increased, varied, and dependable food availability; and a mosaic of habitats that are important to the various life requirements of migrating and breeding waterfowl (Patterson 1976, Mack and Flake 1980). Other authors (as reviewed in Ruwaldt et al. 1979 and Leschisin et al. 1992) stress the importance of high numbers of small, shallow, vegetated wetlands to dabbling ducks during spring and early summer. Lokemoen et al. (1984) suggested the best waterfowl habitats contained about 12-40 wetlands/km^2 of various sizes and shapes. Although this density may not be achievable with bentonite wetlands, it is an indication that "more is better." The formation of wetland complexes through bentonite mining is relatively easy since ore outcrops are found in close proximity (Davis 1963), although it is not a standard practice.

The average size of a bentonite wetland is 1.2 ha (McKinstry and Anderson 1994a) and is constrained by the size of the clay bed. Likewise, the depth of bentonite wetlands is constrained by the configuration of the mining disturbance and by the economics of excavating the mineral from deeper pits. The average water depth at these wetlands is < 2 m (McKinstry unpublished data) but some wetlands are > 5 m, and many support populations of fish (McKinstry unpublished data). Size and depth can be decisive factors in dictating amount and type of waterfowl use. Hammer (1992) discussed the importance of wetland size and recommended building wetlands larger than minimum requirements for several reasons: 1) larger size may reduce long-term maintenance, 2) larger wetlands may support broader assemblages of plant and animal populations, 3) larger wetlands may support more diverse and more complex food chains, 4) larger wetlands may improve flood storage, 5) larger wetlands may be more likely to retain water during droughts, 6) for wastewater treatment, larger wetlands reduce contaminant loading, and 7) larger wetlands are more apt to meet project goals. Although small constructed wetlands can provide specialized requirements for certain species, larger wetlands may provide greater numbers of habitats, and are more likely to attract a greater number of species (Brown and Dinsmore 1986, Weller 1990). Hudson (1988) mentioned that wetlands < 0.5 ha were of little importance to dabbling duck broods and increased surface area was the single most important variable affecting pair use by puddle ducks on created wetlands in northwestern Minnesota (Leschisin et al. 1992). Lokemoen (1973) recommended a minimum pond size of at least 0.6 ha and recommended construction of stock ponds near other wetlands. While wetland size during the reclamation stage may be constrained by the size of the ore bed, adjacent habitats, and willingness of the miner to increase the wetland basin, it is probably the single most important factor to consider when creating wetlands in this landscape. When a wetland smaller than 0.5 ha will result from mining, it may be possible to provide extra funds (from Ducks Unlimited, state wildlife agency, cost share programs, etc.) to the mining companies to defray costs of enlarging the basins.

With respect to waterfowl use, it is unknown how these created wetlands compare to natural wetlands in the study area since essentially no natural wetlands exist. While these created wetlands are high in density, and seem to offer adequate migrating and breeding habitat, they are relatively new in this region and may not yet be fully exploited. Furthermore, these wetlands are successionally young, often built on unproductive substrate high in sodium and clay content, and may not have reached their full productive potential. These wetlands are also isolated from others, creating what could be considered an "island effect" (MacArthur and Wilson 1967). Wetlands in northeast Wyoming are considered to be in the Central Flyway, but are actually far removed from traditional areas and may not receive high use until large populations of ducks and geese discover them.

Wetland Vegetation

No effort was made by WAML to establish aquatic vegetation as part of its reclamation. As a result, all wetland vegetation present at the sites has established as natural volunteers. The most common emergent vegetation at bentonite wetlands is spikerush (*Eleocharis palustris*), and cattail (*Typha latifolia*), a wind-dispersed emergent, which were found at 88% and 62% of 42 wetlands, respectively (Table 1). Sago pondweed (*Potamogeton pectinatus*) is the most abundant submersed aquatic and was found at 53% of 42 wetlands. Only 17 total species of aquatics were found in a sample of 42 wetlands (Table 1). Furthermore, vegetative cover was limited to less than 20% at all of the sampled wetlands.

Table 1. Aquatic plant species and the percent of sampled wetlands where they were found for 42 bentonite wetlands in northeast Wyoming.

