Report of the
Mica Research Project

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Introduction

In the summer of 2003, a team of soil scientists was assembled to study and evaluate how mica has historically been described in soil profile descriptions (official soil descriptions and field descriptions) and to determine if a need exists to refine quantification and description techniques as related to soil classification and making and interpreting soil maps.

In addition to soil scientists, resource specialists (geologists, engineers, research specialists, and university staff) were asked to provide input, guidance, and historical perspective. The following individuals participated in a series of meetings, teleconferences, and field exercises to (1) evaluate methods for quantifying mica in soil profile descriptions, (2) review taxonomic classification and use of mica as criteria for separation of soil series, and (3) determine the effect of mica on soil performance. Each contributed significantly to the conclusions and recommendations presented in this report.

Team Members:

- Alan Walters, Resource Soil Scientist, NRCS, Salisbury, NC
- Chip Smith, MLRA Project Leader, NRCS, Asheville, NC
- Doug Thomas, Soil Survey Project Leader, NRCS, Waynesville, NC
- John Kelley, Soil Data Quality Specialist, MO-14, NRCS, Raleigh, NC
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- Mike Sherrill, Resource Soil Scientist, NRCS, Waynesville, NC
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Resource Specialists:

- Angela Jessup, Civil Engineer, NRCS, Yadkinville, NC
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- Howard Tew, Supervisory Civil Engineer, NRCS, Waynesville, NC
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- Kim Kroger, Geologist, NRCS, Raleigh, NC
- Mike Wilson, Research Soil Scientist, NSSC-SSL, Lincoln, NE
- Roy Vick, MLRA Team Leader, MO-14, NRCS, Raleigh, NC
- Stan Buol, Professor, NCSU, Raleigh, NC
- Tom Reedy, Soil Scientist, NSSC-NRCS, Lincoln, NE

Overview

Over a two-year period, seven meetings of the mica research team (MRT) were conducted. During the first meeting, held August 2003, the team discussed numerous issues related to mica. All participants had been actively involved in mapping high-mica soils, correlating soils series, or providing technical soil services. The following four major areas of study with related subtopics were identified:

I. Field Morphology

A. Determine how mica that is visible without magnification should be described.
B. Study the relationships of geology, climate, topography, etc. to mica content and determine if repetitive patterns exist.
C. Develop a list of field indicators as influenced by mica.

II. Data Population and Soil Interpretations

A. Determine an appropriate depth for the interpretative control section of soils influenced by mica (possibly 0 to 200 cm or bedrock contact).
B. Define use and management factors that affect interpretations.
C. Determine a list of soil properties or qualities that are affected by mica.
D. Establish parameters, or ranges, and appropriate class separations for limitation classes.
E. Choose methods (field, laboratory, etc.) for comparing soil conditions within the interpretive control section.

III. NASIS (NRCS-National Soil Information System) Issues

A. Determine which NASIS data elements (primarily representative values) should be modified in order to achieve appropriate soil interpretations.
B. Determine NASIS reports needed to reflect soils influenced by mica.

IV. Application-Soil Series Descriptions and Soil Classification

A. Revise existing series range in characteristics on a continuum to eliminate gaps in the range of soil properties.
B. Study taxonomic criteria and make necessary recommendations.

Over a two-year period, six additional meeting were held to address the areas of study identified by the MRT. Each team member had the opportunity to make suggestions, express concerns, offer solutions, and invite participation of additional resource specialists. During each meeting, action items were identified and assigned to team members.

Most of these meetings consisted of open discussion forums held in the Iredell County Agricultural Center, Statesville, NC. One meeting consisted of a field trip to view selected sites to determine consistent identification and quantification of mica, discuss related soil interpretations, and identify representative sites to sample. Another meeting was dedicated to sampling representative pedons where data voids had been identified.

Exhibit 1 provides a list of soil series and pedon identification numbers. Individual pedon data may be queried via the NRCS-NSSC Soil Survey Laboratory Soil Characterization Database: http://ssldata.sc.egov.usda.gov/querypage.asp.

This report does not include a detailed discussion of the numerous processes evaluated by the team or the progression of thought as different methods and ideas were tested. A complete record of the minutes from team meetings, methods, or procedures evaluated during the course of the study, copies of related research, laboratory data, soil descriptions, images, and pertinent correspondence is available from MLRA Region 14, Raleigh, NC.

Results and Discussion

I. Field Morphology

A. Determine how mica that is visible without magnification should be described.
The MRT concluded three issues need to be addressed when describing mica: 1) the quantity of mica, 2) the size of the mica and its relation to the coarseness of non-platy soil material, and 3) the manner in which aggregates respond when exposed to pressure.

1) Quantity of mica. When describing soils in the field, the quantity of mica has been expressed as a percent of area covered or it has been grouped into traditional concentration classes: few (< 2 percent), common (2 to 20 percent), and many (> 20 percent). These class separations have been used to separate soils at the series level (e.g., Cecil series versus Madison series).

Several of the MRT members expressed concern that the “many” class limit of more than 20 percent was not adequate to clearly group soils that have a larger amount of mica and the potential for a greater degree of limitation. For example, a soil with 25 percent mica is classed the same as a soil with 50 or 75 percent mica.

It was agreed that a field procedure for determining the quantity of mica should be expressed as a numerical value. However, complete agreement for a universal methodology of estimating mica content could not be agreed upon. The field procedure for determining the content of mica (percent of the area covered) most widely accepted by the MRT members is as follows:

- *Break apart a 25 to 50 mm size ped (fig.1).*
- *Evaluate the soil material on < 2 mm base. This may require sieving with a No. 10 sieve or visually eliminating the material coarser than 2 mm if it occurs in small amounts.*
- *For broken peds, compare the face with a quantity estimate chart and record the numerical value. If a ped cannot be obtained or the material is sieved, spread a sufficient amount onto a solid surface and compare to the chart (fig.2).*
- *Re-examine with a 10X hand lens to identify any additional mica.*

Figure 1. Evaluating ped for mica content.

Figure 2. Effort should be made to visually exclude mica > 2 mm.

Within the soil science community, mica content has been expressed as (1) percent of area covered, (2) percent by volume, (3) percent by weight, and (4) numerical grain count. Percent (by area covered) represents a two-dimensional perspective. Percent (by volume) represents a three-dimensional perspective. Numerical values obtained by these methods are considered similar. Values obtained by weight or grain count are measured differently and may have a predictive relationship however; a universally accepted conversion factor from one data value to another has not been developed.

The *Keys to Soil Taxonomy, Eight Edition (1998)* indicates that 25 percent mica by weight equates to about 65 percent mica by grain count, and 40 percent mica by weight equates to about 80 percent mica by grain count. In 2003, the relationship was revised so that 25 percent mica by weight is equal to about 45 percent mica by grain count, and 40 percent mica by weight to about 70 percent mica by grain count.

The MRT was not able to identify any algorithm that consistently converted data from one of these methods to percent of area covered or percent by volume. Without some method of conversion or a system to relate grain counts or percent by weight to percent area covered, it is difficult to consistently identify horizons (in the field) that have potential paramicaceous or micaceous mineralogy.

The MRT conducted a review of soil pedon data (primarily from the NRCS-Soil Survey Laboratory) of high-mica soils sampled throughout the Southern Appalachian Mountains, focusing on grain count data. Grain counts are routinely conducted on the dominant fraction within the range limits defined in Soil Taxonomy. The fractions analyzed have been significantly narrowed over the years from 0.02 mm to 20 mm in 1975, from 0.02 mm to 2.0 mm in 1999, and from 0.02 mm to 0.25 mm in 2003.

In order to determine the mica content of the < 2.0 mm soil, the percent mica in the analyzed fraction was extrapolated to represent the coarse silt through very coarse sand fraction. This value was used to represent the percent mica on a < 2.0 mm basis. The total percent of coarse silt through very coarse sand was multiplied by the percent mica to approximate mica content. The MRT used this procedure to select representative pedons for characterization and bulk sampling. In each of the pedons, differences in the results of the two methods did not affect mineralogy class.

Example:

- grain count data of the fine sand fraction (0.10 to 0.25 mm) of a horizon contains 35 percent muscovite and 15 percent biotite, for a total of 50 percent mica minerals.
- the coarse silt through very coarse sand fractions are 75 percent of the < 2mm fraction.

$$\frac{50 \times 75}{100} = 37.5$$ *or about 35 to 40 percent mica (about 1/3 to 1/2 of a broken ped surface)*

This procedure was established in order to provide a link between laboratory analysis and field identification of mica. Without this link, calibration of field soil scientists or consistent comparison of the high-mica components from map unit to map unit could not be achieved.

