MASTER

SOIL STUDIES
PHYSICAL AND CHEMICAL ANALYSIS,
NATIVE AND RETORT SOILS

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6.1.1

INTRODUCTION

Soil Investigations on the Geokinetics Oil Shale Project LOFRECO site, Uintah County, Utah have four components:

- o physical and chemical analysis of soil samples taken from undisturbed native soils and from retort sites;
- o soil series identification, classification, and mapping;
- o soil/plant interrelationship studies and;
- o soil productivity and toxicity studies.

Information obtained in each of these four components during the baseline study period will be accumulative. Data and analysis reports will be produced as information becomes available.

This interim report contains baseline data derived from the physical and chemical analysis of native soils and a number of retort soils. Data obtained from similar analysis on other retort sites were reported during 1978.

OBJECTIVES

The objectives of the soil studies on the LOFRECO site relative to physical and chemical analysis of the soils are as follows:

1. to produce a descriptive baseline relative to physical, chemical, and distributional characteristics of soil;
2. to derive a functional set of data that can be used to better understand soil/plant interrelationships;
3. to further derive functional relationships in other parts of the food chain, particularly those relating soil/plant interactions to herbivores and their predators and;
4. to employ the descriptive and functional data gathered as a decision making tool in the process of isolating impacts and designing mitigation methods.

METHODS

Soil samples obtained from native soils and retort soils were analyzed by standard laboratory techniques as contained in this report. Four native soil types were samples, as defined in the soil mapping and description report. These four soils are LR gravelly loam, JR loam, Havre silt loam, and Luhon loam. Three retort soils and a control soil were also sampled. The retort samples reported on include numbers 14, 15, and 17;

the control sample is number 1.

Samples from native soils were collected in two ways: 1) samples were taken from each soil horizon (regolith and lithic horizons were not sampled) of each soil series during the soil series description, 2) so called bag samples were taken from each of the eight vegetation study sites, each bag sample consisted of twenty subsamples taken at depths ranging from 15 to 46cm.

Samples from the retort soils were collected at depths approximating 15cm. These samples were collected prior to retort blasting and again following retort burning. The control sample was taken from a depth approximating 15cm.

Two types of laboratory analysis were used in determining the physical and chemical characteristics of both native and retort soils. The parameters analyzed are listed in Tables 1 and 2. Table 1 contains the agronomic characteristics determined. Table 2 contains those special types of analyses performed in order to determine the levels of soil toxigens that may potentially occur in the retort soils. The second type of analysis was also performed on native soils for the purposes of comparing naturally occurring levels with those determined in retort soils.

Tables 1 and 2 also indicate the units in which individual soil parameters are reported, as well as specific information relating to the method employed in analysis in cases where more than one type of analysis/extraction might have been suitable.

RESULTS AND DISCUSSION

The results of the physical and chemical soils analyses are contained in Tables 3 through 7.

The analysis results are partitioned in these tables to facilitate comparisons. Table 3 contains the analysis of soils underlying pinyon juniper woodlands on north and south-facing slopes (JR loam, V-20, V-21 and LR loam, V-10, V-11, respectively). Table 4 presents the analysis of soils underlying upland and lowland sagebrush dominated sites (Luhon loam, V-40, V-41 and Havre loam, V-30, V-31, respectively). In the tables, for purposes of comparison, the results of the analyses for Havre, Luhon, and JR loam were broken down from the complete determinations shown in Table 6. This was done in order to show the levels of parameters at depths approximating those at which samples V-10 through V-41 were taken.

