# Evaluation of land reclamation practices on the Fort Peck Dam

by Mark Joseph Gruener

A professional paper submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Rehabilitation
Montana State University


Abstract:
The construction of large earth filled dams, such as that at Fort Peck in northeastern Montana, often results in land disturbances that require reclamation. The U.S. Army Corps of Engineers has completed several reclamation projects at Fort Peck and is interested in using state of the art technology in future land rehabilitation efforts.

The most recent reclamation project involved the regrading, topsoil salvage and respreading and revegetation of approximately 50 acres of land on the powerhouse slope. Although this project produced a vigorous stand of crested wheatgrass (Agropyron cristatum), the native species contained in the seed mixture were not successfully established. Upward migration of sodium, which may hinder the long term success of this reclamation project, was measured.

Lessons learned from evaluation of the powerhouse slope rehabilitation project and technologies developed through reclamation research on mined lands are applicable to future reclamation of disturbed areas around the Fort Peck Dam.

One such disturbed area, the spillway slope, has been scheduled for rehabilitation in the future. The most promising technologies involve the use of chemical amendments which may prevent topsoil sodication and reduce the amount of topsoil required for plant root zones.

It is recommended that the U.S. Army Corps of Engineers initiate a pilot study designed to evaluate the use of chemical amendments for rehabilitation of the spillway slope.

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Date 12 August 1988

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## ABSTRACT

The construction of large earth filled dams, such as that at Fort Peck in northeastern Montana, often results in land disturbances that require reclamation. The U.S. Army Corps of Engineers has completed several reclamation projects at Fort Peck and is interested in using state of the art technology in future land rehabilitation efforts.

The most recent reclamation project involved the regrading, topsoil salvage and respreading and revegetation of approximately 50 acres of land on the powerhouse slope. Although this project produced a vigorous stand of crested wheatgrass (Agropyron cristatum), the native species contained in the seed mixture were not successfully established. Upward migration of sodium, which may hinder the long term success of this reclamation project, was measured.

Lessons learned from evaluation of the powerhouse slope rehabilitation project and technologies developed through reclamation research on mined lands are applicable to future reclamation of disturbed areas around the Fort Peck Dam. One such disturbed area, the spillway slope, has been scheduled for rehabilitation in the future. The most promising technologies involve the use of chemical amendments which may prevent topsoil sodication and reduce the amount of topsoil required for plant root zones.

It is recommended that the U.S. Army Corps of Engineers initiate a pilot study designed to evaluate the use of chemical amendments for rehabilitation of the spillway slope.

# INTRODUCTION

Reclamation research has produced technology that is applicable to a wide range of reclamation challenges. The Fort Peck Dam, built and operated by the U.S. Army Corps of Engineers in northeast Montana, has completed two reclamation projects and is currently awaiting funding for another. These projects are intended to stabilize and revegetate areas that have been disturbed during the construction of the dam and power generation facilities. The technology used on these projects employs reclamation techniques that are similar to those used on many mining reclamation projects.

At Fort Peck, slope stability is a critical concern. Three areas have been the focus of attention: the face of the dam, the powerhouse slope and the spillway slopes. Following construction, the dam and powerhouse slopes were recontoured to a maximum grade of 4:1. The spillway slopes were not recontoured. The spillway slope contour is variable but badly eroded slopes on grades of 3:1 are common. The downstream face of the dam, extending through approximately 5 km (3 mile) sections, was successfully revegetated following the completion of construction in the early 1940's. The powerhouse slope was recontoured and revegetated in the fall of 1978. The success of this project has not been evaluated. A design memorandum outlining specifications for the stabilization of slopes in the vicinity of the spillway is presently being reviewed by the Omaha District, Corps of Engineers. The specifications require that an area of approximately 120 hectares in the vicinity of the spillway be stabilized and seeded with native grasses. Since the Corps of Engineers desires to enhance the probability of reclamation success, recent advances in reclamation technology may be applicable to this project.

The Corps of Engineers is particularly interested in using state of the art technology to complete construction projects in an economical and timely manner. This study will review past reclamation efforts in the Fort Peck area and make recommendations for future Corps of Engineers reclamation projects. The objectives of the study are:

1) To evaluate the success of the 1978 powerhouse slope stabilization project.

2) To investigate potential reclamation problems that may be encountered during the spillway slope stabilization project.

3) To make rehabilitation recommendations to the U.S. Army Corps of Engineers for possible inclusion in reclamation contract specifications.