Table 1 compares quantity estimates of mica from a single-fraction grain count to grain count of the coarse silt through very coarse sand fraction. Fine sand was dominant for the 0.02 to 0.25 fraction of each sample.

Table 1. Grain count comparisons.

Sample number	Grain count						Percent mica*	Percent mica**
	CoSi	VFS	FS	MS	CoS	VCoS		
2-1	55	69	61	48	60	58	52	50
2-2	63	77	66	59	64	45	50	49
2-3	71	73	71	72	76	62	63	63
2-4	46	57	41	25	4	4	20	18
2-5A	47	54	72	49	28	12	33	22
2-5B	70	82	90	81	51	1	67	57

* Single grain count (fine sand); ** Multiple grain count (coarse silt through very coarse sand)

It must also be kept in mind that the content of mica in a sample is only one of the important factors in developing interpretations. Some variability of the reported percent mica is likely not critical to the success of any developed criteria. It appears that inclusion of particle-size data, landform criteria, and geologic information are also important to any generalized interpretation. Therefore, the continued use of data on a single, dominant fraction seems adequate in most cases.

As in the past, laboratory flexibility for the needs of the data user is critical. The option of the soil scientist to request the analysis of additional fractions should be maintained as particle-size data accompanied by field examination of the site warrant. The MRT concluded that grain count of the single dominant fraction, for the most part, was adequate for determining mineralogy and volume estimates.

The grain conversion method was applied to several datasets of high-mica soils to determine its applicability. Of the 57 datasets reviewed, the coarse silt plus sand fraction averaged about 50 percent for fine and fine-loamy horizons and about 75 percent for coarse-loamy and sandy horizons. Table 2 shows the relationship of fine- or coarse-textured soils that have paramicaceous or micaceous sand mineralogy to estimated mica content.

Table 2. Relationship of particle size, mineralogy, and mica content.

Particle-size class	Sand mineralogy	Content estimate
Fine-loamy or fine: Wt. avg. CoSi + S = 50	**Paramicaceous** (45% mica by GC x 50% (CoSi + S) / 100) = 23%	about 1/5 to 1/3
	Micaceous (70% mica by GC x 50% (CoSi + S) / 100) = 35%	greater than 1/3
Coarse-loamy or sandy: Wt. avg. CoSi + S = 75	**Paramicaceous** (45% mica by GC x 75% (CoSi + S) / 100) = 34%	about 1/3 to 1/2
	Micaceous (70% mica by GC x 75% (CoSi + S) / 100) = 53%	greater than 1/2

Following this guide, a fine-loamy horizon with paramicaceous mineralogy would typically have a content of about one-fifth (20%) to one-third (33%) mica in the coarse silt to very coarse sand fraction. The same approximate content would be observable on a broken-face ped. This procedure provides a *"general"* guide for field soil scientists to determine if a horizon has sufficient mica content to classify in a paramicaceous or micaceous mineralogy family.

The MTR recommends content of mica be evaluated and recorded in all pedon descriptions, where present, and the method of measurement identified (e.g., comparison to quantity chart, conversion from grain count data, etc.).

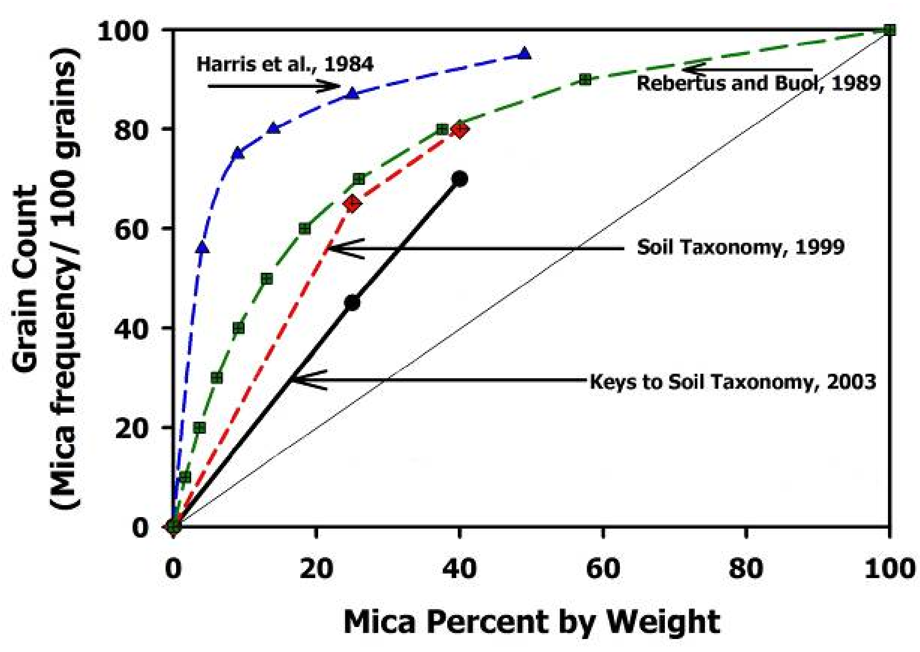
It has come to the attention of the MRT that the quantity charts provided in the Field Book for Describing and Sampling Soils may not be accurate. Reference to these charts by field soil scientists are an important step to properly identifying mica content as well as other soil features.

The MTR recommends evaluation and conformation of the quantity charts provided in the Field Book for Describing and Sampling Soils.

The MRT questioned the value of determining mica by weight for application in the Cooperative Soil Survey Program. Even though methods have been developed to determine content by weight (froth flotation, electromagnetic separation, vibration, etc.), none are routinely conducted by soil science laboratories nor could universally accepted procedures be identified.

In addition, there is very limited published data available for review and comparison of methodologies. The research of Harris in the 1980's suggested there was a curvilinear relationship (fig. 3) between grain count and weight and that dividing grain count data by a factor of 8 (diameter to height ratio of platy grains) would be a possible procedure to convert grain count data to a weight percent basis.

Figure 3. Methods used to convert grain count values to percent mica by weight.



Rebertus and Buol (1989) developed an equation to model the conversion, but were unable to independently verify the model. They indicated that grain shape, size, cleavage, and density were all factors that influenced this relationship and concluded that any conversion of grain count data to another reporting basis (weight or volume) was impractical. At that time, the consensus was that a grain count was the measure of the mica content of the soils, reflecting both the size and shape of the grains. Therefore, scientists researching this topic recommended grain count values as a reporting basis (Harris and Zelazny, 1985; Rebertus and Buol, 1989).

Five bulk samples were sent to the North Carolina Minerals Lab, Asheville, NC, for weight analysis. Using the weight to grain count relationship identified in the *Keys to Soil Taxonomy, (2003), c*omparison of grain count data by the NRCS-SSL to weight data from the Minerals Lab was relatively consistent. The process was complicated by the fact that the time required for the NC Minerals Lab to conduct tests and report their findings was lengthy, and when additional samples were submitted, analysis could not be completed.

A possible method for converting mica by grain count to percent mica by weight was suggested by the National Soil Survey Center by dividing the percent mica by grain count by (the percent mica by weight plus 5 times the other grains in the count). This number should be multiplied by the amount of silt plus sand in the fine-earth fraction (as a decimal fraction).

Example: (Pedon 00NC-021-015, Chandler Series, C horizon)
- 88 percent (wt.) silt plus sand
- 70 percent mica (by grain count)
- 30 percent other grains in the count
- 70 percent (wt.) mica

$$\frac{70\%\ mica\ by\ grain\ count}{70\%\ mica\ by\ wt. + (5 \times 30\%\ other\ grains)} \times 88\%\ (wt.)\ silt\ plus\ sand = \%\ mica\ (wt.)\ for\ the\ 2\mu\ to\ 2\ mm\ fraction$$

Using this formula, the percent mica, by weight is about 28 percent. This is the approximate value identified in the Robertus and Buol model.

The MRT agreed the central focus when quantifying mica should be a laboratory procedure to confirm field observations or to allow for calibration of field soil scientists. Since grain counts are the established procedure used by the NRCS-Soil Survey Laboratory for identifying mica content and a conversion procedure has been proposed for comparison of field estimated content to measured grain counts, the need for identification of mica (by weight) may not serve any additional purpose.