TABLE 1

PHYSICAL AND CHEMICAL SOIL CHARACTERISTICS
 AGRONOMIC CHARACTERISTICS-ANALYSIS 1

Characteristic	Symbol	Analysis Method/Unit Reported
Nitrate-nitrogen	NO ₃ -N	ppm (parts per million)
Phosphorus	P	ppm
Sodium	Na	ppm
Potassium	K	ppm
Calcium	Ca	ppm
Magnesium	Mg	ppm
Ammonium-nitrate	NH ₃ -N	ppm
Sulfate-sulfur	SO ₄ -S	ppm
Manganese	Mn	DTPA extractable/ppm
Iron	Fe	DTPA extractable/ppm
Copper	Cu	DTPA extractable/ppm
Zinc	Zn	DTPA extractable/ppm
Boron	B	ppm
Molybdenum	Mo	Ammonium acetate extractable/ppm
Cobalt	Co	DTPA extractable/ppm
Chlorine	Cl	meq./liter
Organic matter	OM%	percent
Lime	%Lime	percent
pH	pH	saturated paste
Sodium absorption ratio	SAR	calculated (SAR = Na/√Ca+Mg/2) meq./liter
Electrical conductivity	EC	mmhos/cm
Cation exchange capacity	CEC	meq./100g
Exchangeable sodium percentage	ESP	calculated
Particle Size	Sand	Sn
	Silt	Sl
	Clay	Cl
Bulk density	B.D.	gm/cm ³
Permeability	Perm.	inches/hour
Field capacity	FC1/3	bar/percent
Wilting point	FC15	bar/percent
Saturation capacity	Sat.%	bar/percent
Available water capacity	AWC	cm H ₂ O/1cm soil/calculated

$$AWC = \frac{FC1/3 - FC15}{100} \text{ (bulk density)}$$

$$\text{sample thickness}$$

TABLE 2

PHYSICAL AND CHEMICAL SOIL CHARACTERISTICS:

SPECIAL CHARACTERISTICS

ANALYSIS 2

Characteristic	Symbol	Analysis Method/Unit Reported
Selenium	Se	ppm soluble
Arsenic	As	ppm soluble
Cyanide	CN	ppm soluble
Organic carbon	OC	percent
Organo-metallics	Org-Met	hexane soluble/ppm
Total hallides	Hallides	ppm
Flourine	F	ppm
Phenols	Phenols	water soluble/ppm
Lithium	Li	ppm
Mercury	Hg	ppm
Bromine	Br	ppm
Beryllium	Be	ppm

TABLE 3

PHYSICAL AND CHEMICAL SOIL CHARACTERISTICS:

LR LOAM AND JR LOAM

	LR Loam			JR Loam		
	Pit#4	V-10	V-11	Pit#2	V-20	V-21
NO ₃ -N*	1.0	15.0	14.0	1.5	17.0	18.0
P	4.0	8.0	5.0	5.5	3.0	4.0
Na	53.0	110.0	140.0	57.5	160.0	120.0
K	94.0	210.0	230.0	94.0	110.0	190.0
Ca	2600.0	2500.0	2500.0	2300.00	2500.0	2600.0
Mg	380.0	490.0	490.0	325.0	500.0	500.0
NH ₄ -N	1.5	2.9	2.8	1.2	3.6	3.7
SO ₄ -S	14.0	120.0	36.0	43.0	39.0	34.0
Mn	1.8	2.2	2.2	2.6	1.7	1.8
Fe	3.8	4.1	3.5	4.5	2.7	2.7
Cu	1.1	1.0	0.6	1.4	0.9	0.6
Zn	0.8	0.7	0.6	0.8	0.3	0.5
B	2.0	1.0	0.6	1.8	0.6	0.7
Mo	0.03	0.02	0.03	0.02	0.04	0.02
Co	0.1	0.1	0.1	0.1	0.1	0.1
Cl	2.6	2.3	1.4	1.6	1.2	1.3
OM%	3.5	5.8	4.3	4.4	3.4	5.5
%Lime	11.0	10.0	10.0	13.5	10.0	10.0
pH	8.4	8.0	8.2	8.4	8.4	8.3
SAR	1.3	1.0	1.1	1.5	1.6	1.3
EC	0.6	2.3	0.9	0.7	0.9	1.0
CEC	15.7	19.0	23.0	12.6	20.0	21.0
ESP	0.6	1.3	1.4	0.9	1.9	1.5
Sn	28.0	61.0	31.0	41.0	63.0	32.0
Sl	69.0	23.0	37.0	47.0	13.0	37.0
Cl	3.0	16.0	32.0	13.0	24.0	31.0
B.D.	1.41	1.51	1.43	1.47	1.49	1.45
Perm.	0.27	0.29	0.14	0.25	0.21	0.15
FC1/3	26.0	19.0	28.0	24.0	23.0	29.0
FC15	13.0	10.0	15.0	13.0	12.0	16.0
Sat%	54.0	35.0	48.0	47.0	41.0	51.0
AWC	0.18	0.14	0.19	0.16	0.16	0.19