The work was conducted on land owned by the U.S. Army Corps of Engineers in Valley and McCone counties in Montana.

# LITERATURE REVIEW

Rehabilitation research in the western United States has included a wide range of subjects. Techniques that have been the focus of extensive research include: soil properties, topsoiling, vegetation establishment, fertilization, irrigation and surface manipulation. The importance of using techniques that are compatible with the specific reclamation objective and the limitations and capabilities of the land has been repeatedly emphasized (Coenenberg 1982, Williams et al. 1983).

The U.S. Army Corps of Engineers has long recognized the importance of applying research findings to water development projects. In 1939, following a mass soil movement that resulted in the partial failure of the dam and claimed the lives of eight workers, the Corps of Engineers concluded that the success of the project would require extensive monitoring and periodic stabilization. The primary objective of stabilization efforts at Fort Peck has been erosion control. Secondary objectives include forage for wildlife, livestock and aesthetic considerations (Wallem 1987).

## Soil Characteristics and Reclamation

The primary resource that governs the success or failure of a reclamation project is the soil. The sodium dominated montmorillonite clays found in the Fort Peck area are particularly suitable for the construction of earth filled dams (Wallem 1987), but research studies have shown that this type of soil may inhibit or, in some cases, be toxic to the growth of plants (Goodin 1977, Veseth and Montagne 1980). Studies conducted by Byron (1984) found that the soils on the powerhouse slope are characterized by adverse physical and chemical plant growth parameters and may require special reclamation techniques.

Clay mineralogy and the chemical and physical properties of soils are important considerations in the development of a reclamation plan. Byron (1984) classified the soils near the powerhouse as a Ustic Torriorthent, fine loamy mixed. These soils are derived from Bear Paw Shale parent material described by Veseth and Montagne (1980). They are high in clay and are dominated by smectite mineralogy (Klages and Montagne 1985). Byron found that although the soil pH (7.6) was not inhibitory, the sodium adsorption ratio (SAR) of 27 and the electrical conductivity (EC) measured at 7.9 ds/m were indicative of a saline-sodic soil (Richards 1954). The soil contained approximately 10% sand, 28% silt and 62% clay.

Smectite clays, dominated by an excess of exchangeable and soluble sodium, can severely limit the establishment of vegetation. Goodin (1977) found that some plants may experience a sodium induced nutrient imbalance and noted that in some cases high levels of sodium may be directly toxic to sensitive plants. Dollhopf et al. (1985) stated that an excess of sodium tends to disperse the clay system causing a general loss of soil structure. This results in decreased water infiltration-permeability rates thereby increasing overland flow and surface erosion. Byron (1984) concluded that this type of soil was an unacceptable plant growth medium.

A commonly employed reclamation practice designed to overcome the limitations of sodic soils involves the reconstruction of the root zone by placing good quality topsoil over the sodic material. Barth (1984) found that 71 cm of good quality material was the minimal depth for establishing a suitable root zone over sodic spoil. Shallow depths of material may deteriorate because of an upward migration of salts. Merrill et al. (1983), working in soils similar to those encountered in the Fort Peck area, found that when 15 to 30 cm of good quality material was placed over sodic spoils (SAR = 27), the topsoil became sodic in three years. Other research has shown that this contamination is the result of upward migration of salts caused by diffusion (Sandoval and Gould 1978), but the rate of contamination may be slower than that reported by Merrill (Dollhopf et al. 1985). Working with 70 cm of sandy loam topsoil placed over sandy loam sodic spoil, Dollhopf et al. (1985) found no detectable increase in SAR during the first two years of a seven year study. After seven years, a trend toward upward migration was observed, but the study estimated that it would take 18 to 36 years for the soil profile to become sodic. The study concluded that the rapid upward movement of salts reported by Merrill et al. (1980 and 1983) was not a problem in soils dominated by non-swelling illite or kaolinite clays. These results confirmed the findings of earlier research (Dollhopf et al. 1980) that concluded that a loamy cover soil placed over a saline and/or sodic loam-clay-loam spoil can support highly productive vegetation and the probability is low that sodium salts will migrate upwards and contaminate the topsoil (Dollhopf 1983).

