BATTLE RIVER SOIL RECONSTRUCTION PROJECT: RESULTS THREE YEARS AFTER CONSTRUCTION

By

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ABSTRACT

The Battle River Reconstruction Project involves four (4) experiments designed to assess methods of reconstructing soil profiles in order to ameliorate the problems caused by the saline/sodic nature of the subsoils and bedrock.

The experiments assess soil reconstruction methods in terms of (a) varying subsoil depths; (b) separating and mixing subsoil horizons; (c) the use of bottom ash as a capillary barrier to salt movement; (d) altering the surface configuration (slope and aspect) of the reclaimed land; and (e) the use of gypsum and bottom ash as surface amendments. Yields from cereal and forage plots and soil salt and moisture movement have been monitored for 3 years. This paper discusses the results from the third growing season of the project.

This year's yields indicate that (a) forage production is more successful than cereal production; (b) topsoil is essential for reclamation; (c) increased subsoil depth results in higher yields and more favorable salinity and sodicity in the upper rooting zone; (d) bottom ash applied on the surface or above spoil increases forage production; and (e) gypsum applied at 20 T/ha helps to ameliorate the sodium problems that occur in reclamation of Torlea soils.

In 1983, a drought stressed season, it seems that crop yields were mainly determined by soil moisture supplying capability of the soils rather than soil chemical properties. Nevertheless, there is ample evidence of salt migration and continued monitoring will allow confirmation of trends.

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INTRODUCTION

The Battle River Soil Reconstruction Project (BRSRP) was established in 1979 to determine the most effective methods of reclaiming lands disturbed by surface mining of coal in the Battle River Coal Fields. The Soil-Plant Subcommittee of the Plains Coal Reclamation Research Program defined the objectives, designed the experiments, and is supervising the on-going project. Funding for research activities is provided from the Alberta Heritage Savings Trust fund through the Alberta Land Conservation and Reclamation Council (Plains Coal Reclamation Research Program, PCRRP). Industry participants, namely, Alberta Power Ltd., Luscar Ltd., and Manalta Coal Ltd., funded initial construction activities, and continue to jointly manage the project through their membership on the Soil/Crop Subcommittee.

The project objectives are:

1. To determine the required depth of soil replacement over sodic mine spoil to ensure that mined land, particularly in the Battle River Coal Field, meets reclamation objectives. In this area, the reclamation objective is to return mined land to former levels of agricultural productivity.
2. To develop methods of sustaining re-established productivity, with emphasis on controlling salt movement from mine spoil into the reconstructed root zone.
3. To develop treatments which will minimize soil quantities needed to restore the original land productivity.

This project is located about 20 km north of Halkirk on lands transferred from Manalta Coal Ltd. to the County of Paintearth. The Project is comprised of four experiments situated within a fenced compound (Figure 1). The experiments are:

1. Subsoil Depth
2. Torlea Soil
3. Bottom Ash
4. Slope Drainage

The findings and opinions expressed in this paper are those of the author, and not of the Ministry of Alberta Environment or any of its representatives.

BACKGROUND

The dominant soils of the area before mining ranged from Dark Brown Solonetz to Orthic Dark Brown Chernozems developed on till deposits overlying the Horseshoe Canyon Formation. The topsoil and subsoil materials for the Subsoil Depth, Bottom Ash and Slope Drainage experiments were obtained locally from an area of Orthic Dark Brown Chernozemic and Dark Brown Solod soils. The soil materials used for the Torlea Soil Experiment originated from Dark Brown Solonetz soils which have significantly poorer chemical characteristics (Table 1).

Climate is continental with a frost-free period of approximately 100 days and an average annual precipitation of approximately 400 mm, 60 percent of which falls as rain during May through August.

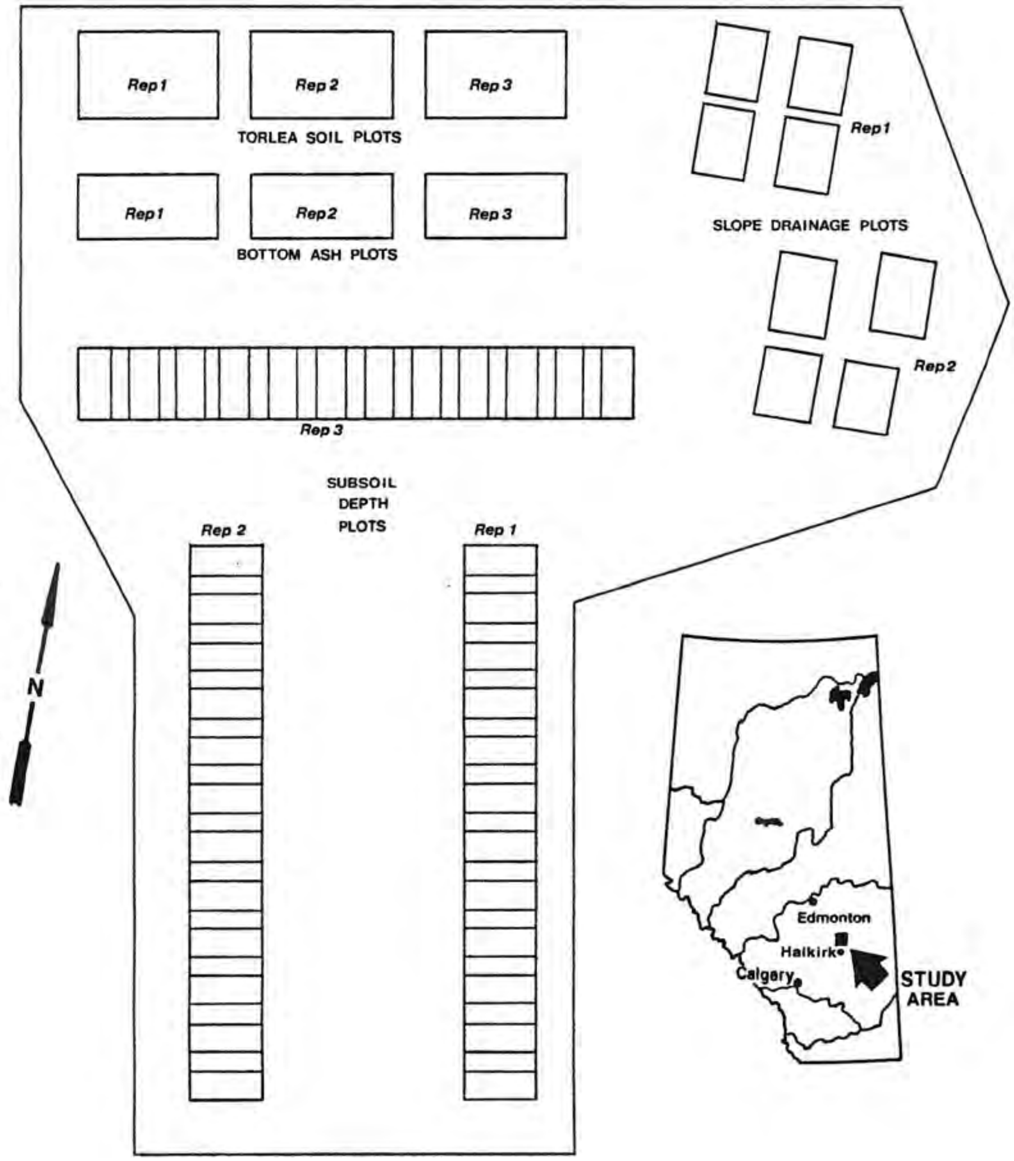

Figure 1. Location and Layout of Experiments.

Table 1. Chemical Analyses of Materials used in Plot Construction (Baseline conditions).

EXPERIMENT	MATERIAL	pH Mean	pH Standard Deviation	EC(mS/cm) Mean	EC(mS/cm) Standard Deviation	SAR Mean	SAR Standard Deviation	RECLAMATION SUITABILITY RATING[1]
Subsoil Depth	Topsoil	6.8	0.18	3.6	0.48	3.5	0.77	F(EC)
	Subsoil	7.8	0.10	5.8	0.67	8.4	1.60	F-P(EC;SAR)
	Spoil	8.0	0.14	2.9	1.00	23.9	2.73	U
Torlea Soil	Topsoil	7.7	0.10	2.4	1.00	13.5	1.25	U(SAR)
	Subsoil	7.4	0.28	5.7	1.33	14.2	1.65	U(SAR)
	Spoil	7.7	0.21	2.7	0.72	20.2	4.64	U(SAR)
	Ash	7.8	0.23	1.2	0.23	24.5	3.71	-
Bottom Ash	Topsoil	6.8	0.19	3.4	0.72	4.5	2.42	F(EC;SAR)
	Subsoil	7.6	0.12	5.5	0.86	8.5	2.86	F-P(EC;SAR)
	Spoil	7.7	0.25	2.7	0.63	22.7	3.60	U
Slope Drainage	Topsoil	6.8	0.39	3.5	1.49	5.9	4.16	F(EC)
	Subsoil	7.4	0.33	5.8	1.45	12.6	6.61	F-P(SAR)
	Spoil	7.9	0.18	2.8	0.30	24.0	1.67	U(SAR)

[1] Proposed Alberta Soil Quality Criteria (A.S.A.C., 1981)

<u>Ratings</u>

F - Fair
P - Poor
U - Unsuitable

<u>Constraints</u>

EC - high electrical conductivity (salinity)
SAR - high sodium adsorption ratio (sodicity)

<u>Topsoil</u>: Topsoil is loam to clay loam textured A horizon removed from the native soils before mining.