*see Table 1 for explanation of units

TABLE 4

PHYSICAL AND CHEMICAL SOIL CHARACTERISTICS:
HAVRE LOAM AND LUHON LOAM

	Havre Loam			Luhon Loam		
	Pit#	V-30	V-31	Pit#	V-40	V-41
NO ₃ -N*	4.5	13.0	22.0	2.0	27.0	27.0
P	12.0	9.0	8.0	4.5	6.0	6.0
Na	70.5	120.0	180.0	44.5	160.0	150.0
K	330.0	310.0	470.0	370.0	610.0	660.0
Ca	2450.0	2500.0	2400.0	2400.0	2500.0	2500.0
Mg	460.0	480.0	490.0	740.0	500.0	500.0
NH ₄ -N	1.2	3.8	3.4	1.6	4.1	3.1
SO ₄ -S	53.5	40.0	90.0	6.5	160.0	36.0
Mn	2.2	1.6	1.1	3.0	3.5	2.5
Fe	3.3	3.9	3.6	2.6	2.2	2.8
Cu	1.1	1.0	1.0	1.1	0.6	0.8
Zn	0.6	0.7	0.8	0.9	0.6	0.6
B	2.4	1.0	2.0	2.3	3.2	1.2
Mo	0.03	0.03	0.03	0.04	0.02	0.02
Co	0.1	0.1	0.1	0.1	0.1	0.1
Cl	1.9	1.3	1.3	2.2	1.8	1.6
OM%	4.6	5.5	5.6	3.1	4.1	4.4
%Lime	11.5	10.0	10.0	12.5	10.0	10.0
pH	8.4	8.2	8.3	8.5	8.4	8.3
SAR	1.6	1.2	1.6	1.7	1.4	1.4
EC	0.9	1.0	1.1	0.7	1.6	1.2
CEC	14.5	18.0	24.0	14.8	25.0	23.0
ESP	1.0	1.7	1.9	1.1	1.8	1.7
Sn	14.0	58.0	33.0	14.0	18.0	18.0
Sl	72.0	24.0	38.0	74.0	49.0	53.0
Cl	15.0	18.0	29.0	14.0	33.0	29.0
B.D.	1.45	1.50	1.41	1.43	1.41	1.40
Perm.	0.19	0.27	0.16	0.23	0.13	0.18
FC1/3	25.0	19.0	27.0	24.0	26.0	24.0
FC15	13.0	10.0	15.0	13.0	14.0	13.0
Sat%	51.0	37.0	48.0	49.0	49.0	47.0
AWC	0.17	0.14	0.17	0.16	0.17	0.15

*see Table 1 for explanation of units

TABLE 5

PHYSICAL AND CHEMICAL SOIL CHARACTERISTICS:

RETORT SOILS: 14, 15, and 17
(Before and After Retort Burning)

	14 B ⁺	14 C ¹	15 B	15 C	17 A*	17 B	Control(001)
NO ₃ -N*	210.0	10.0	18.0	3.0	21.0	31.0	20.0
P	4.0	6.0	5.0	8.0	4.0	12.0	8.0
Na	no data	110.0	140.0	130.0	160.0	99.0	no data
K	310.0	240.0	200.0	190.0	130.0	220.0	410.0
Ca	1700.0	2400.0	2300.0	1900.0	2300.0	2400.0	2300.0
Mg	490.0	490.0	490.0	330.0	490.0	360.0	510.0
NH ₄ -N	7.2	2.6	3.4	1.8	3.1	2.1	2.4
SO ₄ -S	72.0	110.0	95.0	100.0	41.0	100.0	3.0
Mn	3.8	2.0	2.2	7.5	1.7	4.7	2.4
Fe	5.6	4.1	4.4	5.8	3.9	5.1	3.2
Cu	1.1	0.9	0.8	1.3	0.8	1.3	0.9
Zn	1.1	0.7	0.6	1.8	0.4	1.6	0.4
B	3.0	2.2	1.3	3.8	0.7	3.6	0.5
Mo	0.03	0.03	0.02	0.03	0.03	0.02	0.03
Co	0.1	0.01	0.01	0.01	0.01	0.01	0.01
Cl	1.2	1.1	1.3	1.1	1.7	1.6	1.0
OM%	4.1	3.0	3.5	2.8	2.3	4.2	3.0
%Lime	1.5	10.0	10.0	11.0	10.0	12.0	10.0
pH	8.1	8.2	8.3	8.0	8.3	7.9	8.2
SAR	6.7	1.2	1.5	4.2	1.4	3.6	0.5
EC	5.8	1.3	1.2	1.2	1.0	1.5	0.8
CEC	12.6	18.0	17.0	9.1	21.0	11.5	21.0
ESP	7.6	1.6	2.1	4.7	1.9	3.4	0.9
Sn	56.0	60.0	59.0	82.0	57.0	69.0	45.0
Sl	20.0	23.0	26.0	15.0	25.0	28.0	26.0
Cl	24.0	17.0	15.0	3.0	18.0	3.0	29.0
B.D.	1.41	1.47	1.45	1.57	1.46	1.53	1.49
Perm.	0.13	0.25	0.27	0.37	0.29	0.31	0.16
FC1/3	28.0	18.0	19.0	17.0	20.0	22.0	25.0
FC15	15.0	10.0	10.0	9.0	11.0	12.0	12.0
Sat%	51.0	35.0	34.0	31.4	38.0	40.6	46.0
AWC	0.18	0.12	0.13	0.13	0.13	0.15	0.19