The MRT recommends mica by weight be dropped as measurement criteria used for mineralogy families in soil taxonomy.

It was agreed that once characterization and reference samples for the Mica Research Project were collected, subsamples should be made available to field staff (upon request) for calibration. These samples are in storage at the MLRA Region 14 Office located in Raleigh, NC. Subsamples may be obtained by contacting John Kelley, MLRA Soil Scientist. See Exhibit 2 for a list of available calibration samples and associated data.

The MRT recommends standardized samples of micaceous soils be made available to field soil scientists so they can be used for comparison and calibration of mica content and size.

2) Size of the mica and its relation to the coarseness of non-platy soil material. Often, mica dominantly occurs in the finer sand fractions. The identification and quantification of mica in these fractions is very difficult and requires the use of a hand lens. It is not uncommon for a horizon that has sufficient grain counts of mica for the paramicaceous or micaceous mineralogy family to have only a small amount of observed mica (e.g. few flakes of mica).

The *Keys to Soil Taxonomy, Ninth Edition, 2003,* indicates only the 0.02 to 0.25 mm fraction (coarse silt to fine sand) be considered when determining placement in the micaceous or paramicaceous mineralogy families. This requires each horizon, when described, to be examined with a hand lens if a realistic estimate of the volume of mica is to be obtained or if a comparison to grain count data is made.

Mica is presently described as a concentration of inherited minerals. Concentrations are defined by kind, quantity, size, contrast, color, moisture state, shape, location, hardness, and boundary. Sizes of concentrations are not subdivided by class for materials less than 2 mm. Since cemented materials greater than 2 mm in size are identified as rock or pararock fragments, additional separations are needed for mica minerals or other cemented materials finer than 2 mm.

Subdividing the "fine" class of concentrations will lead to misunderstanding of point data presently stored in the NASIS Pedon program. To adequately describe and define inherited materials, these geogenically formed remnants should be separated into their own unique group. Exhibit 3 provides criteria for the establishment of "inherited materials".

The MTR recommends a separate property table for "Inherited Materials" be established for point and aggregate data as used in the NASIS data structure, Soil Survey Manual, National Soil Survey Handbook, Soil Taxonomy, etc.

Once mica content reaches a significant amount, it affects the way in which the soil ribbons, influencing the determination of soil texture (fig. 4 and fig. 5). Many soil scientists over estimate the amount of clay due to the "slick" feel imparted to the soil as it is ribboned. This requires re-calibration by the soil scientist similar to that required when texturing soils with high amounts of organic matter. To identify this characteristic, a "micaceous" texture modifier is proposed. An operational definition for the micaceous texture modifier is provide in Table 3.

Table 3. Pedon horizon texture modifier.

Types	Code		Criteria:
	PDP	NASIS	
OTHER			
Micaceous			*≥ 1/3 of ribboned surface covered by mica flakes (ribbon formed by gradually increasing pressure to a specimen held between extended thumb and forefinger in such a manner that some shear force is exerted on the specimen.)*

Figure 4. Texture ribbon with more than 1/3 of the surface covered with mica.

Figure 5. Mica residue remaining on hand after texturing.

The MTR recommends "micaceous" be added to the list of "other" compositional texture modifiers as used in the NASIS data structure, Soil Survey Manual, National Soil Survey Handbook, Soil Taxonomy, etc.

Mica fragments greater than 2 mm are populated in the NASIS data structure as rock fragments. The pedon description programs presently being used by NRCS require populating fragment-kind from a choice list. This list does not include mica. The only related option is schist, mica. Adding mica to the choice list will more accurately reflect horizon composition.

For example, a soil with about 50 percent mica (many mica flakes) that has flakes ranging from 0.02 to 20 mm in size (about 1/2, 2mm-20 mm) would appropriately be described as:

...; 10 *percent fine mica flakes and 15 percent coarse mica flakes; 25 percent 2 mm to 20 mm mica fragments; ...*

The MRT recommends "mica" be added to the Pedon Horizon Fragment-Kind choice list in NASIS Pedon.

3) Manner in which aggregates respond when exposed to pressure. Another physical property of mica when ribboned (as when determining texture) is the characteristic "greasy" feel. As a soil aggregate is broken and rubbed between thumb and forefinger, the platy particles impart a "slick feel" to the fingers and a "sheen" or shiny appearance to the ribboned aggregate. When smeared, the stacked plates of mica break down similar to a deck of cards being fanned. Soil aggregates when crushed in hand leave a residue of mica (fig. 6 and fig.7).

The observance of this characteristic is often used by field soil scientists to verify the presence of mica. If the aggregate contains large amounts of mica, the ribbon will appear to be completely covered by mica. This often leads the soil scientist to over-estimate the mica content as compared to laboratory grain counts or weight determinations. However, this greasy feel is a characteristic unique to soils with significant amounts of mica and may be an important indicator when evaluating soil performance.

Figure 6. High-mica soil aggregate.

Figure 7. Residue from high-mica soil.

Greasiness can be defined as the capacity of the soil, when ribboned, to impart a "slick feel" to the fingers and a sheen or shiny appearance to a ribboned aggregate. Table 4 lists the classes and criteria for greasiness that are proposed.

Table 4. Greasiness classes.

Failure Class:	Criteria: Use a 3 cm block. (Press between thumb and forefinger.)
Non-greasy[1]	Material ribbons as expected for texture class. Little or no mica residue on hands when rubbed.
Semi-greasy[1]	Material ribbons easily between thumb and forefinger. Moderate mica residue on hands when rubbed.
Greasy[1]	Material ribbons very easily between thumb and forefinger. Significant mica residue on hands when rubbed.

[1] Greasiness failure classes are used dominantly with soil materials that contain significant amounts of mica.

The MRT recommends that greasiness classes be added to the traditional manner of failure classes described in the NRCS Soil Survey Manual.

B. Study the relationships of geology, climate, topography, etc., to mica content and determine if repetitive patterns exist.

The MRT reviewed geology maps, soil maps, topographic maps, and other related materials. It was agreed that representative landscape and geologic units (formations, groups, etc.) could be used to roughly determine the geographic extent of high-mica soils. The team members were confident these types of resource materials should be used when plotting or revising soil boundaries or geographically separating or correlating soil components at the series level.

However, it was noted that geologic formations in and of themselves were only an indication of the dominant parent materials and subsequent mica content of the overlying soil. This did not exclude the possibility of non-mica soils occurring in areas mapped by geologists as high-mica geologic materials. It was agreed that a consistent method of quantifying mica was imperative if correlating mapunits and component composition were to be consistent from area to area.

C. Develop a list of field indicators as influenced by mica.

It was noted by several of the MRT that land surface conditions (i.e., degree of erosion, type of erosion, slip scars, cat steps, failed water impoundments, etc.) may be a means of identifying or confirming the presence of high-mica soils. Time did not allow for adequate investigation of this issue and no conclusions or recommendations are offered.

II. Data Population & Soil Interpretations

A. Determine an appropriate depth for the interpretive control section of soils influenced by mica (possibly 0 to 200 cm or bedrock contact).

The term "control section" has multiple meanings as applied to soil taxonomy. It is used as a reference zone for family and series level criteria. Field soil scientists make and record observations and commonly communicate on the basis of the soils control section; however, no attempt has been made to establish a control section for soil interpretations. The lack of an established interpretive control section prompted several hours of discussion by the MRT. Many members were concerned that recording soil properties to a depth of only 150 or 200 cm may not be adequate, especially when evaluating soil performance in high-mica areas.

Individuals working in the mountains suggested that the base depth of consideration be extended to hard bedrock, even where bedrock occurs at a depth of several meters. Although the MRT members were in agreement that the underlying geological materials should be considered when making interpretations, it would not be practical to routinely conduct such extremely deep (2 to 10 meters) observations or attempt to populate soils properties to these depths in the NASIS database.

It was agreed the zone of consideration when interpreting soils high in mica should be at a minimum depth of two meters or to hard bedrock, whichever is shallower. Where observations can be made in deep cuts, this information should be recorded and used as a basis to modify or adjust concepts.

B. Define use and management factors that affect interpretations.

In traditional Soil Survey Reports, map unit descriptions and the use and management section provide users with a list of potential soil concerns, limitations, and practices that may help to overcome a particular limitation posed by a soil property or quality. The MRT reviewed these sections and discussed different ways to identify factors related to the use and management of high-mica soils.