<u>Subsoil</u>: Subsoil includes the B and C horizons plus underlying material that has chemical and physical properties suitable for sustaining vegetative growth.

<u>Spoil</u>: Spoil consists of sodic bedrock materials of the Horseshoe Canyon Formation.

<u>Bottom Ash:</u> Bottom Ash is the waste product of coal burnt at the Battle River Thermal Power Station. It is a sandy textured, pumice-like material characterized by relatively high calcium content and often toxic concentrations of boron.

Experimental plots were constructed in 1980 using mine machinery (dozers and scrapers) simulating the "take and put" system of mine reclamation (Parker, 1981).

On the plots, forage and cereal cropping practices are those commonly used by farmers in the area. Forage on the Slope Drainage plots was successfully established in 1981 and yields have been measured twice annually since. Forages on all other experiments were established in 1982 and yields were measured in the fall of 1982 and in the summer and fall of 1983. Wheat yields were measured in 1982 and 1983 on cereal plots within the Subsoil Depth and Bottom Ash experiments.

MONITORING ACTIVITIES AND METHODS

Crop and soil monitoring activities are conducted annually as part of the on-going study. The following procedures used in 1983 are similar or identical to those used in 1982, 1984 and planned for the future. Further details are given in the project quarterly and annual reports (Pedology Consultants, 1982, 1983, 1984).

CROP HUSBANDRY AND YIELD DETERMINATIONS

Agronomic activities on the cereal plots, during 1983, included preparing the seedbed (two cultivations and harrowing), broadcasting fertilizer (23-24-0) at a rate of 150 kg/ha, seeding Neepawa wheat at a rate of 100 kg/ha on April 30, hand spraying the plots with Hoegrass II and Torch, and harvesting on August 18.

Forage was established on the Slope Drainage Experiment in 1981 (Charlton bromegrass at 4 kg/ha and Beaver alfalfa at 16 kg/ha). The three other experiments were established in 1982 with Charlton bromegrass at 8 kg/ha and Rambler alfalfa at 15 kg/ha. In 1983, 150 kg/ha of 23-24-0 was broadcast on April 30. The first harvest was completed on July 20 and the second on September 21.

Forage yields are expressed on a dry weight basis (kg/ha) calculated from entire plot fresh weights measured in the field and subsamples dried to constant weight. Wheat yields in kg/ha were calculated from plot moist grain yields and subsamples dried for 24 hours at 60 degrees C.

SOIL MOISTURE MONITORING

Neutron probe access tubes were installed in all plots in 1982. A Campbell Scientific Subsoil Moisture Gauge, Model #503 was and is continuing to be used for monitoring soil moisture. Measurements are taken monthly, May through September.

SOIL BULK DENSITY MEASUREMENTS

A Campbell Scientific Model #501 moisture/density probe was used to measure soil bulk densities in all access tubes at various depths within the reconstruction materials. These measurements, conducted in May 1983, provide the first records of soil bulk density following construction of these plots.

SOIL FERTILITY

Soil samples were taken in early spring from forage and cereal plots to determine fertilizer requirements. Norwest Labs conducted the analyses and provided recommendations as for farmers. The recommendations serve as a guide to ensure that fertilizer applications meet minimum crop requirements for average yields.

SOIL SALINITY

The soils in each plot were sampled, in October, at 15 cm intervals to at least 50 cm into the underlying spoil. Chemical analyses included pH, EC (electrical conductivity, saturated paste), SAR (sodium adsorption ratio), saturation percent, soluble cations (Ca, Mg, Na, K) and soluble anions (SO_4, Cl), using standard analytical procedures (MacKeague, 1978). Results of 1983 soil analyses are summarized in the appended Tables (A1-4).

CLIMATE

A rainfall gauge was installed on the compound in 1983 and is being monitored by the Alberta Research Council. Figure 2 shows the weekly rainfall and corresponding crop calendar.

STATISTICAL ANALYSIS

Crop yields, soil electrical conductivities and sodium adsorption ratios were analyzed in detail for each experiment. In 1983, the Subsoil Depth and Slope Drainage experiments were analyzed as a randomized block design; Torlea and Bottom Ash experiments as split-plot designs.

For crop yield analysis, treatments and replicates were treated as fixed effects, and for soil analysis, treatments, replicates and crop type were assumed to be fixed. The treatment effects of primary interest for which there were a priori hypotheses were decomposed into orthogonal planned comparisons. For the Subsoil Depth and Bottom Ash experiments,

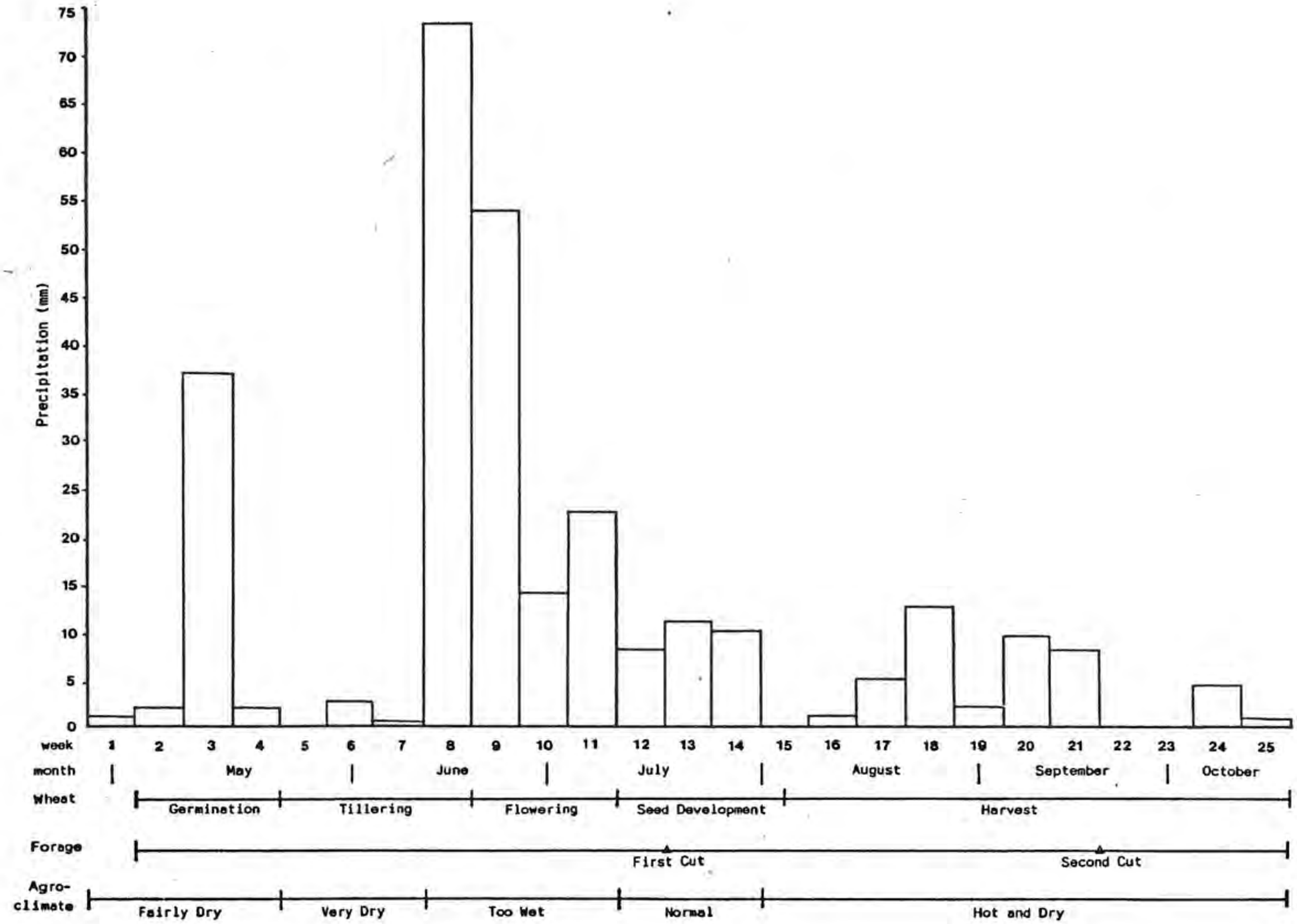

Figure 2. Weekly Precipitation Data - 1983 (April 27 - October 16).

the planned comparisons consisted of linear and quadratic trends over subsoil depth and deviations from those trends. For the other experiments, contrasts were also based on a priori hypotheses about treatment effects. Where trend analyses were conducted only, linear effects were found to be significant. For all analyses, the assumption of homogeneity of variance was tested with Bartlett's test and Hartley's test at p = 0.05 (Winer, pp. 200-210). All post-hoc tests were done with Tukey's HSD test at p = 0.05. (For specific statistical procedures concerning each experiment, the reader is referred to the 1983-84 Annual Report, Leskiw et.al., 1984.)