* A= predisturbance

+ B= post blast

1 C= post burn

see Table 1 for explanation of units

TABLE 6

PHYSICAL AND CHEMICAL SOIL CHARACTERISTICS:

HORIZON PROPERTIES OF NATIVE SOILS

	LR Loam A1 0-15cm	JR Loam A11 0-18cm	A12 18-31cm	C1 31-61cm	Havre Loam A1 0-20cm	C1 20-71cm	C2 71-152cm	Luhon Loam A1 0-15cm	B2 15-41cm	C1ca 41-58cm	IIC2 58+cm
NO ₃ -N*	1.0	2.0	1.0	1.0	5.0	4.0	9.0	2.0	2.0	2.0	4.0
P	4.0	5.0	6.0	3.0	18.0	6.0	3.0	6.0	3.0	2.0	1.0
Na	53.0	65.0	50.0	52.0	56.0	85.0	730.0	45.0	44.0	88.0	200.0
K	94.0	120.0	68.0	46.0	240.0	420.0	270.0	480.0	260.0	77.0	63.0
Ca	2600.0	2100.0	2500.0	1600.0	2800.0	2100.0	1500.0	2400.0	2400.0	1700.0	1800.0
Mg	380.0	280.0	370.0	870.0	290.0	630.0	1400.0	630.0	850.0	1400.0	2000.0
NH ₃ -N	1.5	1.2	1.1	0.6	1.1	1.3	1.9	1.4	1.7	1.8	1.0
SO ₄ -S	14.0	79.0	7.0	17.0	42.0	65.0	370.0	11.0	2.0	57.0	210.0
Mn	1.8	3.4	1.7	1.8	1.9	2.4	1.6	3.3	2.6	1.0	0.8
Fe	3.8	5.4	3.6	2.7	3.6	3.0	3.4	2.7	2.5	3.3	2.5
Cu	1.1	1.2	1.5	2.4	1.0	1.1	1.5	1.0	1.1	0.9	1.3
Zn	0.8	0.7	0.9	1.1	0.7	0.5	0.6	1.2	0.6	0.8	0.7
B	2.0	1.9	1.7	2.3	2.1	2.6	5.8	2.3	2.3	2.7	3.2
Mo	0.03	0.01	0.02	0.02	0.03	0.02	0.03	0.03	0.04	0.02	0.0
Co	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Cl	2.6	1.3	1.8	2.1	1.8	2.0	4.2	2.2	2.1	1.3	2.0
OM%	3.5	4.8	3.9	3.8	5.8	3.4	2.4	3.6	2.6	4.7	5.0
%Lime	11.0	13.0	14.0	12.0	11.0	12.0	11.0	14.0	11.0	14.0	13.0
pH	8.4	8.3	8.4	8.9	8.3	8.4	8.0	8.4	8.5	8.6	8.7
SAR	1.3	1.8	1.2	1.6	1.1	2.0	6.5	1.5	1.8	2.7	3.5
EC	0.55	0.69	0.71	0.67	0.66	1.1	8.3	0.69	0.69	1.2	1.3
CEC	15.7	13.3	11.9	12.9	13.7	15.3	13.6	15.3	14.3	10.6	15.5
ESP	0.6	1.3	0.5	1.0	0.4	1.5	7.2	0.8	1.4	2.8	3.9
Sn	28.0	23.0	58.0	24.0	12.0	15.0	18.0	21.0	6.0	73.0	4.0
SI	69.0	58.0	35.0	68.0	76.0	68.0	73.0	76.0	69.0	19.0	80.0
Cl	3.0	19.0	7.0	8.0	12.0	17.0	9.0	3.0	25.0	8.0	16.0
B.D.	1.41	1.42	1.52	1.40	1.46	1.43	1.48	1.43	1.42	1.48	1.4
Perm.	0.27	0.19	0.31	0.24	0.21	0.17	0.25	0.29	0.16	0.29	0.1
FC1/3	26.0	28.0	19.0	26.0	24.0	25.0	24.0	25.0	23.0	24.0	27.0
FC15	13.0	15.0	11.0	14.0	13.0	13.0	13.0	12.0	13.0	13.0	14.0
%	53.5	56.5	37.4	53.9	51.0	50.6	53.2	51.7	46.9	44.2	53.1