Resource specialists such as engineers, geologists, and university staff were invited to participate in two of the MRT meetings. Some attended the session and others responded in writing or provided input by telephone. Both private and NRCS engineers were in agreement that soil limitations posed by mica could be overcome by special design. The major concern identified by these specialists was type of design and installation costs, not the severity of the limitation.

Other sources indicated mica sand was a poor sand source for construction materials. No new or additional use and management statements were developed or are recommended.

C. Determine a list of soil properties or qualities that are affected by mica.

In conjunction with resource specialists, the MRT identified compaction, compression, strength, slippage, erodibility, and piping/jugging as soil properties and qualities that could potentially be affected by content and size of mica. Time did not allow for a thorough review of each of these properties. Team efforts concentrated on soil strength, slippage, and erodibility.

Using the guides established in sections I. A. 1) and I. A. 2), soils were placed into four general groups to evaluate performance and associated soil properties:

Group 1—Fine mica in a fine matrix
Group 2—Fine mica in a coarse matrix
Group 3—Coarse mica in a fine matrix;
Group 4—Coarse mica in a course matrix

(Fine mica is dominantly < 0.25 mm in diameter; coarse mica is dominantly 0.25 to 2.0 mm in diameter)
(Fine matrix ≥ 50 percent passing No. 200 sieve and ≥ 18 percent clay; coarse matrix is < 50 percent passing No. 200 sieve)

1) Soil Strength. Even though consensus exists that mica affects soil strength, its effect has not been fully investigated or documented. For example, the "Pavement Design Guide for Subdivision and Secondary Roads" (Virginia Department of Transportation), identifies mica, in association with the AASHTO classification, as a factor when rating soil load support characteristics (strength). No methodology for measuring mica is provided. Content is determined by visual observations and subjectively identified as low, moderate, or high with borderline cases decided by the District Materials Engineer, Virginia Department of Transportation. No attempt is made to empirically quantify mica.

NRCS uses AASHTO Group Index (GI) to identify "low strength" as a soil limitation. For example, a group index of ≤ 5 is considered not limiting, a group index of > 5 to < 8 is considered somewhat limiting, and a group index of ≥ 8 is considered limiting for local roads and streets. A total of 26 horizons of representative high-mica soils from the Southern Appalachian Mountains and the Western Piedmont were submitted to the Soil Mechanics Laboratory, Ft Worth, TX, for analysis. A review of the data indicated 20 of the samples (77 percent) had a group index of < 5, 2 of the samples (8 percent) had a group index of 5 to < 8, and 4 of the samples (15 percent) had a group index of > 8.

Of the samples with a "very limiting" rating, the AASHTO classification was A-7-5 and the Unified classification was MH. The soils rated "somewhat limiting" had an AASHTO classification of A-5 or A-6 and a Unified classification of ML. Soils with a "very limiting" rating had a clay content of 40 percent or more and the soils with a "somewhat limiting" rating had a clay content of 18 to 30 percent.

Mica is not the overriding factor in determining soil strength. The percent fines, liquid limit, and plasticity index are the critical properties used in determining soil strength. The MRT concluded that the incremental effect of additional amounts of mica or the varying size of mica cannot be determined without further study. However, the MRT did conclude that significant amounts of fine or coarse mica in association with a fine matrix (Groups 1 and 3) have a limiting effect on soil strength.

2) *Soil Slippage Potential.* The hazard for soil slippage is used with the NASIS data structure. Criteria used in the rating are in the National Soil Survey Handbook, Part 618, Exhibit 17. Soil interpretations that use soil slippage as criteria to determine a restrictive feature are listed in Exhibit 4 of this report. Criteria used in the NSSH rating guide (NSSH, Part 618, Exhibit 17) center on topography and landform or geologic materials. The content and size of mica are not considerations.

Exhibit 4 of the MRT report is a draft guide proposed for testing in MLRA136 and MLRA130. The guide takes into consideration the increasing potential for soils to slide as slope, mica content, and mica size (for a given particle size) increase.

The guide was developed early in the project and separates mica content into six groups. It is offered only as an example of a general format to help identify the relative soil properties.

Criteria similar to this guide could be incorporated into the NSSH exhibit or a separate independent supplement could be developed. Class assignment population in NASIS would be based on the most limiting class determined by either the modified NSSH exhibit or an independent supplement.

Another factor to consider, which was not implemented in the draft guide, is slope configuration. As slope configuration differs from convex to linear to concave, internal water movement and surface water movement are altered. Concentrated flow of water across or through high-mica soils significantly affects slope stability.

The MRT recommends a guide for soil slippage potential be developed and tested that incorporates criteria for content and size of mica and soil slope percent and configuration.

(3) Soil Erodibility. Observations of high-mica soil landscapes in humid environments indicate a more "rounded" surface morphometry (fig. 8). Where severely eroded, high-mica soils tend to form U-shaped gullies. Based on field mapping experience, several of the MRT members indicated high-mica soils (under similar conditions) were more erosive than soils that contained little or no mica. This was readily observable where the underlying soil materials (primarily C horizons) had been exposed on the soil surface (fig. 9).

Figure 8. Rounded landscapes associated with high-mica soils.

Figure 9. Saprolite underlying high-mica soils.

Soil erodibility factors (Kf and Kw) are used to identify the potential for soil erosion. These factors are the basis for quantifying soil detachment and raindrop impact. The values assigned to the individual factor are based on five soil properties: percent silt plus very fine sand, percent very coarse sand, organic matter content, structure, and subsoil saturated hydraulic conductivity. The Kw factor (whole soil) versus the Kf factor (fine-earth fraction) is adjusted for the armoring effect of rock fragments. Where rock fragments exist, Kw is always less than Kf.

However, with high-mica soils, the fine-earth fraction is significantly affected not only by the size and quantity of the sand grains but by the shape of the grains as well. The present criteria for determining Kf does not take into consideration the shape of the sand grains. The MRT concluded that adjusting the Kf factor for high mica content, possibly increasing the factor by one class, was appropriate but outside the scope and objectives of this project.

The MRT recommends further investigation into modifying soil erosion factors (Kw and Kf) based on particle shape.

The MRT concluded that mica most likely affects all of the properties identified; however, the extent of the effect is not clearly understood or is not sufficiently documented. It was decided that establishing erodibility class criteria for the aforementioned soil properties was outside the expertise of the MRT; therefore, no specific recommendations for adjusting these properties are offered. Onsite investigation and sampling of the soil for related engineering properties was considered the best way to maximize soil performance.

D. Establish parameters, or ranges, for limitation classes and their appropriate class separations.

From the beginning, the MRT struggled with consistently determining mica content in relation to soil performance. What one person identified as 20 percent mica another person identified as 30 or 40 percent mica. This lack of consistency emphasizes the need for an agreed-to method for determining mica content. However, the team was in general agreement as to the degree of limitation mica posed at a particular site. In an effort to establish consensus among team members, several techniques for characterizing mica were tested.

The traditional class separation of low, moderate, and severe was discussed as well as a green, yellow, and red class separation. These classes correspond to management statements such as (1) no additional management required, (2) mica content poses a management concern, and (3) mica content poses a management limitation. In addition, an extensive effort was made to coordinate and develop relational concepts within three main target areas—quantity of mica, interpretive effect of mica, and taxonomic classification of high-mica soils.

Initially, a three-tiered class system was implemented. This seemed to fit best the way NRCS has historically identified class separations. For example, quantity: few, common, or many; interpretive class: not limited, somewhat limited, or very limited; and taxonomic class: mixed, paramicaceous, or micaceous.

Several guides were tested, modified, and re-tested. Over time, it became apparent that as the amount of variables or classes of variables considered increased, the likelihood of developing a useable guide decreased. In addition, limited research in this area indicates a two-tiered system (the soil is either affected or is not affected) may be all that is needed.

From an engineering perspective, the relative effect of mica (Harris et al., 1984) is most pronounced at lower levels (10 to 15 percent by weight) and tapers off significantly as levels increase, indicating that additional classes are unnecessary. In subsequent research, Harris and Zelazny (1985) recommended 10 percent by weight (grain count of 40) be implemented as the break-point for non-micaceous/micaceous soils. This principal was supported by John Witty (NRCS) in a letter addressing series differentia (07/05/1989). Dr. Witty suggested a separation at 10, 12, or 15 be used as series criteria, depending on which value was considered critical for interpretations.