RESEARCH FINDINGS

A comprehensive analysis of yields, soil chemical and physical properties, and soil moisture levels revealed several important findings (Leskiw et.al., 1984). The major statistically significant (p = 0.05) results and important trends with respect to crop yields and soil EC and SAR are summarized for each experiment in the following sections. Soil moisture patterns and bulk density data are compared for all experiments.

SUBSOIL DEPTH EXPERIMENT

This experiment is designed to determine the optimum depth of replaced subsoil over sodic mine spoil required to sustain agricultural production. The following treatments are being assessed in relation to cereal and forage (2 cuts) production.

Treatment		
1	0 cm subsoil over spoil	10 cm topsoil covers all treatments
2	25 cm subsoil over spoil	
3	50 cm subsoil over spoil	
4	100 cm subsoil over spoil	
5	150 cm subsoil over spoil	
6	300 cm subsoil over spoil	

Yields

First and second cut forage crop yields, Figure 3, each increase linearly (statistically significant, $p = 0.05$) with increasing subsoil depth. This relationship probably reflects improving soil chemistry in the upper root zone, greater rooting depth and better moisture supply to the plants with increasing subsoil thickness. Roots are likely not penetrating the spoil due to physical or chemical constraints.

Wheat yields ranged from about 375 to 500 kg/ha and showed no response to treatments. These very low yields are attributed to climatic stress which was an over-riding factor in relation to soil limitations.

Soil Chemistry

Topsoil EC and SAR are higher under wheat than under forage crops (EC 3.2 > 2.5; SAR 3.2 > 2.2) but all values are below critical limits. These differences may be attributed to mechanical mixing by cultivation or to differences in moisture movement under different crops.

Upper subsoils are less saline (EC 5.5) than lower subsoils (EC 7.0). SAR in the upper subsoil decreases from 9.4 to 7.3 (significant trend) as subsoil depth increases from 25 to 300 cm. These findings may indicate that leaching is occurring in the upper subsoils or that sodium is moving upward from the spoil. The former implies that deeper subsoils enhance leaching; the latter suggests that shallower subsoils favor a rise of salts.

Spoil EC is higher under wheat (EC 6.1) than under forage (EC 4.8) but there are no significant differences or trends in SAR.

Treatment 1 (topsoil over spoil) is inferior to all other treatments (with subsoil). There is a clear trend of improving soil quality in the upper profile with increasing subsoil thickness and this is reflected in increasing crop yields. On the contrary, treatments with shallower subsoils may be degrading due to upward salt migration from the spoil. A qualitative (not tested statistically) comparison with original conditions following construction (Table 1) indicates that both processes may be occurring. For example, EC and SAR in topsoils and EC in upper subsoils have improved slightly over time. SAR in upper subsoils of the shallowest subsoil treatments have degraded while in treatments with deeper subsoil, the upper subsoils have improved.

TORLEA SOIL EXPERIMENT

This experiment assesses four methods of reclaiming lands mined from areas of Torlea Soil Series. The treatments tested in relation to forage (2 cuts) yields are:

Treatment

1	spoil
2	10 cm A/spoil
3	10 cm A/20 cm B+C/spoil
4	10 cm A/45 cm B+C/spoil
5	10 cm A/75 cm C/spoil
6	10 cm A/100 cm B+C/spoil
7	10 cm A/45 cm C/20 cm ash/spoil

Surface Amendment

Each reconstruction treatment has surface treatments as follows:

A - Bottom ash (15 cm of bottom ash contains exchangeable calcium approximately equivalent to a 20 T/ha application of gypsum
B - Gypsum (applied at 20 T/ha)
C - Control

Yield data are given in Figure 4.

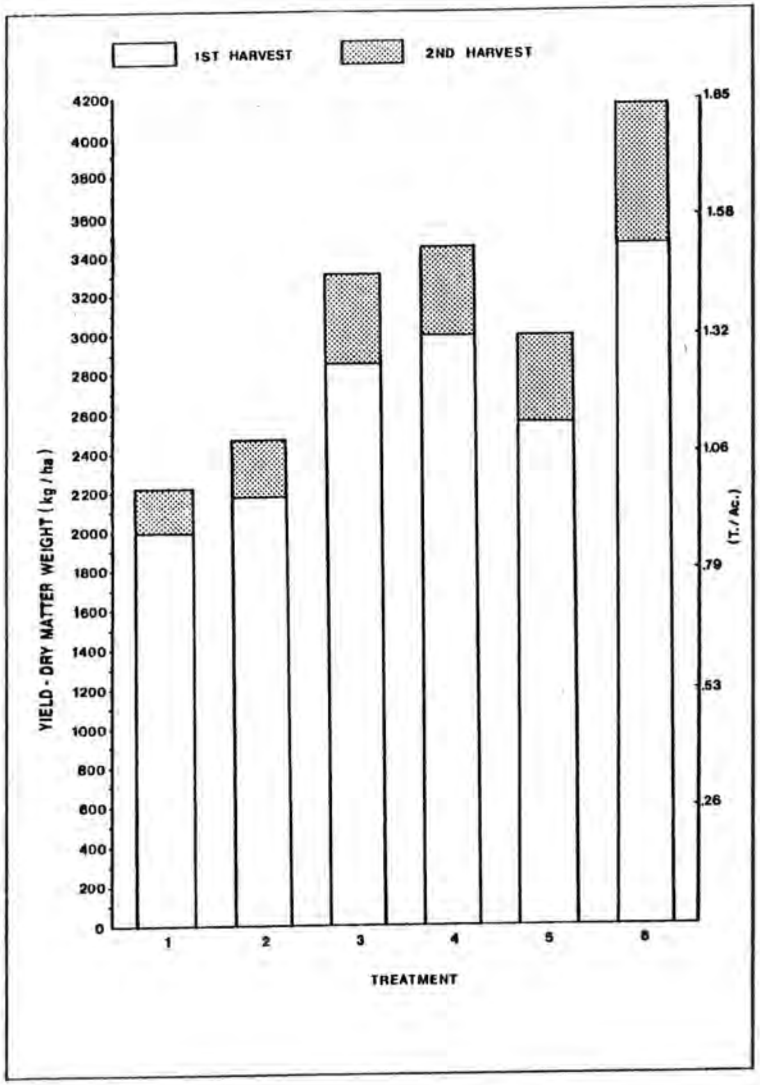

Figure 3. Subsoil Depth Experiment - 1983 forage yields.

Treatment	Soil Reconstruction
1	15 cm topsoil/spoil
2	15 cm topsoil/25 cm subsoil/spoil
3	15 cm topsoil/50 cm subsoil/spoil
4	15 cm topsoil/100 cm subsoil/spoil
5	15 cm topsoil/150 cm subsoil/spoil
6	15 cm topsoil/300 cm subsoil/spoil