*see Table 1 for explanation of units

TABLE 7

PHYSICAL AND CHEMICAL SOIL CHARACTERISTICS:
SPECIAL CHARACTERISTICS ANALYSIS
FOR NATIVE AND RETORT SOILS

	LR Loam	JR Loam	Havre Loam	Luhon Loam	# 14 B	' 14 C	15 B	15 C	= 17 A	17 B	Control (001)
Se*	0.05	0.10	0.05	0.02	0.03	0.03	0.05	0.04	0.03	0.12	0.01
As	0.03	0.03	0.05	0.07	0.06	0.02	0.04	0.03	0.02	0.9	0.02
CN					-1.0	-1.0	-1.0	nd ⁿ	-1.0	nd	-1.0
OC	1.7	2.2	2.2	1.6	2.2	0.4	0.5	1.3	0.4	2.1	1.4
Org-Met					-0.1	-1.0	-1.0	nd	-1.0	nd	-0.1
Hallides	50.0	26.5	35.5	38.0	36.0	15.0	18.0	12.0	24.0	23.0	55.0
F	2.0	2.0	1.5	1.5	-1.0	1.0	2.0	1.0	3.0	3.0	-1.0
Phenols	-1.0	1.0	-1.0	1.0	2.0	-1.0	-1.0	26.0	-1.0	41.0	-1.0
Li	-1.0	-1.0	-1.0	-1.0	nd	-1.0	-1.0	-1.0	-1.0	-1.0	nd
Hg	-0.01	0.02	0.01	0.01	nd	nd	nd	nd	0.01	0.02	nd
Br	-1.0	-1.0	-1.0	-1.0	nd	nd	nd	nd	-1.0	-1.0	nd
Be	-1.0	-1.0	-1.0	-1.0	nd	nd	nd	nd	-1.0	-1.0	nd

= A= predisturbance

B= post blast

' C= post burn

" no data

* see Table for explanation of units

As a result, the values for Havre loam in Table 4 are the mean of values determined in horizons A1 and C1 (Table 6); the values for Luhon loam are those averaged for horizons A1 and B2. In Table 3 the values for JR loam are the mean of horizons A11 and A12. The values for LR loam are those originally determined (LR loam has only one soil horizon).

Table 5 contains the results of the analyses performed on the retort soils and the control soil. This table presents the results of agronomic determinations on the control soil and on the retort soils prior to blasting and following retort burning.

The results of the special type of analysis on retort and native soils are shown in Table 7. The values for JR loam, Havre loam, and Luhon loam are those averaged for the first two horizons of each soil.

Native Soils

The overall nutrient regime of the soils occurring on the LOFRECO site is low. Nitrate-nitrogen is low to near normal in all native soils (less than 8ppm), although slightly high values are found in the upper horizon of the Havre loam series (Table 6). It is noteworthy that high nitrogen concentrations can reduce the availability of both potassium and phosphorus to plants, although phosphorus and potassium present in plant tissues counteracts this to an extent. Sodium is normal in the upper horizons of all soils (less than 200ppm) (Tables 3, 4, and 6). The Havre loam subsoils, however, exhibit high concentrations of sodium (Table 6). Potassium occurs at a wide range of concentrations between soil types. The Havre loam series demonstrates normal concentrations of potassium (200-400ppm), while the Luhon loam series has slightly higher values for this soil constituent in the upper horizon (480ppm). JR and LR loams show potassium levels ranging from deficient to normal (150-50ppm or less). Calcium concentrations in all soils are in the normal range (ca. 2400ppm). Ammonium-nitrate values have a wide range in the soils sampled. In the LR and JR series this nutrient is found at normal levels (ca. 1ppm). In the Havre and Luhon series, ammonium-nitrate ranges from normal to high (1-4ppm). Sulfate-sulfur is normal to high in all soils taken as whole units (30-120ppm). However, some horizons demonstrate low levels of this constituent (less than 7ppm) (Tables 3, 4, and 6). Lime is relatively high in all soils (greater than 8%), but this does