If no more than two separations are needed, only one break-point is required. Below the break-point, no mention of mica as an interpretive limitation is made. Above the break-point, mica is identified as a management consideration with an appropriate statement such as, “*Due to high mica content, special planning and design may be necessary. On-site investigation is recommended.”*

The MRT recommends a two-tiered system be implemented when establishing interpretive classes to separate high-mica soils from low-mica soils.

E. Choose methods (field, laboratory, etc.) for comparing soil conditions within the interpretive control section.

See discussion provided in section 1. A. 1), 2), and 3) of this report.

<u>3. NASIS Issues</u>

A. Determine which NASIS data elements (primarily representative values) should be modified in order to achieve appropriate soil interpretations.

Data elements within the NASIS data structure that are potentially affected by mica include soil slippage potential, liquid limit, plasticity index, AASHTO rating, AASHTO Group Index, and Unified Classification. These elements should be populated from hard data values as determined from standard procedures of representative soils. No additional adjustment for grain shape or quantity is required.

However, new data elements are needed to provide information related to mica, including quantity (percent of area covered), size, and manner of failure. Presently, mica is described in the “Pedon” module of NASIS in the Pedon Horizon Concentrations table. However, data stored in NASIS “Data Mapunit” Component tables are typically used to generate soil interpretations. Once the recommended addition of the inherited materials table to the Pedon Horizon table has been made, the new table could be added as a subtable to the Component Horizon table.

The MRT acknowledges modification of the NASIS data structure would be costly and would require input from numerous individuals (i.e., soil scientists, programmers, etc.). However, the team feels strongly that mica related properties should be captured in the NASIS data structure and that data elements should be reflective of those properties identified by the team as being important to interpreting the soil.

The MRT recommends an appropriate procedure for capturing mica quantity, method of measurement, size, and manner of failure in the NASIS data structure.

B. Determine NASIS reports needed to reflect soils influenced by mica.

Prior to the establishment of NASIS (National Soils Information System), interpretations were generated from the SCS-Soil 5 form. This form identified soil properties and interpretations by mapping phase. If a generated interpretation did not provide the anticipated result, the soil property class used in rating the soil would be edited. For example, micaceous soils in western North Carolina were thought to have low strength even though the generated interpretation did not account for this.

If the associated values for liquid limit, plasticity index, and percent passing the No. 200 sieve did not generate a severe rating, the class was simply changed to severe in the SOI-5 database. This produced the desirable class limit without modifying individual soil properties. This was known as overriding the SOI-5. An asterisk was used to identify the override on the printed SOI-5 form.

A similar override process does not exist in NASIS. This makes it necessary to incorporate all soil properties critical to generating accurate soil interpretations into the database. To judge the potential influence mica has on soil interpretations, the MRT reviewed the standard National Soil Interpretation reports and the criteria used in rating soils.

A summary of the findings are provided in Exhibit 4. The first part of the exhibit identifies the mica related factors (soil properties or qualities) identified by the MRT as important when making a soil interpretation and the restrictive features generated within the report. Rating classes (limitations, suitabilities, and potentials) are also identified.

The second part of the exhibit lists the national interpretive tables commonly used in published soil survey reports and the web soil survey along with the soil property being evaluated and its restrictive feature. Also included are notes made by the team for future criteria modification.

The MRT identified 16 interpretations where mica-related information would be beneficial. Most interpretations could be improved by the addition of soil slippage potential as rating criteria; others could be improved by the addition of the greasiness manner of failure classes.

Another option considered was the incorporation of a data element for mica content in order to generate a rating class and restrictive feature statement without attempting to isolate a particular soil property or quality. For a soil interpretation such as “local roads and streets” with a rating of “not limited,” in place of modifying the present soil slippage potential guide and adding the property to the criteria used when generating the report, simply add mica content as restrictive feature.

For example:

Mica Content. Soils with high mica content affect the soil’s traffic-supporting capacity and slope stability. The soil features considered are the family mineralogy class, and mica content of a layer with RV clay < 18 and mica volume ≥ 35 percent or RV clay ≥ 18 and mica volume ≥ 20 percent. Evaluate layer thickness within 200 cm.

Limiting	≥ 50 cm (or 100 cm)
Somewhat Limiting	≥ 25 cm
Not limiting	< 25 cm

(e.g., Somewhat limited--high-mica materials or unstable materials)

There are several approaches to incorporating mica related soil properties into the NASIS data structure, many of which are outside the scope of the MRT. The support and cooperation of several key individuals from field staff, MO staff, and the National Soil Survey Center are necessary in order to meet the needs identified in this report.

The MRT recommends a new workgroup be created to address NASIS data population and soil interpretation issues.

4. Application--Soil Series Descriptions and Soil Classification

A. Revise existing series range in characteristics on a continuum to eliminate gaps in the range of soil properties.

One of the soil properties historically used to separate soil series in the Southern Appalachian Mountains is mica content. Many of these series have counterparts based on what was thought to be interpretive differences (e.g., slope stability, soil strength, erodibility, etc.). For example, the low-mica Evard series (fine-loamy, parasesquic, mesic Typic Hapludults) is considered a counterpart to the high-mica Fannin series (fine-loamy, paramicaceous, mesic Typic Hapludults). A key to the low- and high-mica soils is provided in Exhibit 6.

Evard soils have less than 20 percent mica throughout and Fannin soils have more than 20 percent mica in the B and C horizons. Soil components that have low mica in the upper part and high mica in the lower part fall into a gap. Some have been included or mapped with the Evard series since they do not have paramicaceous mineralogy, while others have been included with the Fannin series, which is thought to be interpretively similar.

Before a universal correlation decision can be made, it is imperative that standard field procedures for estimating mica and a method for laboratory conformation be established. Procedures outlined in section 1. A. 1), 2) and 3) provide a method for consistent identification of mica. Once these procedures are implemented, consistent correlation can follow. An additional benefit to implementing an agreed-to procedure is that it allows for the review and comparison of previously collected field data and laboratory datasets. Data from older surveys can be compared to those being collected from on-going initial and update soil surveys.

The MRT identified the following three options for correlating soils with low mica in the upper part (upper meter) and high mica in the lower part (lower meter):

(1) Correlate as a “high-mica substratum” phase of the referenced low-mica soil
(2) Correlate as a taxadjunct to the referenced high-mica soil
(3) Establish a new soil series

Options (1) and (2) are appropriate, but would require consistent application from survey area to survey area. Option (3) allows for a more consistent approach.

The MRT recommends establishing new series for those soils that have low mica content in the upper part and high mica content in the lower part.

This recommendation will necessitate a review of published soil surveys and potential maintenance of the spatial and tabular data. Potentially affected soil maps and the associated database do not require immediate revision. This review and revision can be conducted over a period of time as the soil survey program transitions from the traditional "once-over" soil survey to the "new soil survey" and as MLRA soil survey project offices are established. Implementing a creditable agreed-to procedure was considered more important than the time of transition.

B. Study taxonomic criteria and make necessary recommendations.

From the limited research available for high-mica soils, there is an indication that once a critical threshold level has been reached, no additional influence is exhibited on soil performance, even as mica content continues to increase (Harris, et al., 1984). Data from this research and historical NRCS (SCS) communications indicate this critical threshold level may be lower than the values presently assigned to the paramicaceous and micaceous mineralogy families.

Based on available data, the critical mica content for soil interpretations is most likely 40 percent or more (by grain count). Soil taxonomy presently classifies a soil as paramicaceous if it has a grain count value of 45 or more. The MRT concluded that this value is similar enough to the values indicated in the present scientific literature that lowering the value to 40 percent (by grain count), as suggested in some of the literature, is unnecessary.

Presently, there are 71 soil series identified as high mica in the upper part—53 in the paramicaceous family and 18 in the micaceous family. Exhibit 6 has a detailed listing of these series. No series correlated in the eastern U.S. could be identified as being established solely on the basis of paramicaceous versus micaceous mineralogy. It is not anticipated that any series would be dropped by reclassifying family mineralogy from paramicaceous to micaceous.

The MRT recommends eliminating the paramicaceous mineralogy family from Soil Taxonomy and changing the definition of micaceous to "more than 45 percent (by grain count) mica and stable mica pseudomorphs in the 0.02 to 0.25 mm fraction."