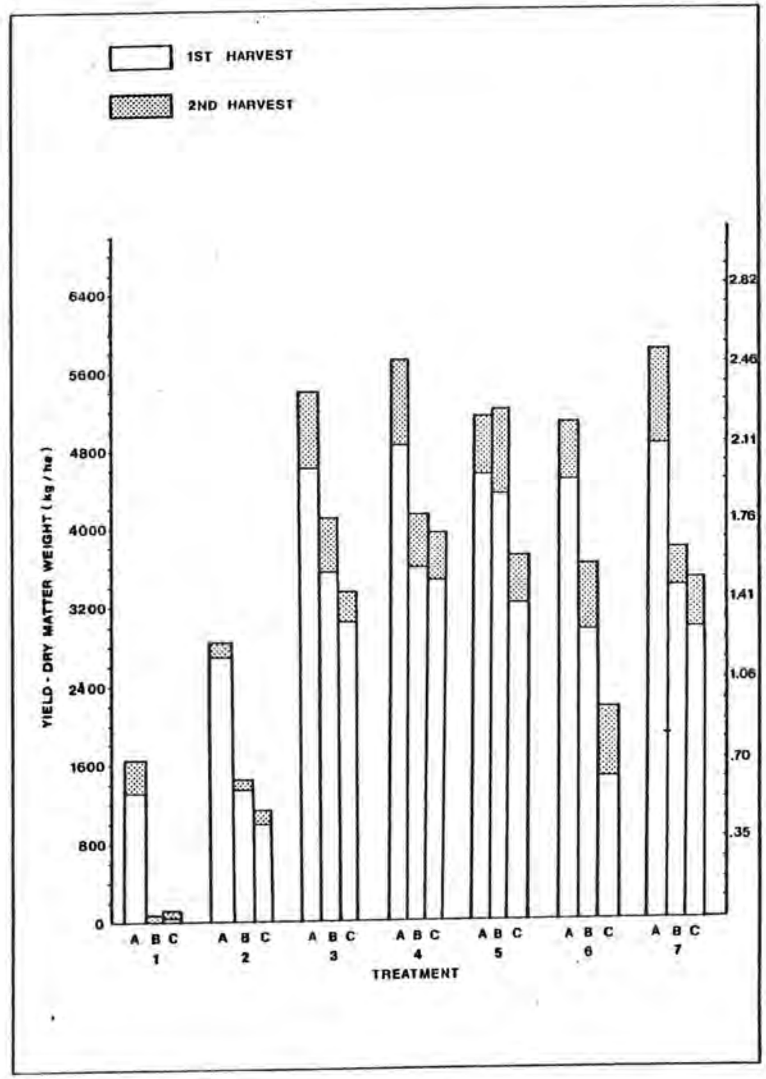

Figure 4. Torlea Soil Experiment - 1983 forage yields. A, B, and C respectively signify surface amendments of 15 cm of Ash, 20 T/ha gypsum and a control.

Treatment	Soil Reconstruction
1	Spoil
2	10 cm topsoil/spoil
3	10 cm topsoil/20 cm B and upper C horizons/spoil
4	10 cm topsoil/45 cm B and upper C horizons/spoil
5	10 cm topsoil/75 cm C horizon/spoil
6	10 cm topsoil/100 cm C horizon/spoil
7	10 cm topsoil/45 cm C horizon/20 cm Ash/spoil

Yields

Treatment 1 had a crop failure on gypsum and control plots and Treatment 2 yielded significantly less than Treatments 3 to 7. With respect to surface amendments, bottom ash yielded higher than gypsum which yielded higher than the control. These findings are applicable to both the first and second cuts even though yields of the latter are very low.

Soil Chemistry

Topsoil EC values are: ash (2.0) < control (3.5) < gypsum (5.0). Also Treatments 2 and 6 have higher EC than Treatment 3 (EC 4.4 and 4.6 > 2.0, respectively). SAR's in topsoils in the ash (10.2) and gypsum (9.7) treatments are lower than in the control (13.3). The foregoing findings are expected, except for the high topsoil EC in Treatment 6.

Upper subsoil EC in Treatment 7 (4.4) is less than in Treatment 3 (8.3) otherwise there are no significant differences even though the rankings produce an expected sequence. The low EC values in Treatment 7 indicate a positive effect of the subsurface ash layer. There is a significant trend relating subsoil depth to EC gradient within the subsoil layer. That is, there are greater differences between upper and lower EC values in deeper subsoil treatments regardless of composition of subsoil (C or B+C material). SAR in the upper subsoil is higher in the gypsum treatments (21.4) than in the ash (16.7) and control (17.0), and gypsum (20.7) is higher than control (17.0) in the lower subsoil.

In spoils there are considerable variances in both EC and SAR values but neither significant differences nor trends occur.

BOTTOM ASH EXPERIMENT

This experiment assesses the potential of bottom ash as a capillary barrier to upward movement of sodium salts from the underlying spoil. Forage (2 cuts) and wheat yields are tested on these treatments:

Treatment	
1	15 cm topsoil - 25 cm subsoil - spoil
2	15 cm topsoil - 25 cm subsoil - gypsum[1] - spoil
3	15 cm topsoil - 25 cm subsoil - 5 cm ash - spoil
4	15 cm topsoil - 25 cm subsoil - 15 cm ash[2] - spoil
5	15 cm topsoil - 25 cm subsoil - 45 cm ash - spoil

Notes:

[1] gypsum applied at 20 T/ha

[2] 15 cm of bottom ash contains exchangeable calcium approximately equivalent to a 20 T/ha application of gypsum

Yields are given in Figure 5.

Yields

Both forage harvests indicate a very significant ($p = 0.005$) yield increase corresponding to increasing thickness of ash. There is no difference in forage yields between gypsum and no-ash plots. As in the Subsoil Depth Experiment, wheat yields were very low and showed no significant variation with treatment.

Soil Chemistry

There are no differences among treatments in topsoil, subsoil and spoil EC levels. SAR's in topsoils are higher under wheat (5.1) than under forage (3.3), $p = 0.1$, but no significant differences occur at greater depths.

SLOPE DRAINAGE EXPERIMENT

This experiment is designed to determine the effect of landform (slope and aspect) on productivity through its influence on salt movement and accumulation. Forage yields (2 cuts) are determined for the upper, middle, and lower slope positions on the treatments (Figure 6) as follows:

Treatment	
1	5° - north aspect
2	10° - north aspect
3	5° - south aspect
4	10° - south aspect

Yields

First cut yields on 10° slopes south aspects were better than 10° slopes north aspects. No statistically significant differences occurred among other treatments in the first cut, and among all treatments in the second cut, even though yields were consistently higher in lower than in upper positions.

Soil Chemistry

Topsoil EC and SAR are higher in the lower position than in the middle and upper positions (EC lower, 3.1 > middle, 1.1 and upper, 1.0; SAR lower, 6.2 > middle, 3.7 and upper, 3.0).

Upper subsoil EC and SAR patterns correspond to those in the topsoil (EC lower, 8.4 > middle, 6.4 and upper, 6.1; SAR lower, 15.6 > middle, 12.9 and upper, 11.3).

Spoils have lower EC levels in the lower positions (EC lower, 4.8 < middle, 6.7 and upper, 7.0). EC and SAR values are greater on north than on south aspects.

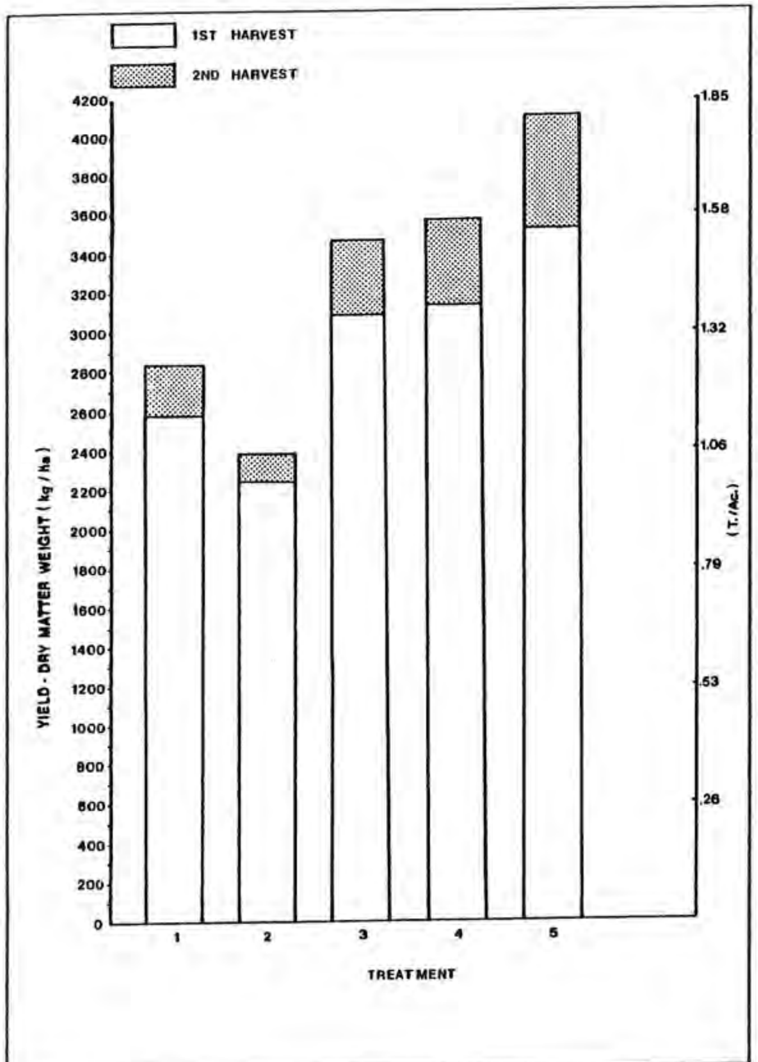

Figure 5. Bottom Ash Experiment - 1983 forage yields.