Species	% of wetlands where present
Emergents	
Eleocharis palustris	88%
Typha latifolia	62%
Scirpus maritimus	54%
Scirpus acutus	33%
Sagittaria cuneata	21%
Rumex crispus	16%
Spartina pectinata	9%
Carex nebraskensis	5%
Mentha arvensis	2%
Alisma plantago	2%
Equisetum hyemale	2%
Submersed	
Potamogeton pectinatus	53%
Ranunculus cymbalaria	36%
Lemna turionfera	7%
Potamogeton richardsonii	7%
Potamogeton filiformis	5%
Chara vulgaris	2%

Evans and Kerbs (1977) and Flake et al. (1977) in South Dakota, and Joyner (1980) in Ontario reviewed the importance of submersed and emergent vegetation to waterfowl and emphasized that submersed vegetation is important both as a direct food source and as habitat for invertebrates, which in turn are used as food. Although submersed or emergent plants were not planted in these created wetlands, they have volunteered through wind dispersal or animal transport, and in a few cases have become well established. Since most of these wetlands do not dry periodically (average drawdown from year to year is < 30% at a sample of 80 wetlands), establishing aquatic vegetation is difficult (Kadlec 1962). Few species of aquatic macrophytes can germinate under salt stressed, highly turbid, flooded conditions. Most research on vegetation of prairie wetlands has been conducted on either natural wetlands or those that are being restored (e.g. tile removal) and have existing seed banks (van der Valk and Davis 1976, 1978, Kantrud et al. 1989, Galatowitsch and van der Valk 1996). Our created wetlands must first develop suitable conditions for vegetation establishment and then be inoculated with a suitable plant species, thus it is not surprising that many of these ponds lack functioning vegetative communities.

Current Research

Research on bentonite wetlands is now focusing on the establishment of aquatic plants at these disturbed sites. Aquatic plants have been slow to establish because of the poor soils and a lack of suitable propagules. Bentonite wetlands are highly alkaline, with turbid water, unconsolidated substrates, and are far removed from seed sources (natural wetlands) that would improve the probability of wetland plants establishing. Soil qualities on abandoned bentonite sites are generally heavy clay in texture with high Exchangeable Sodium Percentages and require physical and chemical amendments to facilitate vegetative growth (Schuman 1997). Terrestrial vegetation growth was improved on over 4,100 ha of terrestrial habitat with the addition of soil amendments, regrading and contouring, seeding, and fertilizing (Uresk and Yamamoto 1986, Schuman 1995, 1997, Schuman and Belden 1991, Schuman et al. 1994). The addition of wood chips, gypsum, and calcium chloride which increase water infiltration and sodium leaching (Richmond 1989, Richmond 1991, Schuman 1995), were found to be the most cost effective strategies to increase terrestrial vegetation.

Water availability is not an issue with aquatic plants, however, water quality is. Several species of aquatic plants are adapted for growth in bentonite wetlands, as evidenced by their presence and persistence there. Experiments using plants purchased commercially are helping to identify those species that can be propagated with a minimum of effort and cost. Likewise, the use of salvaged wetland soil from wetlands that are being filled during reclamation is being tested as an alternative to more traditional planting techniques. In the near future, we hope to develop techniques to improve aquatic plant growth and improve the productivity and value of these created wetlands.

Conclusions

Wetland creation associated with bentonite mining tends to produce small, shallow, unvegetated wetlands. Aquatic vegetation has been slow to establish at these created wetlands due to a lack of suitable propagules and poor growing conditions. Waterfowl use might be improved if efforts were directed at increasing both submersed and emergent vegetation, increasing the diversity of habitat by excavating some wetlands to a deeper depth, and creating larger, more-permanent wetlands. In our review of policies concerning wetland creation through bentonite mining, we found no recommendations concerning construction design, planting requirements, siting guidelines or evaluation techniques. Mining companies might be more amenable to improving wetlands if recommendations were available and if biologists took greater involvement in the construction process. Our future goals are to develop the techniques and tools necessary to improve the establishment and growth of aquatic plants at reclaimed bentonite wetlands.

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