Another consideration discussed by the MRT was the need to identify the type of mica, primarily to differentiate between biotite and muscovite. Many team members thought that the mineralogy of the mica may be a better key to soil performance than the quantity of mica once the critical break-point had been reached. This concept was developed after several hours of debate by the MRT and the comparison of soil performance observations by field soil scientists.

Proposed changes in section E of the mineralogy key in *Soil Taxonomy* are as follows:

E. All other mineral soil layers or horizons, in the mineralogy control section, that have:

1. More than 45 percent (by grain count) mica and stable mica pseudomorphs in the 0.02 to 0.25 mm fraction; more than 75 percent of the total mica minerals are biotite.

Biotitic

or

2. More than 45 percent (by grain count) mica and stable mica pseudomorphs in the 0.02 to 0.25 mm fraction; more than 75 percent of the total mica minerals are muscovite.

Muscovitic

or

3. More than 45 percent (by grain count) mica and stable mica pseudomorphs in the 0.02 to 0.25 mm fraction.

Micaceous

Example: A Bt horizon that has 50 percent (by grain count) mica minerals composed of 40 percent Biotite and 10 percent Muscovite would be in a biotitic mineralogy family.

The MRT recommends the proposed mineralogy key be circulated for review and testing.

Conclusions

The presence of mica in soils in significant amounts has traditionally been thought to affect soil performance. In mountainous areas such as western North Carolina, eastern Tennessee, Virginia, and other parts of the U.S. where high-mica soils exist, slope stability is a concern. Soils high in mica and other platy minerals have low soil strength and are susceptible to accelerated erosion and landslides. The major issues addressed by the Mica Research Team include:

1) Micaceous soils can be identified in the field, but recording properties in the morphological description that quantify the problem is difficult. Methods for describing mica are inconsistent and often the zone where the limiting properties occur are below the depth of observation.

2) Quantification of mica and identification of criteria to reliably predict interpretive problems remains elusive. A single particle-size fraction is commonly quantified in laboratory analysis (by grain count) and this value is equated to the mica content in the total sand and silt. An additional problem is the correlation of mica by volume, grain count, and weight percent.

3) Consistent correlation and classification of high-mica soils from region to region cannot be accomplished without standard conventions.

The MRT was assembled to address these and other mica-related issues. Starting in the summer of 2003, the MRT has made a concerted effort to develop a methodology for field soil scientists to consistently describe mica and its associated properties.

In summary, the MRT concluded the best approach to identification of mica-affected soils may be to separate only low- from high-mica soils. Research does not tend to support the need for additional separations. The critical issue identified by the MRT is consistent documentation of mica. Using the procedures described in this report, content estimates can be confirmed by laboratory grain counts. Soil mechanics data can be used to confirm soil properties that may pose soil limitations. Provisions need to be made that will allow for the types of data identified in this report to be recorded in the NASIS data structure.

The MRT also reviewed soil interpretations as provided in standard soil survey reports and the web soil survey. Until such time as the recommendations in this report or other similar procedures are established, generated soil interpretations will not adequately reflect the limitations posed by high mica content. Additional work in this area remains.

Members of the MRT appreciate the opportunity to have participated in this project and acknowledge the strong administrative support of MO-14 and MO-18. Staff from the National Soil Survey Center, Soil Survey Laboratory, and other resource specialists greatly contributed to the team’s accomplishments. Many of the concepts and methods evaluated by the team are a direct result of conversations with and suggestions by these individuals.

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SUMMARY OF RECOMMENDATIONS

The following recommendations have been reviewed by the project participants and are supported by the mica research team:

Soil Survey Standards Issues

1. Evaluate and record content of mica in all pedon descriptions, where present, and identify the method of measurement (e.g., comparison to quantity chart, conversion from grain count data, etc.).

2. The MTR recommends evaluation and conformation of the quantity charts provided in the Field Book for Describing and Sampling Soils.

3. Drop mica by weight as measurement criteria used for mineralogy families in Soil Taxonomy.

4. Make standardized samples of micaceous soils available to field soil scientists so they can be used for comparison and calibration of mica content and size.

5. Establish a separate property table for "Inherited Materials" for point and aggregate data as used in the NASIS data structure, Soil Survey Manual, National Soil Survey Handbook, Soil Taxonomy, etc.

6. Add "micaceous" to the list of other compositional texture modifiers as used in the NASIS data structure, Soil Survey Manual, National Soil Survey Handbook, Soil Taxonomy, etc.

7. Add "mica flakes" to the Pedon Horizon Fragment-Kind choice list in NASIS Pedon.

8. Add greasiness classes to the manner of failure classes in the Soil Survey Manual.

9. Develop and test a guide for soil slippage potential that incorporates criteria for mica content and size and soil slope percent and configuration.

10. Implement a two-tiered system when establishing interpretive classes to separate high-mica soils from low-mica soils.

11. Identify appropriate methods for capturing mica quantity, method of measurement, size, and manner of failure for incorporation into the NASIS data structure.

12. Create a new workgroup to address NASIS data population and soil interpretation issues.

13. Establish new series for those soils that have low mica content in the upper part and high mica content in the lower part.

14. Eliminate the paramicaceous mineralogy family from Soil Taxonomy and change the definition of micaceous to "more than 45 percent (by grain count) mica and stable mica pseudomorphs in the 0.02 to 0.25 mm fraction."

15. Circulate proposed revision of the mineralogy key for review and testing.

Research Priorities Issues

1. Initiate an investigation to modify soil erosion factors (Kw and Kf) based on particle shape.

Exhibit 1. List of Pedon Data

Soil sampled as:	ID no.	Lab sample number or pedon number	NC county & field stop no. or topo quad	Horizon	Depth (cm)	Char. data	Ref. data	Grain count (single)	Grain count (multiple)	Soil mechanics data
Evard		S03NC-021-001-1	Buncombe 3-**01-1**	B	10-100	NO	YES	YES	NO	YES
Evard	S2	S03NC-021-001-2	Buncombe 3-**01-2**	C	100-200	NO	YES	YES	NO	YES
Evard		S03NC-021-002-1	Buncombe 1-**02-1**	B	10-75	NO	YES	YES	NO	YES
Evard	S5	S03NC-021-002-2	Buncombe 1-**02-2**	C	75-150	NO	YES	YES	NO	YES
Evard	S1	S03NC-021-003-1	Buncombe 2-**03-1**a	B	**10**-75	NO	YES	YES	NO	YES
Evard		S03NC-021-003-1	Buncombe 2-**03**-1b	BC	75-**100**	NO	YES	YES	NO	
Evard		S03NC-021-003-2	Buncombe 2-**03-2**	C	100-200	NO	YES	YES	NO	YES
Edneyville		S03NC-021-005-1	Buncombe 6-**04-1**	B	10-75	NO	YES	YES	NO	YES
Edneyville		S03NC-021-005-2	Buncombe 6-**04-2**	C	75-500	NO	YES	YES	NO	YES
Lauada		S03NC-021-006-1	Buncombe 9-**05-1**	B	10-50	NO	YES	YES	NO	YES
Lauada		S03NC-021-006-2	Buncombe 9-**05-2**	C & Cr	50-300	NO	YES	YES	NO	YES
Chandler	S3	S03NC-009-001-1	Ashe 12-**06-1**	B	10-75	NO	YES	YES	NO	YES
Chandler		S03NC-009-001-2	Ashe 12-**06-2**	C	75-175	NO	YES	YES	NO	YES
Watauga		S03NC-009-002-1	Ashe 14-**07**	Ap	0-15	YES	YES	YES	NO	NO
Watauga		S03NC-009-002-2	Ashe 14-**07**	Bt1	**15**-51	YES	YES	YES	NO	NO
Watauga		S03NC-009-002-3	Ashe 14-**07** **[7-1]**	Bt2	51-74	YES	YES	YES	NO	YES
Watauga		S03NC-009-002-4	Ashe 14-**07**	BC	74-**94**	YES	YES	YES	NO	NO
Watauga		S03NC-009-002-5	Ashe 14-**07** **[7-2]**	C1	94-193	YES	YES	YES	NO	YES
Watauga		S03NC-009-002-6	Ashe 14-**07** **[7-3]**	C2	193-356	YES	YES	YES	NO	YES
Buladean		S00NC-193-001-1	Wilkes 11-**08-1**	B	10-75	NO	YES	YES	NO	YES
Buladean		S00NC-193-001-2	Wilkes 11-**08**-2a	C	**75**-125	NO	YES	YES	NO	YES
Buladean		S00NC-193-001-2	Wilkes 11-**08-2**b	Cr	125-**200**	NO	YES	YES	NO	
Rhodhiss		S03NC-193-001-1	Wilkes 10-**09-1**	B	10-75	NO	YES	YES	NO	YES
Rhodhiss		S03NC-193-001-2	Wilkes 10-**09-2**	C	75-150	NO	YES	YES	NO	YES
Minnieville		S04NC-097-010-1	Iredell 18-**10-1**	B	25-75	NO	YES	YES	NO	NO
Minnieville		S03NC-097-019-1	Iredell 19-**11-1**	B	10-75	NO	YES	YES	NO	YES
Minnieville		S03NC-097-019-2	Iredell 19-**11-2**	BC	75-125	NO	YES	YES	NO	YES
Minnieville		S03NC-097-020-(1)	Iredell 20-**12-2**	B	10-75	NO	YES	YES	NO	NO
Minnieville		S03NC-097-020-1	Iredell 20-12	C1	75-150	NO	YES	YES	NO	NO
Minnieville	S4	S03NC-097-020-2	Iredell 20-**12-1**	C2	150-250	NO	YES	YES	NO	YES
Watauga	2-1	05N0590	Laurel Springs	C	200-300	NO	YES	YES	YES	YES
Chandler	2-2	05N0591	Celo	C	100-200	NO	YES	YES	YES	YES
Cashers	2-3	05N0592	Cashiers	C	100-200	NO	YES	YES	YES	YES
Clifton	2-4	05N0593	Skyland	B	10-100	NO	YES	YES	YES	YES
Minnieville	2-5A	05N0594	Stony Point	B	25-100	YES	YES	YES	YES	YES
Minnieville	2-5B	05N0595	Stony Point	C	150-250	YES	YES	YES	YES	YES