Treatment	Soil Reconstruction
1	15 cm topsoil/25 cm subsoil/spoil
2	15 cm topsoil/25 cm subsoil/gypsum (20 T/ha)/spoil
3	15 cm topsoil/25 cm subsoil 5 cm bottom ash/spoil
4	15 cm topsoil/25 cm subsoil/15 cm bottom ash/spoil
5	15 cm topsoil/25 cm subsoil/45 cm bottom ash/spoil

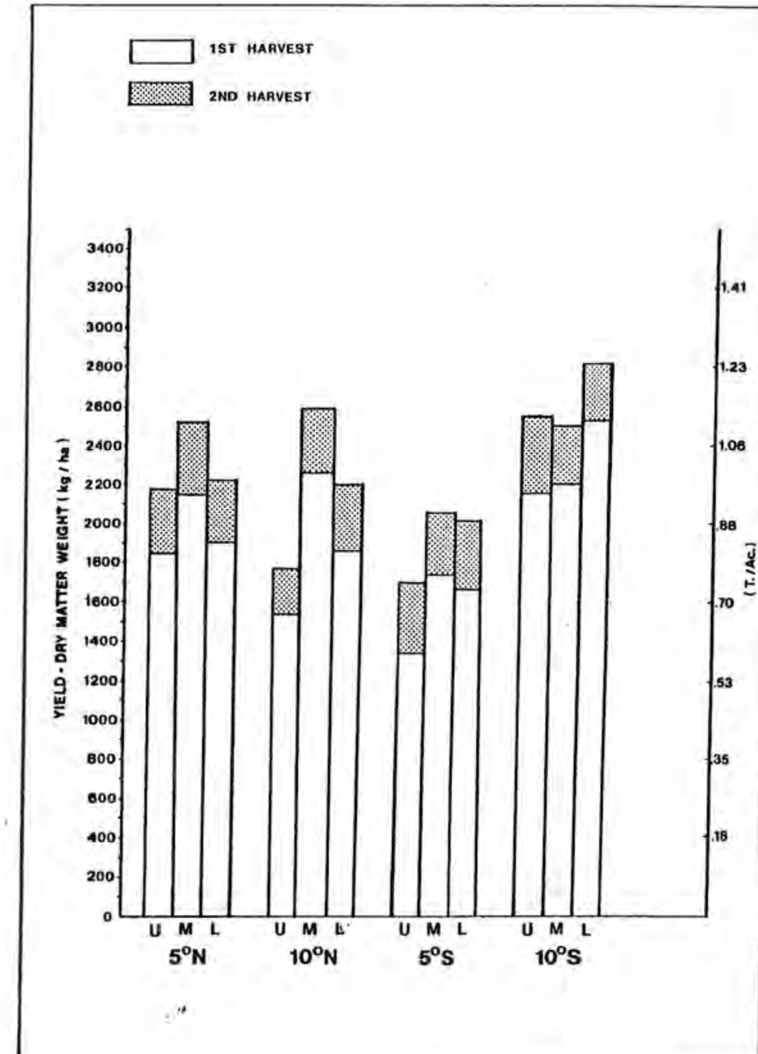

Figure 6. Slope Drainage Experiment - 1983 forage yields. U, M, and L signify upper, middle, and lower slopes, respectively.

ALL EXPERIMENTS

Soil Moisture

Soil moisture contents measured monthly with the neutron probe were converted to mm of water per specified depth of soil. Because of different reading levels among treatments and experiments, it is not possible to make direct comparisons, nevertheless, generalizations have been made for the 0-50 cm and 50-100 cm soil intervals. The following patterns apply to all experiments unless otherwise specified.

Soil moisture levels relate to rainfall distribution as shown in Figure 2. The sequence is:

May - June, moisture depletion - dry weather;

June - July, moisture recharge - heavy rains; and

July - September, moisture depletion - dry weather.

The greatest monthly changes in soil moisture occur in the 0-50 cm zone and slight changes occur in the 50-100 cm zone. Little fluctuation occurs at greater depths.

In comparing forage and wheat plots, the "slopes" of the depletion and recharge curves are generally steeper for forages than for wheat. "Steeper" depletion for forages relates to greater consumptive use. "Steeper" recharge suggests more rapid infiltration, less runoff, more moisture added to replace moisture withdrawn, or a combination of these. At all depths, forage plots tended to be drier throughout the season than wheat plots and the differences were magnified in the shallower zone (0-50 cm).

In the Torlea Soil Experiment, the ash treatments were usually driest followed by gypsum in Treatments 1 and 2 (no subsoil), and followed by control in Treatments 3 to 7 (varying depths of subsoil). Note that ash plots yielded highest.

In the Slope Drainage Experiment the upper positions are comparatively dry and the lower positions are moist, as expected. During the moisture depletion months, south aspects were drier than the north. The July moisture level peaks were similar in all treatments, however, the differences between upper, middle, and lower positions remained. This probably means that full recharge (saturation) did not occur, at least at the time of measurement.

The overall impression is that moisture availability in the rooting zone was more significant this drought stricken year than soil chemical properties. Spoil seems to prevent root and moisture penetration, as indicated by lack of fluctuation in moisture levels, hence, deeper subsoils with a larger rooting zone resulted in better yields.

Bulk Density

Topsoil, subsoil, and spoil materials each have similar densities for the Subsoil Depth, Bottom Ash and Slope Drainage experiments, Table 2. By comparison, Torlea soils have much lower densities in topsoil and subsoil and slightly lower densities in spoil. One possible reason for these differences is related to construction procedures: Torlea plots were completed in winter while others were completed in summer. If the materials were frozen or partially frozen, compaction could have been reduced. Differences in texture, moisture content during construction and soil structure of the source materials, and different handling procedures could also contribute to these differences

Table 2. Mean Bulk Densities of Materials for Different Experiments.

	EXPERIMENT			
	Subsoil Depth	Torlea Soil	Bottom Ash	Slope Drainage
	---gm/cc*---			
Topsoil	1.69	1.01	1.68	1.64
Subsoil	1.84	1.42	1.89	1.80
Spoil	1.56	1.37	1.55	1.56

* Measured with density probe in access tubes used for monitoring soil moisture.

since topsoils and subsoils for the Torlea plots were taken from a different place than for the other experiments.

SUMMARY AND CONCLUSIONS

The 1983 results represent the third cropping year for cereals after soil reconstruction. Forages were established on the Slope Drainage Experiment in 1981 and on the other experiments in 1982. The 1983 agricultural climate was characterized by a dry spring, a wet late June through mid-July, and a dry, hot fall. Crops suffered in early June and August resulting in average first cut forage yields but very low grain and second forage cut yields.

Plot construction was completed in the fall and early winter of 1980, therefore, soil moisture and salt movement had continued through three growing seasons at the time of soil sampling.

The following points represent the main findings to date, focussing on the 1983 growing season. Longer term monitoring is essential to confirm present findings and trends.

1. Subsoil Depth Experiment

   - There are no significant differences in forage or cereal yields between treatments, however, there is a significant linear trend indicating increasing forage yields (both cuts) with increasing subsoil thickness to 300 cm.
   - While salinity and sodicity remain below critical levels in the topsoils, the cereal plots are inferior to the forage plots. This is likely due to mechanical mixing of A horizon and subsoil material

with cultivation, upward salt migration or less leaching in the cereal plots.

- Upper subsoils tend to improve with increasing subsoil thickness.
- Upper spoils are inferior, with respect to salinity, under cereals as compared to forages.

2. Torlea Soil Experiment

- A lack of topsoil results in complete crop failure and topsoil over spoil results in very low crop yields -- both are unsatisfactory reclamation techniques.
- Application of 20 cm or more of subsoil, regardless of composition (C, B+C or C+ash), resulted in significantly higher yields.
- In terms of surface amendments, yields on ash are best, followed by gypsum, and control. Note that crop establishment on ash treatments was most difficult due to poor traction.
- Upper profile soil quality is unacceptable on Treatment 1, spoil only. Other treatments indicate that increasing subsoil thickness results in more leaching/less rise of salts in the upper subsoil.
- Ash surface treatments have superior quality with respect to EC and SAR in the topsoil and upper subsoil.

3. Bottom Ash Experiment

- There is a very significant relationship between forage yields and subsurface ash thickness: yields increase as ash thickness increases. Gypsum and control plot yields were similar.
- Soil salinity and sodicity in the upper profiles of gypsum and control plots are slightly more favorable than in the ash treatments.

- The higher yields on ash treatments are attributed mainly to higher root zone moisture supply.

4. Slope Drainage Experiment

- The first cut, south aspects yielded better than north aspects on 10° slopes, otherwise there were no significant differences in yields. This is attributed to more favorable soil temperature conditions early in the season.
- As expected, upper and middle slope positions have superior topsoil and upper subsoil quality as measured by EC and SAR.
- There is a tendency for north aspects to have higher EC and SAR values than south aspects. This suggests that higher yields on south aspects may also be attributed to more favorable soil chemistry. Lower positions would be expected to yield best but these generally have highest EC and SAR values.

