# Root Zone Management in North Dakota Coal Mine Reclamation

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**Wheat yields on trenches simulating reclamation were improved by 18-inch thick first lift "topsoil" over three textures of overburden as compared with a thickness of 9 inches, according to the first year's results. For coarse textured overburden best yields were obtained with a minimum of compaction plus 27 inches of first lift. The addition of second lift material over gravelly sandy loam overburden improved grain yield when 9-inch thick first lift was used, and also increased yield for 18-inch thick first lift when this coarse textured overburden was noncompacted. Compaction of overburden material placed in the trenches by scrapers resulted in lower wheat yields than no compaction. Subsidence was almost equal on compacted and non-compacted trenches after one year:**

## INTRODUCTION

Mining of coal in the Northern Great Plains will undoubtedly expand as our nation's demand for energy grows. Projected estimates indicate by the year 1990 about 3000 acres of land per year will be disturbed in North Dakota to produce about 45 million tons of lignite (Sandoval, et al., 1973). Anticipated requirements for gasification plants might significantly increase this figure.

Lignite in North Dakota is found in two main physiographic regions, north and east of the Missouri River under soils developed mainly on glacial till, and south and west of the Missouri under soils developed principally from soft shales, siltstones and some sandstone residues from the Sentinel Butte and Tongue River formations (Wali and Sandoval, 1975). The overburden material at most mine sites south and west of the Missouri River is saline or sodic. Certain overburden samples from four west side mines were reported by Bauer, Gee and Gilley (1976) to have sodium adsorption ratio (SAR) values of 15, 17, 10, and 1. Reclamation requires the replacement of topsoil. Crop forage yields in research at these mine sites were shown to increase when up to 24-28 inches of "topsoil" was replaced (Sandoval and Gould, 1978; Bauer, Berg and Gould, 1978), but the upward migration of sodium may cause deterioration of the topsoil with resulting decreases in productivity (Power, Sandoval and Ries, 1979). Therefore, a greater thickness of topsoil plus subsoil is required on these spoils to ensure long-term productivity.

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The SAR values of overburden material north and east of the Missouri River are generally much lower than the values found south and west of the river. This might be expected since the coal overburden north of the Missouri is primarily glacial till. It is likely that many of the reclamation problems associated with sodicity at mines south and west of the Missouri River will not be encountered to the north and east. Another severe problem is subsidence and piping in reclaimed land (Ries, Sandoval and Power, 1977).

Very little research has been conducted on reclamation problems associated with soils on the north and east side of the Missouri River. Research was initiated in 1978 to study the effects of several textures of overburden materials, first lift or "topsoil" thickness, second lift material, and compaction of overburden on productivity and soil moisture relationships of reclaimed land at the Falkirk Mine near Underwood, North Dakota in cooperation with the Falkirk Mining Company.

## METHODS AND MATERIALS

Eight trenches 50 feet wide by 200 feet long were excavated in the fall of 1978 to a depth of 15 feet. The surface of overburden in trenches 1, 3, 5, 6, 7 and 8 and of second lift material in trenches 2 and 4 were shaped to receive 9, 18, and 27 inches of first lift material on each trench. The first lift treatments are longitudinal strips the full length of each trench and one-third the trench width with the final soil surface being uniform when construction was finished (Figure 1). Each first lift "topsoil" plot was further divided for fertility treatments. There were two areas of comparable size to each trench reserved for non-disturbed comparisons.

The first 4 trenches (Table 1) were refilled with gravelly sandy loam (gsl) overburden to within 9, 18, and 27 inches of the original surface of trenches 1 and 3, and to within five feet of the original surface of trenches 2 and 4. The original clay loam subsoil or second lift material was replaced on trenches 2 and 4 to within 9, 18, and 27 inches of the original surface. Trenches 1 and 2 were refilled using scrapers to compact the overburden material and trenches

3 and 4 were refilled with front end loaders to simulate dragline reclamation. Trenches 5 and 6 were refilled with clay loam (cl) and trenches 7 and 8 were refilled with silty clay loam (sicl) overburden to within 9, 19, and 27 inches of the final surface elevation. Trenches 6 and 8 were refilled using scrapers while trenches 5 and 7 were refilled using front end loaders. The purpose of these treatments was to determine the effect of 1) overburden material of various textural classes on subsidence and plant growth on the reclaimed land, 2) compaction from scrapers as compared to minimum compaction by a front end loader to simulate a dragline on bulk density, subsidence, and plant growth and, 3) the second lift on plant growth.

