III. METHODS AND MATERIALS

Experimental sites for the topsoil/subsoil tillage treatment research were constructed in the fall of 1987 on the BNI Coal LTD. mine near Center and the Coteau Properties, North American Coal Corporation mine near Beulah, North Dakota. The site at Center was approximately 1 ha in size while the plot at Coteau was approximately 2 ha.

Subsoil was respread over 80% of each plot using scrapers applying the soil materials in 10 to 15 cm thicknesses (normal respread depths per scraper pass) followed by grading for surface leveling. The remaining 20% of each plot was replaced with scrapers utilizing minimum traffic patterns and no grading until sufficient subsoil was present to constitute the required depth (deep lift). A final grading operation across the entire plot completed the construction.

Following grading, the area of the plot (other than the deep lift area) was divided into four equal areas for further treatments (Figure 1). Tillage treatments were then applied on three strips across the plots, the other ones remained untilled (no till).

Topsoil was then respread on the entire plot in a manner similar to the subsoil respreading operation. After a final grading, the plots were subdivided into three blocks which were further subdivided into three topsoil tillage strips. Topsoil tillage treatments were randomly assigned within each block and applied perpendicular to the subsoil tillage treatments. The same equipment used for the subsoil tillage treatments was used for the topsoil tillage treatments. The characteristics of these treatments are listed in Tables 1 and 2.

The average depth of the respread topsoil and subsoil at the Center location was 33 and 90 cm, respectively. At Coteau the mean depth of respread topsoil was 41 cm and the mean

depth of the subsoil was 79 cm. The topsoil by subsoil tillage subplots at Center were 21.3 by 6.4 m while at Coteau the subplots were 30.4 by 15.2 m.

Experimental sites for the topsoil tillage/forage research were established in the spring of 1989 at the Basin Cooperative Services Glenharold mine near Stanton and the Knife River Coal Mining Company South Beulah mine near Beulah, North Dakota. Both locations had been respread the previous fall using scrapers respreading an average depth of 0.3 m of topsoil and 0.6 m of subsoil. Each site was approximately 0.5 ha in size.

Surface tillage treatments were applied in strips at each location (Figure 2). The characteristics of the chisel and subsoiling operations are listed in Table 3. Following the initial tillage treatment, each site was lightly disked and harrowed after 112 kg/ha of ammonium nitrate was broadcast on the surface.

Each site was divided into two equal-sized blocks which were subsequently divided into six equal-sized strips perpendicular to the tillage treatments. Five forage crops (mixes and monocultures) and spring wheat (Stoa) were seeded into the strips (Figure 2). Crop by tillage treatment subplots were 12.8 by 7.3 m at Glenharold and 12.8 by 9.7 at Knife River.

Seeding mixtures and rates for the four locations are listed in Table 4. All seeding operations, except for the spring wheat, were performed by mining personnel and equipment. Because of poor germination and growth due to hot, droughty conditions in 1988, the topsoil/subsoil tillage sites were reseeded in 1989 after a light disking.

Soil fertility samples were made each fall on the spring wheat strips prior to a fall chiselling operation. Fertilizer was broadcast the following spring (prior to seeding) to produce a 2.7 Mg/ha crop for the first three years of the experiment. Half of the forage strips were chiselled

in the fall of 1991 (Fig. 2) after three years' growth. Only one block at each site was fertilized for the small grain crop in 1992.

Access tubes for soil water monitoring to a depth of 1.5 m with neutron attenuation probes were installed in all or some of the subplots as shown in Figs. 1 and 2. Tubes were installed in the fall of 1987 at the topsoil/subsoil tillage sites (including the deep rip shank tracks) prior to seeding and in the spring of 1989 at the topsoil tillage/forage plots after seeding was completed. Soil water was measured biweekly at all sites.