5. All Experiments

Topsoil and at least some subsoil (20 cm+) is essential to reasonable crop growth. Yields tend to increase with increasing subsoil thickness but threshold or critical limits cannot be established on the basis of yields this year.

Moisture supplying capacity of the soils (with topsoil and subsoil) seems to be the over-riding factor in determining forage crop yields in 1983.

The application of bottom ash on the surface or between subsoil and spoil has very positive effects as reflected by crop yields.

Major fluctuations in soil moisture levels occur in the upper 50 cm or so of subsoil with minor fluctuations below. There is very little moisture change measured in the spoil.

6. Yearly Comparisons

To date, it is clear that salt migration is occurring. Also, it seems that a salt "bulge" (equivalent of Csa horizon) is beginning to form in many profiles. It tends to be more pronounced and shallower in shallower (<1 m) subsoil treatments than in deeper (>1 m) subsoil treatments.

Although this paper focuses on 1983 results, the objectives of this soil reconstruction study include comparing annual results to baseline conditions and monitoring changes over time. Plans are to present such preliminary results as part of the 1984/85 annual report.

REFERENCES

Alberta Soils Advisory Committee, 1981. Proposed Soil Quality Criteria in Relation to Disturbance and Reclamation. Alberta Agriculture.

MacKeague, J.A., 1978. Manual on soil sampling and methods of analysis. 2nd Ed., Can. Soc. Soil Sci.

Parker, R.W., 1981. Ash Studies in the Battle River Reclamation Research Project. Proceedings: Workshop on Coal Ash and Reclamation. Report #RRTAC 81-3. Alberta Land Conservation and Reclamation Council.

Pedology Consultants, 1982. Battle River Soil Reconstruction Project Quarterly Reports; June, September, December for 1982.

Pedology Consultants, 1983. Battle River Soil Reconstruction Project 1982/83 Annual Report.

Pedology Consultants, 1983. Battle River Soil Reconstruction Project Quarterly Reports; June, September, December for 1983.

Pedology Consultants, 1984. Battle River Soil Reconstruction Project 1983/84 Annual Report.

Winer, B.J., 1971. Statistical Principles in Experimental Design. McGraw Hill. New York.

Table A1. Chemical Analyses of Depth Intervals - Subsoil Depth Experiment.

			Cereal Plots								Forage Plots							
Reconstruction Treatment	Depth	Material	EC (mS/cm)		SAR		SAT %		Na (meq/l)		EC (mS/cm)		SAR		SAT. %		Na (meq/l)	
			$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
1. 0 cm	0-15	topsoil	3.3	0.8	3.7	1.6	32	2.7	17.1	6.0	2.8	1.1	2.0	1.1	34	2.2	9.3	6.5
	15-40	*spoil	5.9	1.7	18.6	5.7	76	27.0	56.3	15.2	7.3	2.7	16.0	3.5	68	9.2	66	23.0
	40-55	spoil	9.0	4.6	37.6	9.6	152	10.4	103.9	55.7	8.0	4.9	39.0	9.6	144	24.7	92.6	80.0
	105-120	spoil	6.6	1.9	39.4	4.3	159	8.4	69.8	23.4	4.4	1.0	33.0	6.6	173	23.3	43.0	13.9
2. 25 cm	0-15	topsoil	4.8	3.1	4.8	2.2	35	2.3	17.9	12.1	3.0	1.4	3.0	1.7	33	4.3	10.5	9.6
	15-40	subsoil	5.6	1.6	10.0	2.5	42	2.6	42.9	15.3	5.7	1.8	9.8	4.0	45	17.0	41.5	20.6
	40-55	*spoil	6.9	0.9	11.8	2.4	51	12.8	90.7	81.3	7.2	0.2	12.0	2.5	49	3.3	55.9	9.4
	105-120	spoil	5.0	0.6	32.3	4.4	168	6.5	48.4	12.0	5.7	2.0	31.6	10.2	146	33.9	56	26.4
3. 50 cm	0-15	topsoil	3.3	1.4	3.4	1.4	33	1.9	12.3	8.8	2.9	1.2	2.1	0.9	36	4.0	6.3	4.7
	15-40	subsoil	7.0	1.0	10.1	2.4	41	2.0	49.7	12.7	6.3	0.9	8.4	1.4	41	1.4	40.3	9.7
	50-65	subsoil	7.3	0.6	10.0	1.3	43	1.5	50.1	6.8	7.5	1.9	10.8	2.7	44	1.7	54.0	19.8
	65-80	*spoil	8.0	0.7	12.9	1.4	46	5.2	62.1	8.1	8.2	1.5	12.6	2.5	48	3.6	61.9	14.4
	130-145	spoil	5.5	1.6	37.3	14.5	162	6.6	59.0	25.7	4.5	1.4	28.9	7.4	190	14.6	40.3	16.4
4. 100 cm	0-15	topsoil	3.5	1.2	3.1	0.6	34	3.5	12.4	4.7	3.6	1.1	3.1	0.5	34	1.4	11.4	5.4
	15-30	subsoil	5.7	1.2	7.2	1.8	41	4.5	32.7	9.7	6.0	0.5	8.7	1.8	40	2.7	40.5	8.5
	50-65	subsoil	6.9	1.3	9.1	1.6	42	5.0	44.7	11.8	7.2	0.8	10.5	0.7	42	2.0	52.1	3.1
	85-100	subsoil	7.3	0.4	10.9	2.0	47	2.6	52.6	7.3	8.3	1.7	12.9	2.1	45	0.8	65.0	15.2
	100-115	subsoil	7.5	0.7	11.0	2.4	49	11.3	53.1	7.7	7.5	0.5	12.0	1.0	44	1.9	56.9	4.2
	115-170	*spoil	7.3	0.8	10.6	1.6	44	2.1	52.5	8.7	8.4	0.9	14.9	2.7	51	7.1	73.5	13.2
	180-195	spoil	6.8	1.2	33.8	4.5	145	5.5	67.9	13.6	5.0	1.4	29.6	7.5	160	19.2	47.2	16.7
5. 150 cm	0-15	topsoil	3.6	1.4	4.0	1.1	35	1.0	15.0	8.0	2.8	1.3	2.7	1.4	36	3.6	8.9	8.2
	15-30	subsoil	5.9	0.4	8.2	0.7	44	6.6	37.6	4.8	5.6	0.7	6.8	2.2	41	4.0	31.7	10.7
	50-65	subsoil	6.5	0.7	9.5	1.8	45	2.1	44.5	5.7	7.0	0.9	10.0	1.4	45	1.7	49.7	9.7
	85-100	subsoil	7.3	0.7	10.4	1.9	44	3.7	51.9	7.2	7.2	0.6	9.6	0.7	46	2.0	49.6	6.9
	120-135	subsoil	7.0	0.4	10.5	1.5	44	2.6	51.6	7.0	7.2	1.2	10.6	1.5	50	9.4	54	14.8
	135-150	subsoil	7.1	0.7	10.4	1.1	44	3.9	52.8	10.2	6.6	1.4	10.6	1.7	46	3.3	48.7	14.4
	150-165	subsoil	7.5	1.0	10.9	1.2	45	1.2	55.1	11.7	7.2	0.9	12.6	4.5	47	2.0	55.6	12.9
	165-180	*spoil	7.4	0.9	11.2	2.6	47	6.0	55.7	14.9	8.0	2.1	14.5	6.2	47	1.9	66.2	28.6
	230-245	spoil	6.9	1.9	26.8	8.9	129	44.6	145	21.2	6.0	3.0	35.6	20.7	147	23.4	63	41.2
6. 300 cm	0-15	topsoil	3.3	1.3	2.5	0.6	33	2	8.7	4.0	2.7	1.4	2.6	0.8	38	5.3	7.9	4.9
	15-30	subsoil	6.5	1.2	8.1	2.2	43	1.9	37.3	14.0	5.5	1.7	7.5	2.5	38	5.6	33.9	5.8
	50-65	subsoil	7.2	0.5	10.5	0.7	44	2.1	49.0	5.6	6.8	0.9	9.1	1.4	43	1.6	44.3	9.2
	85-100	subsoil	6.5	1.0	9.1	2.2	42	2.1	43.5	17.0	7.1	1.0	10.5	2.8	42	0.8	50	12.4
	120-135	subsoil	6.1	1.9	8.3	2.8	42	1.3	38.3	18.1	8.0	1.4	11.8	2.2	44	2.2	58.2	14.4
	155-170	subsoil	6.6	0.5	9.4	0.7	43	2.4	44.4	7.3	7.3	0.6	10.2	1.8	43	1.6	51.1	7.6
	190-205	subsoil	6.9	0.3	10.4	0.7	44	1.6	48.6	3.8	7.4	1.1	11.0	2.4	43	1.0	53.8	13.2
	225-240	subsoil	7.1	0.6	10.6	1.8	42	1.8	49.7	7.2	7.0	1.0	10.0	2.4	43	2.2	49.0	12.8
	260-275	subsoil	7.3	0.8	10.5	1.0	44	2.0	51	7.9	6.5	1.4	8.9	2.9	45	2.9	42.5	15.7
	285-300	subsoil	7.2	1.0	10.3	1.8	44	1.9	50.6	9.6	6.8	0.9	10.0	2.3	44	2.0	48.3	11.9
	300-315	subsoil	7.6	1.1	11.4	2.4	47	11.4	54.9	10.5	7.5	1.5	11.3	3.3	46	2.3	54.6	18.1
	315-330	*spoil	7.7	1.4	11.7	1.9	44	3.5	55.5	7.7	7.0	1.9	15.3	9.5	46	3.5	57.7	21.2
	380-395	spoil	8.4	2.1	21.2	6.9	102	41.0	73.6	14.9	4.9	1.7	29.2	14.2	172	40.7	43	16.1

Table A2. Chemical Analyses of Depth Intervals - Torlea Soil Experiment.