Although the clay mineralogical properties of the soils on the powerhouse slope have not been extensively studied, tests conducted by Byron (1984) found high levels of clay and speculated that montmorillonite dominated the soil system. Research on abandoned bentonite lands near Belle Fourche, South Dakota has shown that chemical and physical amendments may be useful in reclaiming such sodic soils (Dollhopf and Bauman 1981, Dollhopf et al. 1988). This research is supported by the findings of Van Schack (1967) and Pair and Lewis (1959). Van Schack (1967) found that permeability of a montmorillonite dominated soil was nearly zero when the exchangeable sodium percentage (ESP) exceeded 15 to 20. Pair and Lewis (1959) found that gypsum applied at 22 and 44 mt/ha (10 to 20 t/a), on slick spots, increased water intake from .02 cm to .2 and .55 cm per hour. Salt removal with gypsum was directly related to intake rates and both treatments decreased the ESP. Dollhopf (1971) found that gypsum not only increased the ability of saline-alkali soils to transmit water but a greater quantity of water was measured moving through a 15 cm soil mass. He concluded that although application rates may vary depending on site conditions, the application of 22 mt/ha (10 t/a) of gypsum reduced the swelling and shrinking tendencies and improved the infiltration properties of sodium dominated montmorillonitic soils. In cases where topsoil is limited or unavailable, the use of chemical amendments may be the most promising alternative for the reclamation of sodium dominated soils.

## Use of Topsoil

The salvage and redistribution of topsoil is a topic of considerable interest in reclamation research. Williams et al. (1983) noted that because the final goal of a reclamation project will usually be a plant-soil system which will be stable and capable of withstanding a range of environmental perturbations, the role of topsoil is a critical reclamation consideration. However, they also found that because of the high costs incurred in topsoil salvage operations, the question of optimum and minimum depths of material is a sensitive reclamation issue. These concerns are applicable to past and future reclamation programs at the Fort Peck Project (Wallem 1987).

Two key questions have arisen in recent years regarding topsoil salvage and redistribution: (1) what are the effects of topsoil horizon segregation on vegetation production? and (2) how does a topsoil depth influence plant response? Considerable research has been carried out on these issues (Crofts et al. 1987, Barth 1984, Power et al. 1976, 1979, 1981 and DePuit and Coenenberg 1979) but the results have been variable.

Crofts et al. (1987) addressed the question of segregation of topsoil during salvage and redistribution. He noted that topsoil is defined by the Office of Surface Mining (OSM 1983) as "The A and E soil horizon layers of the four master soil horizons. Subsoil is defined as the "B" horizon, the layer typically is immediately beneath the E horizon". Because OSM regulations require the segregation of topsoil from subsoil, it is common practice to salvage and respread topsoil and subsoil in two separate lifts (Walsh 1985). This practice is justified by the belief stated by OSM (1979) that "to mix the various soil horizons, during removal could be counterproductive to restoration of the disturbed area to a level at least equal to the premining capability".

Research has produced conflicting findings concerning the validity of this premise. Allen (1984) studied the effects of disturbance on mycorrhizae and concluded that any practice which sustained the plant mycorrhizae relationship enhanced vegetation establishment. However, Biondini et al. (1984) found that the recovery of dehydrogenase activity and mycorrhizae infection potential after six years was not different between slight and severe levels of soil disturbance. These results were substantiated by Power et al. (1979 and 1981), who found, that over a four year period, yields from native vegetation on mixed horizon soils were within 90% of yields obtained with segregated horizons treatments. Because Power's studies were conducted on sodic soils similar to those found in the Fort Peck area, these findings are particularly noteworthy.

The results of research involving various depths of topsoil are more consistent. When topsoil is placed over good quality spoil, Crofts et al. (1987) found that thicker layers of topsoil were more productive especially during the early stages of succession. Barth (1984) found that shallow soils will support vegetation, but concluded that deeper profiles are required when the underlying spoil is of poor quality.

In addition to providing a growth medium, the use of topsoil has other benefits. DePuit et al. (1980a) reviewed the literature on seed reserves and concluded that most seeds were confined to the upper 5 to 7 cm of the profile. Allen (1984) studied the inoculation of mycorrhizae and suggested that spreading 2 to 3 cm of fresh topsoil might be more advantageous than a thicker application of biologically inert topsoil. These studies have shown that direct hauling topsoil, even in thin layers, can be very beneficial in reclamation.