Soil cores removed during access tube installation in 1987 were sampled in 15-cm depth increment samples for the two topsoil/subsoil tillage sites. Soil cores were sampled in 30 cm increments for the topsoil tillage/forage sites in 1989 and when additional tubes were installed in 1992. The soil samples removed were analyzed for bulk density, particle size, and chemical characteristics (pH, electrical conductivity and SAR). Estimated wilting points were calculated for each 30-cm depth increment using the soil materials removed and a pressure plate apparatus.

All bulk density measurements were conducted using a hydraulic coring machine. Cores were enclosed in plastic bags in the field, transported to the laboratory, weighed, dried at 104° C for 48 h, and reweighed. Bulk density (both wet and dry) was calculated by dividing the weight of the core by the volume of the core.

Forage yields at the various sites were generally taken in June of each year. This was based upon a 10-20% bloom of alfalfa in the plots. Samples were harvested by hand from 1 m^2 areas in each subplot, dried at 60° C for 48 h and then weighed. Small grain yields were also harvested by hand in each subplot from a 4 m^2 area. Following both forage and small grain

harvests, all remaining forages and small grains from the subplots were mechanically harvested either by research or mining personnel or by cooperating farmers.

Beginning in the spring of 1990, and each subsequent spring, soil strength in all the subplots was measured with a hydraulically-driven cone penetrometer to a depth of 1 m. The penetrometer cone had a basal area of 506 mm^2 for 1990 only. Because of the difficulty encountered due to high soil strengths in penetrating the soil profile to a depth of 1 m, the cone basal area was reduced to 285 mm^2 for data collection in 1991 and 1992. Soil cores were removed adjacent to the cone penetrometer areas in 15 cm depth increments for bulk density and soil water determinations. The values were used to correlate the effect these variables had on the measured soil strength values.

All site data was analyzed as a nonrandomized modified split block design with technical statistical designs formulated after consultation with statisticians from North Dakota State University. All analyses including analysis of variance (ANOVA) and correlation/regression procedures were done with SAS (1990).

Least significant difference (LSD) values were calculated from the ANOVA outputs to delineate statistical differences among mean values where sample sizes were the same. For comparison among mean values of different sample sizes, individual comparisons between pairs of means were done using LSD values weighted for the differences in sample sizes. The level of significance (P) was generally set at the 10% level. Sample means were considered significantly different if the difference between the two means exceeded the LSD value. If the level of significance in the ANOVA output exceeded the 10% level, the mean values were treated as equal statistically and not significantly different (NS). Variables with the

correlation/regression analyses were also subjected to a P level of 10%. Variables were included in the reported models only if their significant level was 10% or less.

Beginning in the fall of 1989, rooting characteristics of the alfalfa or forage grasses (depending upon location) were measured. Soil cores (15-cm long, 6-cm in diameter) were removed directly over the top of the plant to the depth of root penetration. The upper 0 to 5 cm of the first sample was discarded to remove crown effects. The soil was washed off the roots and root length was determined by hand (large taproots) and/or an electronic image analyzer. Root mass was determined by drying the roots at 70° C for 24 hours before weighing. Root length density was calculated by dividing the total length of roots by the sample volume. Root mass density was calculated similarly using root weights or is listed as total mass per sample (see units used).

Three locations where bulk density by depth had been measured several years previously were used to determine changes in bulk density with time. One location, the Falkirk trench site, had been excavated to a depth of 4.6 m in 1979 and reclaimed with various subsoil textures and topsoil depths. This site was cropped from 1980 through 1983 and has been seeded to a forage mixture since 1984. A detailed description may be found elsewhere (Halvorson et al., 1986).

The other two locations had been used since 1986 for a study on the effect of topography on forage and small grain yields. These sites were located on the BNI Ltd. mine near Center, North Dakota and the North American Coal Corporation Falkirk mine near Washburn, North Dakota. The Center location was reclaimed in 1983 while the Falkirk location was reclaimed in 1984. Detailed descriptions of the two locations are given elsewhere (Schroeder, 1991).

Soil bulk density by depth at these three locations were measured using the previously described soil core method. ANOVA models used to analyze time effects were a split split-block design at the Falkirk trench location and a single-factor block design at the two topography locations.