Reconstruction Treatment	Depth (cm)	Material	Ash Plots								Gypsum Plots								Control Plots							
			EC (mS/cm)		Na (meq/l)		SAR		SAT. %		EC (mS/cm)		Na (meq/l)		SAR		SAT. %		EC (mS/cm)		Na (meq/l)		SAR		SAT. %	
			x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd
1. Spoil	0-15	spoil	3.7	1.74	41.6	25.3	31	11.8	118	55	10	4.08	118.4	50.7	36	3.7	139	13	5.1	2.55	57.9	32.7	33	12.4	160	17
	15-40	spoil	4.3	2.93	47.2	36.5	35	9.6	194	22	4.1	.77	44.9	11.9	33	5.5	175	11	3.4	.53	36.1	5.9	30	3.9	177	2
	80-95	spoil	5.1	2.24	57.8	26.7	38	1.9	168	19	3.0	.79	32.9	5.4	29	4.3	200	11	4.3	3.0	48.2	34.0	35	14.0	202	80
2. 10 cm A/	0-15	topsoil	3.3	1.27	33.9	15.8	19	5.8	83	24	6.5	.89	60	16.4	14	4.7	79	17	3.1	.57	31.3	7.0	16	7.0	93	36
spoil	15-40	spoil	3.5	1.43	32.6	17.4	25	4.1	182	25	3.7	1.05	40.8	13.7	30	4.2	179	12	5.0	2.36	56.9	28.0	33	7.5	179	25
	80-95	spoil	6.0	4.33	61.6	40.7	31	4.4	168	37	4.6	1.29	52.4	18.1	42	6.6	182	5	3.1	1.09	35.4	14.3	31	6.1	201	27
3. 10 cm A/	0-15	topsoil	.9	.16	6.4	4.2	4	3.1	51	3	3.5	1.62	24.6	12.9	6	1.9	62	2	1.6	.11	16.0	1.9	9	1.3	70	4
20 cm B + C/	15-40	B+upper C	5.9	2.07	56.5	19.7	15	1.2	78	5	9.3	2.19	98.7	27.3	24	6.3	95	14	8.0	1.93	76.2	11.3	15	1.1	76	1
spoil	40-55	spoil	5.5	1.10	60.4	5.5	25	6.5	142	26	3.9	1.86	42.2	21.2	31	6.8	188	35	10	2.41	30.1	38.1	44	9.5	141	15
	105-120	spoil	5.3	3.35	59.1	40.7	36	17.1	183	33	4.5	3.83	48.1	43.7	37	20.5	199	31	4.9	2.53	50.4	28.1	31	4.3	179	9
4. 10 cm A/	0-15	topsoil	1.2	.51	9.7	5.3	6	2.8	55	6	3.6	1.64	26.6	17.1	7	3.9	62	6	1.8	.30	17.5	2.2	9	1.7	69	3
45 cm B + C/	15-30	B+upper C	4.5	1.57	46.1	16.7	15	3.5	72	3	7.6	2.44	73.4	22.6	15	1.9	72	1	5.0	1.79	49.1	18.3	14	1.0	74	2
spoil	30-50	B+upper C	5.8	2.00	61.7	23.0	19	5.7	79	7	9.6	.73	92.9	7.2	20	8.7	81	20	8.9	.21	83.7	6.5	15	1.5	76	7
	50-65	spoil	9.1	.85	87.7	9.2	19	5.0	92	25	4.3	3.49	45.5	34.2	23	4.5	157	83	8.1	1.97	83.1	10.4	28	12.1	132	31
	115-130	spoil	4.3	.54	46.6	8.1	38	3.6	160	22	5.9	3.94	65.3	44.3	38	16.5	209	64	4.9	2.83	54.5	32.2	34	10.0	179	32
5. 10 cm A/	0-15	topsoil	1.9	1.26	21.7	16.3	11	7.3	58	5	4.0	.59	21.6	10.9	4	2.5	60	.5	6.3	2.38	60.9	21.1	17	2.9	81	15
75 cm C/	15-30	C horizon	5.5	2.85	55.9	22.6	18	5.1	92	21	6.8	1.97	68.1	13.6	18	1.5	97	10	5.8	5.06	59.8	47.4	17	5.9	86	21
spoil	30-45	C	7.3	4.37	68.5	38.9	17	.5	115	45	8.9	.56	89.7	7.0	19	.7	106	17	8.4	2.75	83.8	18.4	21	3.6	95	17
	45-60	C	7.4	2.99	76.0	25.5	20	3.7	103	20	7.6	1.04	80.7	13.8	22	1.1	102	18	7.9	1.39	78.5	6.2	19	6.1	85	20
	60-75	C	6.4	4.08	63.0	38.9	17	1.7	110	39	10	1.22	100.5	15.1	19	.7	87	11	7.1	2.05	70.6	16.0	18	4.4	95	10
	75-90	C	5.8	2.11	62.9	13.1	25	9.3	140	22	8.9	.61	89.5	7.9	18	1.6	95	13	6.5	2.71	60.2	27.0	18	6.3	118	45
	140-155	spoil	4.6	3.02	50.6	36.7	41	14.5	189	45	5.8	3.77	66.6	43.0	38	18.9	179	61	4.1	1.74	44.6	23.0	33	7.7	204	28
6. 10 cm A/	0-15	topsoil	2.7	1.87	28	19.7	12	3.6	69	14	6.8	.55	61.4	10.0	13	1.7	71	3	4.0	2.10	38.2	18.4	12	1.8	72	3
100 cm B + C/	15-30	B + C	6.3	.99	65.1	3.9	21	7.8	103	25	10	1.33	112.3	19.6	21	3.6	86	2	7.4	1.28	72	10	17	1.3	93	14
spoil	30-45	B + C	7.4	1.56	76.5	10.6	21	5.6	102	16	6.9	2.53	68.2	24.3	19	3.5	108	23	8.3	.92	85.1	7.2	22	5.4	102	15
	45-60	B + C	6.9	2.70	71.2	26.8	21	5.8	109	32	8.1	2.01	81.9	20.9	18	.4	93	10	7.2	2.13	73.7	20.4	19	2.4	98	4
	60-75	B + C	8.2	.90	83.6	11.1	17	2.2	79	15	7.9	1.22	76.8	12.0	17	2.1	86	3	7.5	2.29	74.0	16.0	18	3.9	85	21
	75-100	B + C	9.5	.69	93.0	12.1	17	2.7	80	13	8.1	1.22	80.5	9.7	16	1.5	79	7	7.6	.26	74.0	7.2	15	2.4	67	5
	100-115	spoil	6.4	1.75	74.8	19.5	40	2.6	144	8	6.6	1.85	77.5	25.0	32	3.5	139	31	9.3	4.05	04.3	42.3	35	3.3	132	33
	165-180	spoil	8.5	4.43	101	54.1	41	5.7	153	50	3.4	.37	35.3	2.8	30	3.4	184	19	6.8	3.07	74.8	34.9	32	10.1	139	32
7. 10 cmA/	0-15	topsoil	1.4	.35	11.0	2.1	6	2.0	56	2	5.0	2.48	45.4	26.0	12	5.8	70	9	4.2	2.06	42	21.2	15	3.6	80	16
45 cm C/	15-30	C horizon	3.0	1.36	31.0	15.3	16	4.4	97	21	5.3	1.06	58.2	13.6	24	3.0	121	15	4.7	2.09	48.8	24.7	18	6.7	121	21
20 cm Ash/	30-50	C horizon	7.3	.44	74.5	2.1	21	4.6	103	16	7.9	2.25	87.6	26.6	24	6.6	103	21	5.4	2.79	53.1	23.4	18	2.1	112	39
spoil	50-65	ash	7.5	1.01	70.5	4.1	17	2.1	90	12	8.6	1.13	89.2	19.8	19	4.1	85	9	6.9	.48	67.8	4.4	17	3.5	93	18
	115-130	spoil	5.5	2.84	55.6	27.3	28	9.4	147	50	5.4	2.09	60.3	22.6	34	7.7	161	23	5.6	2.84	61.2	30.5	32	7.2	170	19

Table A3. Chemical Analyses of Depth Intervals - Bottom Ash Experiment.