not represent a deliterious level. Magnesium occurs at normal levels in all soils (200-700ppm) except for the lower horizons of the Havre and Luhon series where it reaches high values of approximately 1400 to 2000ppm. The ph of all the soils sampled is high at 8.0 to 8.5. In the Havre and Luhon series ph is excessive in the lowermost horizons (8.7- 8.9). Organic matter percent is normal to slightly high (greater than 3-4%). The electrical conductivity of all surface soil horizons is acceptable (ca. 0.5-1. 5mmhos/cm). The subsoil of the Havre loam has excessive electrical conductivity values (greater than 6mmhos/cm). The cation exchange capacity of all soil horizons is normal (less than 20 meq/100gm) to slightly low. Trace element concentrations of Manganèse, Copper, Zinc, Molybdenum, and Cobalt are in acceptable ranges for all soils. Iron is normal in all soils at approximately 2.5 to 5ppm. Boron is slightly high in all soils (greater than 1ppm), but can not be termed excessive. Selenium concentrations are not problematical (less than 2ppm). Arsenic is slightly high in most soils at greater than 0.5ppm. The range of the sodium absorption ratio is acceptable in all soils (less than 8%). Available water capacity is moderate to low in all soils (compared with a mean adequate level of greater than 0.25cmH₂O/cm soil).

The general reclamation potential of all soils is acceptable. Figure 1 illustrates a comparison of the levels of soil parameters typically evaluated in determining a soils reclamation potential. (Wyoming DEQ 1976) The comparisons made in this figure reveal no special problems likely to be encountered in reclaiming sites based on soil properties. However, it must be noted that the lowermost horizons of the Havre and Luhon loams may present problems in terms of electrical conductivity and sulfate-sulfur.

Although there are no apparent reclamation problems indicated by the comparison of certain soil constituents with standard values, other considerations of soils must be made in terms of reclamation. The low nutrient status of the native soils may require fertilization during the reclamation process. In addition, the relatively high erodability

PH

FIGURE 1

COMPARISON OF SELECTED
SOIL RECLAVATION
POTENTIAL STANDARDS
WITH SOILS OCCURING
ON THE LOFRECC SITE

ELECTRICAL
CONDUCTIVITY
(MMHOS/CM)

SATURATION
PERCENTAGE

SODIUM
ABSORPTION
RATIO

BORON
(PPM)

Acceptable range shown by stipled pattern

of soils, particularly susceptibility to wind erosion, must be considered during revegetation activities. Finally, the interactions between various soil constituents, such as the effects of nitrates on potassium and phosphorus must be considered during the reclamation of soils that demonstrate high values of nitrate (Havre loam). The disturbance of soils with higher lime concentrations is another important consideration. This is a consideration in the Luhon loam series.

Retort Soils

The values for most soil constituents in retort soils are comparable with those of the native soils discussed above; Figures 2 through 12, illustrate a comparison of some of the more important soil characteristics. This is also true of the constituents determined in the special analysis (Table 7). Several points of significance are, however, apparent from the analysis. The first of these is ostensibly the result of activities on the retorts prior to blasting. There is a noted increase in nitrate nitrogen in some of the retort soils. (Figure 2). This is the result of spillage of ANFO during the process of loading blast holes. The effects of this spillage are, however, not deleterious. In fact, they appear to have a positive effect on plant growth since ANFO is primarily composed of nitrates. The only potential damage due to ANFO might occur if an excess of this material created a nitrate inhibition of potassium and phosphorus. The second type of significant soil alteration ostensibly caused by retorting is the alteration in soil structure. The analyses show a significant change in two soil parameters that relate to structure and to water holding capacity (although the first is of greater significance). The concentration of clay sized particles is decreased after the burning of retorts (Table 5, Figure 3). Bulk density of the soil samples shows a significant increase following burning of the retorts (Figure 4). Although the changes in these two parameters are the apparent result of retorting, they must be considered, instead, to be significant changes caused by the process of creating the retort mounds. The decrease in percent clay content is most probably the result of the loss of these particles during wind erosion. This alteration can be controlled through the use of temporary physical erosion control measures. The increase in bulk density is the apparent result of