Research has shown a wide variety of plant responses following topsoil spreading and there is little question that the use of topsoil is a valuable reclamation tool. However, the availability of topsoil may be limited. If topsoil is stripped from native range, the borrow area must be reclaimed. Dollhopf and LoPiccolo (1987) studied the process of natural revegetation of a topsoil borrow area and found that if pH, EC, texture and saturation percentage are not inhibitory, the B horizon material can support productive vegetation. Because reclamation at Fort Peck is not subject to OSM regulatory restrictions concerning the use of borrow pits, these findings may be relevant to any revegetation program at the site. Although stripping topsoil from native range does offer an alternative for reclamation, there are adverse impacts. By excavating topsoil from native range, the area of disturbance is increased. The Corps of Engineers was able to alleviate this problem in the 1978 revegetation project by removing topsoil from fish rearing ponds they were constructing adjacent to the Fort Peck Reservoir. The excavated soil was moved to the powerhouse slope and the resulting borrow pits flood during high water and are used by the Montana Department of Fish Wildlife and Parks to rear warm water game fish. Because no additional fish ponds are required, future reclamation projects may be forced to consider the impact of increasing the size of the disturbed area by excavating topsoil from native range.

## Selection of Vegetation

The ultimate success of a reclamation project is reflected by the establishment of the vegetation. Valentine (1971) noted that certain ecological principles, especially competition and succession, must be considered when selecting plant species for rangeland seeding. In addition, the selection of plant materials should be based on climate, soils and post disturbance land use (Thornburg and Fuchs 1978). Because the primary purpose of reclamation at Fort Peck is erosion control, the species used must establish quickly and firmly anchor the soil on the slope.

Considerable research has been conducted to evaluate those species adapted for reclamation use. Hafenrichter et al. (1968) emphasized the importance of developing cultivars that are capable of performing specific reclamation functions. DePuit (1984) commented that some early reclamation research results may not accurately evaluate the full potential of some cultivars which were released in the early 1970's. Four cultivars are particularly important for this study: Rosana western wheatgrass (Agropyron smithii), Critana thickspike wheatgrass (Agropyron dasytachyum), Lodorm green needlegrass (Stipa viridula) and Wytana fourwing saltbush (Atriplex canescens). These species have been used for reclamation in the Fort Peck area and have been included in several mineland reclamation studies (Meyn et al. 1976, DePuit et al. 1980b, Coenenberg 1982, and Rennick et al. 1984). Each grass has specific characteristics and must be analyzed both individually and collectively in a mixture.

Rosana western wheatgrass was developed specifically as a reclamation species for use on dry, clayey sites (Stroh 1973). Thornberg (1982) noted that it is a strongly rhizomatous grass, salt tolerant and attains optimum performance when annual precipitation exceeds 30 cm. Nichols (1969) found that western wheatgrass can be established successfully in dense, deteriorated clays. DePuit et al. (1980a) found that when adequate moisture is available, western wheatgrass establishes quickly and competes well with annual species, but noted that in a dry year (1978-79) at Colstrip, Montana, canopy cover of this species declined. They attributed the decline to increased competition from more drought tolerant species such as thickspike wheatgrass.

The release of Critana thickspike wheatgrass has had a substantial impact on reclamation. Developed from a strain originally collected near Havre, Montana, Critana is particularly well adapted for use in the northern Great Plains (Stroh 1972). Thornburg (1982) noted that thickspike performs well on silty or clayey textured soils. It is salt tolerant and can survive on less than 20 cm of rain per year. The drought tolerance of thickspike wheatgrass has been confirmed by DePuit et al. (1980b) who found that even in a dry year (1978-79) thickspike can compete effectively with other native species such as green needlegrass and western wheatgrass.

Lodorn green needlegrass is a cool season bunch grass that is commonly used in native species mixtures. Green needlegrass required more moisture than thickspike or western wheatgrass (35 to 50 cm/yr), but is well adapted to clayey sites (Hafenrichter et al. 1968 and Thornburg 1982). DePuit and Coenenberg (1979) found that if problems with seed dormancy such as those noted by Dollhopf and Majerus (1975) can be overcome, green needlegrass may persist as a dominant species. Although the production of green needlegrass may be lower than some wheatgrasses, it establishes a dense ground cover at low seeding rates and is well adapted for use in a mixture with western and thickspike wheatgrass.

Wytana fourwing saltbush is a long lived shrub well adapted to xeric sites (Thornburg 1982). Although fourwing saltbush may decline in vigor during cold winters or when faced with competition from perennial grasses, DePuit et al. (1980a) found that it was compatible with a wide range of native grass mixtures. Rennick et al. (1984) noted that this species traditionally performs well on revegetated areas and is an important part of many plant communities on reclaimed land.