RECONSTRUCTION TREATMENT	DEPTH (cm)	MATERIAL	CEREAL PLOTS EC (mS/cm) $\bar{x}$	sd	SAR $\bar{x}$	sd	SAT. % $\bar{x}$	sd	Na (meq/l) $\bar{x}$	sd	FORAGE PLOTS EC (mS/cm) $\bar{x}$	sd	SAR $\bar{x}$	sd	SAT. % $\bar{x}$	sd	Na (meq/l) $\bar{x}$	sd
1. Control	0-15	topsoil	2.9	1.6	3.7	1.3	36	2.6	14.2	9.5	2.6	2.2	2.9	2.9	35	3.6	12.2	15.1
	15-40	subsoil	6.2	0.6	9.1	1.8	41	2.0	43.6	7.3	6.4	2.9	9.8	7.2	46	19.5	46.5	34.3
	40-55	spoil	5.3	0.1	27.9	3.3	135	31.0	58.7	1.3	7.4	0.6	40.5	6.8	155	43.8	79.8	4.6
2. Gypsum	0-15	topsoil	4.2	1.8	6.6	3.1	34	3.5	27.4	15.7	2.0	1.9	2.9	2.2	36	4.6	10.2	11.4
	15-40	subsoil	8.9	1.9	16.5	3.8	51	6.1	77.4	19.6	5.8	2.5	10.0	4.3	43	8.9	44.9	24.8
	40-55	spoil	6.5	1.8	29.6	11.8	78	15.6	88.5	38.7	6.9	3.5	17.4	2.4	105	76	60.7	26.8
3. 5 cm of Ash	0-15	topsoil	3.8	2.9	5.7	4.1	37	4.9	23.8	23.8	3.2	1.5	4.2	1.2	35	3.2	16.5	8.5
	15-40	subsoil	7.6	2.4	12.2	4.3	43	2.6	33.2	31.8	8.2	1.2	13.4	3.3	44	0.6	66.7	13.9
	40-55	spoil	12.6	-	55.2	-	159	-	149	-	6.2	1.0	33.7	7.6	127	3.0	67.9	14.8
4. 15 cm of Ash	0-15	topsoil	4.4	1.8	4.8	5.2	36	4.2	21.9	23.2	3.3	1.0	4.1	1.8	36	6.4	14.6	0.6
	15-40	subsoil	7.3	1.4	12.1	3.3	45	5.0	57.6	14.5	8.3	1.6	12.9	3.7	46	6.2	66.3	18.6
	40-55	ash	1.9	0.1	8.0	5.4	61	18.3	13.0	5.1	3.2	1.5	12.0	5.1	59	12.7	27.5	5.2
5. 45 cm of Ash	0-15	topsoil	3.6	2.3	4.5	4.7	38	4.5	19.8	22.1	2.7	0.8	2.3	1.2	35	0.6	8.4	2.9
	15-40	subsoil	4.4	1.5	7.5	1.7	43	6.6	28.5	9.8	8.7	4.1	16.2	10.4	41	6.5	83.4	61.8
	40-55	ash	1.7	0.8	7.3	0.7	58	13.0	12.1	4.0	5.0	2.7	12.8	10.9	53	15.4	40.5	41.7
	60-85	spoil	5.8	-	39.1	-	150	-	59.6	-	7.4	-	37.3	-	94	-	82.6	-

Table A4. Chemical Analyses of Depth Intervals - Slope Drainage Experiment.

			Upper Slope								Middle Slope								Lower Slope							
Reconstruction Treatment	Depth (cm)	Material	EC (mS/cm)		Na (meq/l)		SAR		SAT. %		EC (mS/cm)		Na (meq/l)		SAR		SAT. %		EC (mS/cm)		Na (meq/l)		SAR		SAT. %	
			$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
1. 5° - N	0-15	topsoil	1.1	.59	5.1	5.2	2	2.5	32	1	.7	.26	3.3	.9	2	.5	35	3	2.7	1.43	19.1	12.9	6	4.5	47	12
	15-40	subsoil	6.6	3.22	55.1	37.9	12	7.7	40	7	4.4	3.78	36.1	35.8	9	6.6	36	8	8.1	2.98	96.1	72.2	15	7.9	55	17
	50-65	subsoil	8.9	2.56	86.7	31.1	21	9.6	74	51	7.6	2.26	74.3	17.9	21	4.8	67	9	5.4	2.10	59.6	24.2	38	8.4	158	28
	65-80	spoil	10.0	1.70	116	25.7	47	10.5	135	39	7.4	2.55	79.4	22.0	36	6.2	151	14	7.5	2.67	81.3	26.4	38	6.2	151	51
	130-145	spoil	7.1	1.21	79.9	13.8	40	5.3	138	39	5.5	1.52	61.5	14.7	36	3.7	166	31	5.1	3.17	52	32.9	30	3.0	156	28
2. 10° - N	0-15	topsoil	2.9	2.75	16.9	25.9	2	1.5	37	9	1.5	.29	9.4	1.2	4	1.0	32	4	4.2	3.57	32.3	37.8	8	7.6	41	7
	15-40	subsoil	6.7	3.13	55.3	30.9	12	6.1	53	19	8.5	2.62	72.3	20.6	16	.9	49	2	8.4	2.17	73.2	24.9	15	5.3	45	4
	50-65	subsoil	9.1	3.76	85.8	42.1	18	6.6	80	63	7.8	1.23	60.9	11.9	13	4.2	54	23	5.5	4.52	51.4	36.8	22	4.4	162	79
	65-80	spoil	7.2	4.21	62.6	37.5	23	6.8	68	48	5.0	1.01	52.4	14.6	30	8.1	163	19	6.9	1.58	69.5	11.8	24	5.1	148	18
	130-145	spoil	7.8	1.93	75.8	13.4	33	6.2	134	57	7.2	2.21	74.1	17.9	30	4.5	160	15	6.2	1.61	64.3	13.9	28	4.6	147	7
3. 5° - S	0-15	topsoil	.9	.57	5.8	3.0	4	3.2	32	1	.9	.78	6.8	5.6	4	1.6	32	2	2.2	2.59	15.0	20.7	4	3.8	35	4
	15-40	subsoil	5.8	2.10	49.1	22.5	12	4.4	40	7	6.0	3.31	53.6	32.1	13	5.7	40	12	8.1	1.05	67.2	10.1	14	2.2	42	3
	50-65	subsoil	7.3	4.11	67.9	41.5	15	7.3	50	6	8.5	3.12	80.2	31.5	17	4.2	47	8	6.7	2.36	64.7	18.9	26	6.1	572	503
	65-80	spoil	8.0	2.88	78.3	21.6	26	8.6	111	73	10.7	2.30	106.7	22.3	30	4.7	109	45	5.6	2.35	56.0	23.9	28	5.2	403	510
	130-145	spoil	6.9	1.71	77.5	20.6	39	5.5	156	8	6.7	1.86	73.9	23.0	38	10	165	13	9.1	2.75	95.1	29.5	44	11.6	412	496
4. 10° - S	0-15	topsoil	.6	.23	3.9	2.0	2	1.3	30	.9	1.3	.66	6.3	4.7	3	2.2	33	3	3.2	1.79	18.1	13.4	4	2.5	42	8
	15-40	subsoil	4.6	1.03	32.8	10.0	8	2.7	34	2	6.4	1.54	48.6	18.7	12	6.0	50	16	8.8	2.10	73.5	17.8	16	3.8	48	5
	50-65	subsoil	6.6	2.36	58.6	20.5	18	6.4	84	59	4.9	3.02	38.8	25.8	10	2.8	43	3	4.6	3.14	43.2	29.0	24	3.0	141	33
	65-80	spoil	4.2	.87	41.2	8.4	27	1.3	157	17	3.7	1.70	38.1	19.0	26	8.0	159	23	2.8	.90	27.1	11.3	25	2.7	164	31
	130-145	spoil	5.3	2.09	56.1	25.1	36	10.6	181	22	3.9	.72	39.5	6.4	28	3.2	159	18	3.8	.72	38.9	11.6	26	5.1	152	33

Note* material at the 50-65 cm depth interval, in the lower slope position is actually spoil.

CLRA

NINTH ANNUAL MEETING CANADIAN LAND RECLAMATION ASSOCIATION

RECLAMATION IN MOUNTAINS, FOOTHILLS AND PLAINS: **DOING IT RIGHT!**

AUGUST 21-24, 1984
Calgary, Alberta, Canada

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