Exhibit 2. Calibration Samples

ID number	Percent mica by volume (single fraction)	ID number	Percent mica by volume (CoSi through VCS)
S-1	15	2-1	50
S-2	30	2-2	49
S-3	60	2-3	63
S-4	75	2-4	18
		2-5A	22
		2-5B	57

Exhibit 3. Inherited Materials

Some choices in “concentration kind” are not concentrations, and therefore should be assigned to a new horizon table “inherited materials.” This requires deleting **glauconite pellets** and **mica flakes** from “concentration - kind” and adding the following choices to “inherited materials - kind.”

Inherited materials definition – Less than 2mm materials that are not formed by soil forming processes (additions, removals, transfers, transformations). No cementation class is recorded. Inherited materials that are greater than 2mm are fragments. Noncemented inherited bodies of fine earth that are greater than 2mm are recorded either as a repeating texture or described in the free form notes. Noncemented pseudomorphs greater than 2mm are described in the free form notes.

a) Pedon_inherited materials_kind

INHERITED MATERIALS		
Kind	**NASIS Code**	**Definition**
Glauconite pellets	GLI	Silt to sand-sized, nodular aggregates with a characteristic greenish color, dominantly composed of the clay mineral glauconite; formed in near-shore marine sediments and subsequently exposed by a drop in sea level or rise of a land mass, as on a coastal plain. Glauconite pellets have a high potassium content and higher CEC and moisture retention compared to other mineral sands. Compare - greensands. Enter as a percent by area covered.
Mica flakes	MIC	Mica and stable mica pseudomorphs in the <2 mm fraction. Enter as percent by area covered.
Kaolin bodies (geogenic relict)		**Needs definition.**
Feldspar minerals		**Needs definition.**
Ferromagnesian minerals		Ferromagnesian- and magnesium-silicate minerals, such as the serpentine minerals (antigorite, chrysotile, and lizardite) plus talc, olivines, Mg-rich pyroxenes, and Mg-rich amphiboles, in the fine-earth fraction. Entered as a percent by area covered
Volcanic glass		Volcanic glass, glass aggregates, glass-coated grains, and other vitric volcaniclastics in the 0.02 to 2.0 mm fraction. Entered as a percent by grain count.

b) Pedon_inherited_materials_dominant_size

Size Class	Code	Criteria
Fine		< 0.25 mm
Coarse		0.25 to 2 mm

c) Pedon_inherited materials_shape

Shape	Code		Criteria
	PDP	NASIS	
cylindrical	C	C	tubular and elongated bodies
irregular	Z	I	bodies of non-repeating spacing or shape
platy	P	P	relatively thin, tabular sheets, lenses
cube-like			rounded to angular, crudely cubicle bodies
spherical	O	S	well-rounded, crudely spherical bodies

Exhibit 4. MICA Related Soil Properties, Qualities, and Interpretations

FACTOR		FEATURE
Soil properties (RV)	**Code**	**Table restrictive feature**
Liquid limit	LL	Hard to pack, piping
Plasticity Index	PI	Hard to pack, piping
Particle-size separates (% retained on #200 sieve)	PS	Sandiness, too sandy, texture
Percent passing #200 sieve (0.074 mm) (splits VFS)	PP	Bottom layer, hard to pack, piping
Soil erodibility factor (Kw)	SE	Slope; erodibility, water erosion
Slope percent	SP	
Soil Quality--value/class	**Code**	**Table Restrictive Feature**
Unified classification	UC	Low strength, hard to pack
AASHTO group index	GI	Low strength
Soil slippage potential**	SS	Landslides

***Slippage is an important consideration for engineering practices, such as constructing roads and buildings, and for forestry practices. Soil slippage hazard (potential) is the observation of surface slippage features that indicate a mass of soil could possibly slip when the vegetation is removed,, when soil water is at or near saturation, or when the slope is undercut. Saturating a slope with water from altered drainage or irrigation has an effect on slippage hazard but is not considered when making these ratings.*

NATIONAL INTERPRETIVE TABLES

TABLE and COLUMN NAME	***Prop./Qual.***	***Restrictive Feature***
Agricultural Disposal of Manure, Food-Processing Waste, and Sewage Sludge		
C1 Application of manure and food-processing waste (NL, SL, VL)		
C2 Application of sewage sludge (NL, SL, VL)		
Agricultural Disposal of Wastewater by Irrigation and Overland Flow		
C1 Disposal of wastewater by irrigation (NL, SL, VL)		
C2 Overland flow of wastewater (NL, SL, VL)		
Agricultural Disposal of Wastewater by Rapid Infil. and Slow Rate Treat.		
C1 Rapid infiltration of wastewater (NL, SL, VL)		
C2 Slow rate treatment of wastewater (NL, SL, VL)		
Haul Roads, Log Landings, and Soil Rutting on Forestland		
C1 Limitations affecting construction of haul roads and log landings (S, M, S)	SS, PI, PS, UC	Landslides, stickiness, sandiness, low strength
--Use SSP & greasiness (if SG or GR=MS) total of >50 cm (w/i 2 meters)	GR	Slipperiness (?)
	SS	Landslides
C2 Suitability for log landings (WS, MS, PS)	PI, PS, UC, SS	Stickiness, too sandy, low strength, landslides
--Greasiness (if SG or GR=MS) any layer (w/i 15cm)	GR	Slipperiness (?)
C3 Soil rutting hazard (S, M, S)	UC	Low strength
**Revise SSP guide to allow unlimited depth.		
Hazard of Erosion and Suitability for Roads of Forestland		
C1 Hazard of off-road or off-trail erosion (S, M, S, VS)	SE	Slope; erodibility
--Review representative MLRA-DMU components for K-factor correctness**		
C2 Hazard of erosion on roads and trails (S, M, S)	SE	Slope; erodibility
--Review representative MLRA-DMU components for K-factor correctness		
C3 Suitability for roads (natural surface) (WS, MS, PS)	PI, PS, UC, SS	Stickiness, too sandy, low strength, landslides
--USE SSP & Greasiness (If SG or GR=MS)	GR	Slipperiness (?)
** Use NASIS calculator to compare Evard v. Fannin Bt horizons (MLRA DMUs); if same, consider arbitrary adjustment for higher mica.		
Forestland Planting and Harvesting		
C1 Suitability for hand planting (WS, MS, PS)	PS, PI	Sandiness, stickiness
C2 Suitability for mechanical planting (WS, MS, PS)	PS, PI	Sandiness, stickiness
C3 Suitability for use of harvesting equipment (WS, MS, PS)	PI, PS, UC	Stickiness, too sandy, low strength