Other native species that appear to be well adapted for use at Fort Peck include streambank wheatgrass (Agropyron riparium), bluebunch wheatgrass (Agropyron spicatum) and slender wheatgrass (Agropyron trachycaulum). Each of these species is well adapted to clayey soils, but precipitation requirements are variable. Streambank wheatgrass can survive under a wide range of precipitation conditions (30 to 50 cm/yr), but achieves optimum performance when annual precipitation is between 30 to 40 cm per year. Bluebunch wheatgrass required 30 cm of rain per year to sustain productivity, but is well adapted to shallow upland sites. Slender wheatgrass thrives under more mesic conditions (35 to 50 cm/yr), but can establish quickly with excellent early vigor if sufficient moisture is available.

Although other native species may be adapted to the soil and precipitation regime at Fort Peck, reclamation research has shown that satisfactory results can be achieved with the species previously discussed. A number of introduced species are well adapted for erosion control, but the Corps of Engineers has expressed a preference for the use of native species in reclamation at Fort Peck (Wallem 1987).

## Seeding Techniques and Surface Manipulation

One of the most widely studied areas of reclamation involves the influence of seeding techniques and seed mixtures. Research has shown that seeding rates have a direct influence on canopy cover and production (Packer and Aldon 1978). DePuit (1984) found that heavy seed rates 22.4 Kg/ha (20 lbs PLS per acre) produce high plant densities in the first year following seeding, but production was greater when a lighter rate 11.2 Kg/ha (10 lbs PLS/a) was used. These trends are generally applicable for both drill and broadcast seedings, but each technique has certain advantages and limitations.

Some studies have shown that drill seeding is preferable to broadcast seeding (Cook et al. 1970, 1974). Drill seeding uniformly distributes the seed and physically places it into the soil. This minimizes seed loss from wildlife depredations and has produced higher germination rates than those achieved by broadcast seeding (Valentine 1971). Other advantages of drill seeding include: improved infiltration and moisture storage, wind protection, easy application to mulched surfaces and usually more rapid production of seeded plants (Valentine 1971, DePuit et al. 1980a). However, Hodder and Atkinson (1974) noted limitations associated with drill seeding. These included: 1) access problems on steep and uneven terrain, 2) higher cost for seeding large areas and 3) incomplete compatibility with the range of variation of seed characteristics of diverse seed mixtures.

Broadcast seeding has achieved variable degrees of success in reclamation. DePuit et al. (1980a) stated that some bias against broadcast seeding may have been caused by seeding failures on adverse sites. He suggested that a combination of factors were involved in these failures, and noted that previous mined land revegetation studies in Montana (Meyn et al. 1976) established no clear superiority of one method over the other. In studies at Colstrip, Montana, DePuit et al. (1980b) noted that although drill seeding appeared to favor larger seeded species of *Agropyron* (thickspike wheatgrass, streambank wheatgrass and western wheatgrass), fourwing saltbush and green needlegrass established better cover when broadcast seeded. This study also found that optimum stand densities were achieved by drill seeding at a rate of 25.8 Kg/ha (23 lb PLS/ac) and broadcast seeding at 50.5 Kg/ha (45 PLS/ac). The study concluded that the final decision concerning seeding technique must be based on an evaluation of area accessibility, location, slope, seedbed preparation, topsoil characteristics seasonal timing of seeding and individual seed characteristics.

# STUDY SITE DESCRIPTION

## Location

The study site was located on the U.S. Army Corps of Engineers' Fort Peck Project, approximately 32 km (20 m) south of Glasgow, Montana. Figures 1 and 2 show the specific study areas.

### The Fort Peck Dam Study Area

The downstream face of the dam is approximately 300 m long and 1500 m wide (Figure 1). On the aerial photograph, the dark strip at the bottom of the picture is Fort Peck Lake. The face of the dam slopes gently to the north and is distinctly divided by access roads which traverse the face of the dam in an east-west direction. The slope extending downhill to the north from the crest of the dam to the first east-west access road is approximately 4:1, but gradually flattens out to a 6:1 slope near the downstream toe of the dam. The change in elevation from the crest of the dam to the downstream toe is approximately 77 m. Except during periods of high water, the entire flow of the Missouri River is diverted through the intake structures located in the lower right corner of the picture.