Plots on undisturbed land (UD) were established to the west and south of the trench plots. Several different crop species, including wheat, oats, barley, corn, and sunflower, were grown on these undisturbed plots to obtain yield data for comparison with reclaimed areas. Fertility rates of 0, 30, or 60 lb nitrogen per acre (N/A) and 0, 20, and 40 lb phosporus per acre (P/A), respectively, were broadcast onto all trench and undisturbed plots. The plots were disked and planted to spring wheat on May 18.

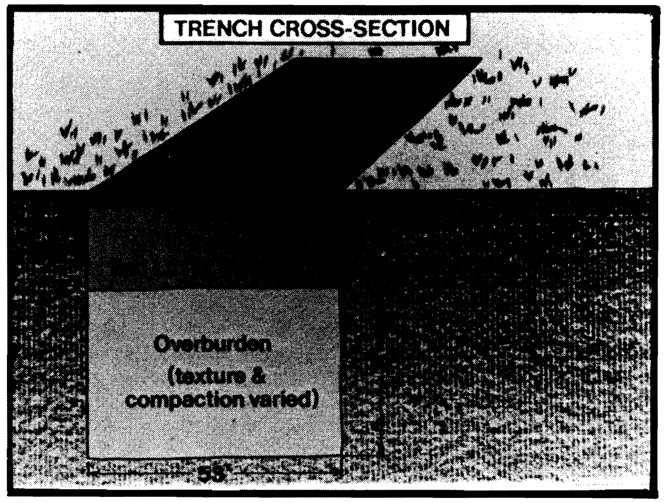


**Figure 1.** Cross section of one of the trenches showing the placement of first lift, second lift, and overburden material.

**Table 1. Texture and compaction characteristics of overburden in trench plots.**

| Trench number | Description (symbols) |
|---|---|
| 1 | Compacted gravelly sandy loam (Cgsl). |
| 2 | Compacted gravelly sandy loam + clay loam 2nd lift (Cgsl+cl). |
| 3 | Noncompacted gravelly sandy loam (NCgsl). |
| 4 | Noncompacted gravelly sandy loam + clay loam 2nd lift (NCgsl+cl). |
| 5 | Noncompacted clay loam (NCcl). |
| 6 | Compacted clay loam (Ccl). |
| 7 | Noncompacted silty clay loam (NCsicl). |
| 8 | Compacted silty clay loam (Csicl). |
| | Undisturbed sites (UD). |

**Table 2. Effect of topsoil depth on grain yield of wheat from all trenches. Falkirk, 1979.**

| Topsoil thickness | Trench[1/] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| | Cgsl | Cgsl+cl | NCgsl | NCgsl+cl | NCcl | Ccl | NCsicl | Csicl | Aver |
| inch | bu/A | | | | | | | | |
| 9 | 9.9 | 13.9 | 10.7 | 16.4 | 20.7 | 11.5 | 15.0 | 11.9 | 13.8 |
| 18 | 15.9 | 14.9 | 16.5 | 20.3 | 19.8 | 14.2 | 19.9 | 18.1 | 17.5 |
| 27 | 15.4 | 16.3 | 21.3 | 22.1 | 18.9 | 16.5 | 17.2 | 13.4 | 17.7 |
| Average | 13.7 | 15.0 | 16.2 | 19.6 | 19.8 | 14.1 | 17.4 | 14.5 | 16.3 |
| UD[2/] | -- | -- | -- | -- | -- | -- | -- | -- | 16.5 |

1/ See table 1 for trench identification.

2/ Undisturbed areas, average of all fertility treatments.

Access tubes were installed in the trench plots and undisturbed plots to measure soil water. Core samples from the access tubes were used to measure bulk density and were analyzed chemically for sodium, calcium, and magnesium. Sodium adsorption ratio (SAR), a measure of the potential sodium problem in soils, was calculated from these chemical data. Subsidence in the trench plots was measured with a surveyor's transit from a benchmark on an undisturbed point nearby.