FIGURE 2
COMPARISON OF NATIVE AND RETORT SOILS
NITRATE-NITROGEN

FIGURE 3

COMPARISON OF NATIVE AND RETORT SOILS
% CLAY

FIGURE 4

COMPARISON OF NATIVE AND RETORT SOILS
BULK DENSITY

FIGURE 5
COMPARISON OF NATIVE AND RETORT SOILS
PHOSPHORUS

FIGURE 6
COMPARISON OF NATIVE AND RETORT SOILS
POTASSIUM

FIGURE 6

COMPARISON OF NATIVE AND RETORT SOILS
AMMONIUM-NITRATE

FIGURE 7
COMPARISON OF NATIVE AND RETORT SOILS
SULFATE-SULFUR

FIGURE 8
COMPARISON OF NATIVE AND RETORT SOILS
CALCIUM

FIGURE 9
COMPARISON OF NATIVE AND RETORT SOILS
IRON

FIGURE 10
COMPARISON OF NATIVE AND RETORT SOILS
SODIUM

FIGURE 11
COMPARISON OF NATIVE AND RETORT SOILS
PERMEABILITY

FIGURE 12

COMPARISON OF NATIVE AND RETORT SOILS
EXCHANGEABLE SODIUM PRECENTAGE

compaction due to drilling and other traffic. This increase occurs in the soil surface layer and can be reversed by roughing during the revegetation of the retorts. The last soil alteration requiring discussion is the increase in sulfate-sulfur. Although this parameter does not increase to excessive levels it should be carefully monitored as a potential source of problems in reclamation.

The soil constituents analyzed in samples collected from retorts before blasting and after burning were subjected to a paired t-test in order to assess any significance of change in any parameter. The results of this test are given in Table 8. This table shows that two significant alterations before blasting and after burning occurred at the 95% confidence interval. These alterations were in the decrease of percent clay and increase of bulk density. The remaining differences in soil constituents were determined to be of no real significance. It should also be noted that the natural variation in soil characteristics revealed by all of the data presented (Tables 3 through 7) is a further indication of the low level change in the soil constituents of the surface layer on retorts.

CONCLUSIONS

This report represents the findings of the soil analyses performed on native soils and on the condition of retort soils before and after the completion of the retorting process. There are no apparent differences between native soil types and retort soils. This difference has not been evaluated statistically due to the difficulty in applying rigorous tests to soil parameters without large samples from each site. Moreover, it is not considered to be necessary to perform such sampling, since rigorous statistics are not warranted in comparing the native soils with the retort soils. Instead, the most acceptable basis for comparison between baseline soil conditions and retort soil conditions is that made on the retort sites themselves. The statistical approach used in this first-run analysis of differences in retort soil before and after retorting has revealed no real significant changes. The loss of fine soil particles and increased bulk density can be easily mitigated.

It is suggested that the sampling of retort soil prior to blasting and following retort burning be continued. The sampling approach to be used is reiterated below with several suggested alterations.

1. samples be taken from ten to twenty isolated points on

each retort site, before disturbance and blasting and following the completion of the retort burn (the sites should be isolated using a plastic cone, sample number will be that providing 1 to 2 pounds of soil);

2. sampling depth should be as great as possible --optimal depth (considering the rockiness of the soil surface) should be between 15 and 50cm (6 to 20 inches);

The final step in the analysis of physical and chemical constituents of native soil is the comparison of these values with other environmental parameters, such as vegetation productivity, and the comparison of soil parameters with other soil parameters. This analysis will elucidate the interrelationships between soils and vegetation and between soils parameters themselves. This information will enable us to potentially revise the retort soil sampling program in the direction of sampling soil constituents that provide the greatest amount of information concerning the reclamation of these sites and potential soil toxicities. This analysis is now in process and will be reported on in the near future.

LITERATURE CITED

Wyoming Department of Environmental Quality, 1976. Guideline No. 3, Land Quality Division, Parameters for Determining Soil Suitability.