## DISCUSSION OF RESULTS

Wheat yields ranged from 10 to 22 bushels per acre. These yield differences were caused by combinations of texture and compaction or noncompaction of overburden materials and by different thicknesses of first or second lift material. Wheat yields were relatively low because the first half of the summer was very dry. Nitrogen and phosphorus fertilizers did not produce significant grain yield increases. The average yield on nondisturbed areas was only 16.5 bu/A which was in part a reflection of the dry soil conditions.

Increasing the thickness of first lift "topsoil" from 9 to 18 inches increased wheat yield from 13.8 to 17.5 bu/a, when data of all 8 trenches were averaged (Table 2). The overall averages showed little difference for the 27-inch thickness. However, when data for the non-compacted gravelly sandy loam without second lift are examined separately (Table 3), trench 3 for example produced yields of 10.7, 16.5, and 21.3 bu/A for first lift thicknesses of 9, 18 and 27 inches, respectively. However, with the addition of second lift material, 18-inch thick first lift produced essentially maximum yield. There was little advantage of more than 18 inches of topsoil on clay loam or silty clay loam overburden at the yield levels obtained in 1979. The effects of the first lift thickness in the gravelly sandy loam trenches not having second lift were probably related to additional soil water in the thicker material having a higher water holding capacity.

**Table 3. Effect of second lift and compaction of overburden on grain yield of wheat from trench plots filled with gravelly sandy loam (gsl). Falkirk, 1979.**

| | Grain Yield | | | |
|---|---|---|---|---|
| Topsoil thickness | C | | NC | |
| | - | + | - | + |
| inch | T/A (1) | T/A (2) | T/A (3) | T/A (4) |
| 9 | 9.9 | 13.9 | 10.7 | 16.4 |
| 18 | 15.9 | 14.9 | 16.5 | 20.3 |
| 27 | 15.4 | 16.3 | 21.3 | 22.1 |
| Average | 13.7 | 15.0 | 16.2 | 19.6 |

Letters are: C = compacted; NC = noncompacted.
Symbols are: - = no second lift; + = second lift added.
Numbers in parentheses identify trenches, see Table 1.

The addition of the second lift to the gravelly sandy loam overburden increased wheat yields from 15.0 to 17.3 bu/A (Table 3). Improved water relations resulting from the addition of second lift material were probably the main factors causing the higher yields in addition to restricted root growth in the compacted overburden. Total water content of the top four feet of the gravelly sandy loam material was greater where the second lift had been added (Table 4). This is reasonable since the finer textured clay loam in the second lift should have a greater water holding capacity than the coarse textured gravelly sandy loam. The addition of the second lift had its greatest effect in improving yields in those plots with only nine inches of topsoil and which contained the least amount of water (Tables 3, 4).

Trenches containing compacted materials yielded less than the trenches with noncompacted overburden (Table 5). The average yield of wheat was 14.3 bu/A for compacted and 18.2 bu/A for noncompacted trenches.

**Table 4. Average total soil water contents in the surfact 48 in. of the trench plots during May, June and July of 1979.**

| Date | Topsoil thickness | Trench[1/] 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | UD |
|---|---|---|---|---|---|---|---|---|---|---|
| | inch | in/48-in depth | | | | | | | | |
| May 28-29 | 9 | 9.1 | 10.5 | 9.3 | 10.3 | 11.5 | 11.1 | 11.6 | 11.3 | |
| | 18 | 9.8 | 10.7 | 9.8 | 10.6 | 11.8 | 11.1 | 11.7 | 12.0 | 10.5 |
| | 27 | 9.9 | 10.5 | 10.5 | 10.7 | 11.4 | 11.2 | 11.7 | 11.8 | |
| June 25 | 9 | 9.3 | 9.7 | 10.3 | 10.4 | 12.1 | 11.4 | 12.0 | 11.5 | |
| | 18 | 10.0 | 10.8 | 10.1 | 10.5 | 12.1 | 11.5 | 12.0 | 12.3 | 10.1 |
| | 27 | 10.4 | 10.9 | 10.6 | 11.0 | 11.6 | 11.4 | 12.3 | 12.3 | |
| July 9-12 | 9 | 8.6 | 10.2 | 8.6 | 9.8 | 11.5 | 10.9 | 11.1 | 11.5 | |
| | 18 | 9.4 | 10.4 | 9.4 | 10.1 | 11.7 | 10.9 | 11.2 | 11.9 | 9.8 |
| | 27 | 9.9 | 10.4 | 10.1 | 10.2 | 11.4 | 11.1 | 12.0 | 12.1 | |

[1/] For trench identity see Table 1.

**Table 5. Grain yield of wheat comparing all compacted trenches with all noncompacted trenches for the three topsoil thicknesses. Falkirk, 1979.**

| Topsoil thickness | Grain Yield[1/] C | Grain Yield[1/] NC |
|---|---|---|
| inches | bu/A | bu/A |
| 9 | 11.8 | 15.7 |
| 18 | 15.8 | 19.1 |
| 27 | 15.4 | 19.9 |
| Average | 14.3 | 18.2 |

[1/] C and NC are compacted and noncompacted trenches, respectively.

**Table 6. Bulk densities of trench plots for two compaction levels and averaged over topsoil thicknesses. Date of sampling, May 1979.**

| Trench | Depth of Sampling - Ft. 0-1 | 1-2 | 2-3 | 3-4 |
|---|---|---|---|---|
| | $g/cm^3$ | | | |
| **Compacted** | | | | |
| gsl (1)[1/] | 1.71 | 1.91 | – | -- |
| gsl+c (2) | 1.71 | 1.79 | 1.66 | 1.60 |
| cl (6) | 1.07 | 1.06 | 1.20 | 1.46 |
| sicl (8) | 1.23 | 1.51 | 1.41 | 1.57 |
| **Non compacted** | | | | |
| gsl (3) | 1.53 | 1.60 | 1.29 | -- |
| gsl+c (4) | 1.36 | 1.41 | 1.35 | 1.37 |
| cl (5) | 1.16 | 1.33 | 1.20 | 1.16 |
| sicl (7) | 1.28 | 1.43 | 1.52 | 1.36 |

[1/] For trench identity & explanation see Table 1.

This difference was consistent for the three different textural classes of overburden used in the trenches. The yield decreases resulting from compaction were not directly related to a decrease in stored soil water since the total water content of the compacted trenches was actually higher in the compacted silty clay loam material, for example. It is more likely that compaction from the scrapers resulted in the development of a restrictive layer which prevented root penetration and access to water deeper in the profile. Bulk densities in the compacted gravelly sandy loam trenches were considerably higher than in the noncompacted trenches (Table 6). The high bulk densities in these compacted trenches could have restricted root growth and contributed to lower yields. Compaction of the finer textured clay loam and silty clay loam did not seem to appreciably change the bulk density. Therefore, the measured differences in yield between compacted and noncompacted trenches containing clay loam or silty clay loam cannot be accounted for by bulk density differences.

Six of the trenches showed slight decreases in elevation for the 5-month period of December, 1978 to May, 1979 while 2 showed increases (Table 7). The two showing increases were the compacted gravelly sandy loam and the compacted clay loam. The elevation increase could have been due to a "rebound effect" after compaction by scrapers or due to frost heaving during the winter. After one year all trenches showed significant decreases in surface elevation. Subsidence was only slightly greater in the noncompacted trenches than in the compacted ones.

**Table 7. Average surface elevation change for trench plots during a specified period after construction. Falkirk, North Dakota.**

| | Trench[1/] | Incr. or decr. during time period[2/] 12/78 - 5/79 | 12/78 -9/79 | 12/78 -12/79 |
|---|---|---|---|---|
| | | in | in | in |
| **Compacted** | | | | |
| gsl | (1) | + 1.8 | - 3.7 | - 6.7** |
| gsl+cl | (2) | - 1.2[3/] | - 6.5 | - 6.6** |
| cl | (6) | - 5.5 | - 6.5** | - 6.6** |
| sicl | (8) | - 0.7 | - 6.7** | - 6.6** |
| **Non compacted** | | | | **compacted** |
| gsl | (3) | - 2.0** | - 6.4** | - 7.1** |
| gsl+cl | (4) | - 0.9** | - 6.4** | - 6.6** |
| cl | (5) | - 1.8** | - 7.3** | - 7.8** |
| sicl | (6) | - 1.3* | - 6.6** | - 6.6** |

[1/] Numbers in parentheses indicate trench identification, See Table 1.

[2/] Each value is an average of 18 observations.

[3/] * and ** are different from 12/78 at 5 and 1% levels of significance, respectively.

## SUMMARY

Eight trenches were excavated and refilled in the fall of 1978 with either gravelly sandy loam, clay loam or silty clay loam overburden material. The original second lift material was added as a second lift in two of the gravelly sandy loam trenches. Four of the trenches were compacted as scrapers filled them and four were left essentially noncompacted using front end loaders to fill them. Three thicknesses of first lift material were added to each trench and further subdivided into fertility treatments.

Wheat grown on the plots in 1979 did not respond to fertility treatments. However, for all trenches yields improved with increasing thickness of topsoil from 9 to 18 inches. The addition of second lift material over the gravelly sandy loam increased wheat yields in trenches having 9-inch thick first lift, but for those with 18 inches of first lift over noncompacted overburden significant increases occurred only on noncompacted treatments. These increases probably resulted from greater water availability in plots with deeper topsoil and second lift material. The yield of wheat was lower on compacted trenches compared to noncompacted trenches. After one year noncompacted trenches had subsided only slightly more than compacted trenches.

**Continued on Page 23**

introduced species was increased 7 weeks after seeding by supplementing natural precipitation with additional water by irrigation. The total density of native plants was significantly increased with supplemental water. All individual species did not respond to added water, but alfalfa and blue grama seedlings were significantly more abundant where natural precipitation was supplemented.

The significant interaction shown in Figure 1, demonstrated the importance of providing supplemental water when natural precipitation is lacking. Little benefit was found for plant establishment when the stands were seeded early because the early-season amounts of precipitation were high. The stands seeded late responded significantly to added water because late season precipitation was low. This further demonstrates the importance of supplemental water for plant establishment, even for early planting, if natural precipitation is lacking. In some cases, it can mean the difference between a successful seeding or a failure.

The late seeding date, made possible by the use of supplemental water, allowed tillage early in July prior to the late seeding. This tillage produced a dramatic reduction of weed species in both the late-seeded native and introduced stands.

Results can be summarized as follows: 1) The use of irrigation to supplement natural precipitation can help insure rapid and successful perennial plant establishment especially when natural precipitation is low. 2) The use of irrigation to supplement natural precipitation will permit planting later into the growing season which can help control weedy species. 3) The application of different levels of water after seeding can provide for some control of the final species composition in newly established stands.

Initial results from the study (1977) of poor quality water for perennial plant establishment have been encouraging. Stands established with good or poor quality water have been found equal. Even where natural precipitation plus poor quality water was used for two seasons, the stands of seeded species established produced more dry matter than the stand of seeded species established with only natural precipitation. Increases in salt, soluble sodium and SAR were moderate where poor quality water was used. It appears the use of natural precipitation plus supplementation with poor quality water (EC of 3.0 to 4.0 mmhos/$cm^2$) can enhance perennial plant establishment with only moderate increases in the salinity of permeable soil/spoils in North Dakota.

In conclusion, the use of added water applied by irrigation to supplement natural precipitation has been found beneficial for plant establishment. While not an absolute necessity in North Dakota, supplementation of natural precipitation can provide protection agains plant establishment failures and warrants consideration as a reclamation technique when water is available and the risk of failure is costly.

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## Continued from Page 12


In conclusion, considering one year's data, coarse textured overburden required thicker topsoil or the addition of the second lift to achieve maximum spring wheat yields on strip mined reclaimed land. General yield levels were comparable with yields of grain on nondisturbed soils. Compaction made little difference in the amount of subsidence in these trenches. Final conclusions will be reserved until several more years of data are collected and evaluated.

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