TABLE and COLUMN NAME	*Prop./Qual.*	*Restrictive Feature*
Forestland Site Preparation		
C1 Suitability for mechanical site preparation (surface) (WS, MS, PS, US)	PI	Stickiness
C2 Suitability for mechanical site preparation (deep) (WS, MS, PS, US)		
Damage by Fire and Seedling Mortality on Forestland		
C1 Potential for damage to soil by fire (L, M, H)		
C2 Potential for seedling mortality (L, M, H)		
Camp Areas, Picnic Areas, and Playgrounds		
C1 Camp areas (NL, SL, VL)		
C2 Picnic areas (NL, SL, VL)		
C3 Playgrounds (NL, SL, VL)		
Paths, Trails, and Golf Fairways		
C1 Paths and trails (NL, SL, VL)	SE	Water erosion
--Greasiness (if SG or GR=MS) any layer (w/i 15cm)	GR	Slipperiness (?)
C2 Off--road motorcycle trails (NL, SL, VL)	SE	Water erosion
--Greasiness (if SG or GR=MS) any layer (w/i 15cm)	GR	Slipperiness (?)
C3 Golf fairways (NL, SL, VL)		
Dwellings and Small Commercial Buildings		
C1 Dwellings without basements (NL, SL, VL)		
--USE SSP	SS	Landslides
C2 Dwellings with basements (NL, SL, VL)		
--USE SSP	SS	Landslides
C3 Small commercial buildings (NL, SL, VL)		
--USE SSP	SS	Landslides
Roads and Streets, Shallow Excavations, and Lawns and Landscaping		
C1 Local roads and streets (NL, SL, VL)	GI	Low strength
--USE SSP	SS	Landslides
C2 Shallow excavations (NL, SL, VL)		
--USE SSP	SS	Landslides
C3 Lawns and landscaping (NL, SL, VL)		
Sewage Disposal		
C1 Septic tank absorption fields (NL, SL, VL)		
C2 Sewage lagoons (NL, SL, VL)		

TABLE and COLUMN NAME	*Prop./Qual.*	*Restrictive Feature*
Landfills		
C1 Trench sanitary landfill (NL, SL, VL)		
C2 Area sanitary landfill (NL, SL, VL)		
C3 Daily cover for landfill (NL, SL, VL)	UC	Hard to pack
Source for Sand and Gravel		
C1 Potential as a source of gravel (G, F, P)	PP	Bottom layer, thick layer
C2 Potential as a source of sand (G, F, P)	PP	Bottom layer, thick layer
--Percent mica (> 20 percent)?		
Source for Topsoil, Roadfill, and Reclamation Material Source		
C1 Potential source of reclamation material (G, F, P)	SE	Water erosion
--USE SSP		Landslides
--Percent mica (> 20 percent)?		Unstable fill
C2 Potential source of roadfill (G, F, P)	GI	Low strength
--Use SSP		Landslides
--Percent mica (> 20 percent)?		Unstable material
C3 Potential source of topsoil (G, F, P)		
C4 Potential source of construction material *(fill material)*		
--USE SSP		Landslides
--Percent mica (> 20 percent)?		Unstable material
Ponds and Embankments		
C1 Pond reservoir areas (NL, SL, VL)		
C2 Embankments, dikes, and levees (NL, SL, VL)	PI, LL, PP	Hard to pack
--Percent mica (> 20 percent)?		Unstable material
C3 Aquifer-fed excavated ponds (NL, SL, VL)		

Limitations:
(NL, SL, VL) = not limited, somewhat limited, very limited
(S, M, S) = slight, moderate, severe
(S, M, S, VS) = slight, moderate, severe, very severe

Suitabilities:
(WS, MS, PS) = well suited, moderately suited, poorly suited

Potentials:
(G, F, P) = good, fair, poor

Exhibit 5. Soil Slippage Potential Guide

FINE	Dominant mica size	Percent mica (volume)																						
		0-10		10-20			20-35				35-50					50-75					>75			
Materials	Fine	<30*	>30	<30	>30	>50	<15	>15	>30	>50	<8	>8	>15	>30	>50	<8	>8	>15	>30	>50	<8	>8	>15	>30
Rate by layer	Coarse	<30	>30	<30	>30	>50	<15	>15	>30	>50	<8	>8	>15	>30	>50	<8	>8	>15	>30	>50	<8	>8	>15	>30
COARSE	**Dominant mica size**	Percent mica (volume)																						
		0-10		10-20			20-35				35-50					50-75					>75			
Materials	Fine	<30	>30	<30	>30	>50	<15	>15	>30	>50	<8	>8	>15	>30	>50	<8	>8	>15	>30	>50	<8	>8	>15	>30
Rate by layer	Coarse	<30	>30	<30	>30	>50	<15	>15	>30	>50	<8	>8	>15	>30	>50	<8	>8	>15	>30	>50	<8	>8	>15	>30

** Percent slope*

Fine materials = ≥ 50 percent passing #200 sieve and ≥ 18 percent clay

Coarse materials = < 50 percent passing #200 sieve (< 18 percent clay)

Fraction in mm	Mica size class
COSI 0.02-0.05 mm	Fine
VFS 0.05-0.10 mm	Fine
FS 0.10-0.25 mm	Fine
MS 0.25-0.5 mm	Coarse
CS 0.5-1.0 mm	Coarse
VCS 1.0-2.0 mm	Coarse

*****Soil slippage potential** is based on the most limiting layer <u>greater than 25 cm thick</u> within 200 cm of soil surface.*

Example: Most limiting layer (30 cm thick) and GR-L with 15 percent clay, 30 percent fine mica, and 40 percent slope.

Low slippage potential--slightly unstable to stable

Medium slippage potential--moderately unstable

High slippage potential--unstable

Exhibit 6. MICA Research Project--Reference Soil Series

MLRA 130				
PSCS		**Mod. deep**	**Deep**	**Very deep**
Coarse-loamy	Low	Chestnut	Buladean	Edneyville
	High	Brownwood	Micaville	Chandler (ls) Cashiers (ds)*
Fine-loamy	Low	Cowee (ul-rd) Pigeonroost (ul-bn)		Evard (rd) Edneytown (bn)
	High	Bellspur (in-ds) Lauada		Cashiers (in-bn-ds) Watauga (ul-bn) Fannin (ul-rd)
Fine	Low			Clifton (mx) Hayesville (ka)
	High			
MLRA 136				
PSCS		**Mod. Deep**	**Deep**	**Very Deep**
Coarse-loamy	Low			
	High			Manor (148)
Fine-loamy	Low			
	High	Mt. Airy (lk)	Kibler	Grover (136)
Fine	Low			
	High			Madison (ul-rd) Hulett (ul-bn)

in--Inceptisol order; ul--Ultisol order; ds--Dark surface; ls--Light surface; bn--Brown subsoil
rd--Red subsoil; lk--Loamy-skeletal pscs; mx--Mixed mineralogy; ka--Kaolinitic mineralogy

* Field texture indicates coarse-loamy PSCS, 15 bar water clay indicates fine-loamy.

Appendix 7. Soil Family Report based on Paramicaceous Mineralogy

SERIES / DESCR. ESTAB.	MO	STATE / OTHER STATES USING	SOIL FAMILY / MLRAS USING
ARCHROCK 12/99 1999	6	CO	LOAMY-SKELETAL, PARAMICACEOUS HUMIC DYSTROCRYEPTS 48A
BELLSPUR 02/05 2004	14	VA	FINE-LOAMY, PARAMICACEOUS, MESIC HUMIC DYSTRUDEPTS 136
BENDEMEERE 12/00 2000	6	CO	LOAMY-SKELETAL, PARAMICACEOUS LAMELLIC HAPLOCRYALFS 48A
BOBTAIL 03/99 1957	6	CO NM	COARSE-LOAMY, PARAMICACEOUS TYPIC EUTROCRYEPTS 43 44 48A 48B
BROWNWOOD 07/01 2001	18	NC	COARSE-LOAMY, PARAMICACEOUS, MESIC TYPIC DYSTRUDEPTS 130
BULLWARK 09/03 1999	6	CO	LOAMY-SKELETAL, PARAMICACEOUS LAMELLIC EUTROCRYEPTS 48A
BUSKA 02/99 1977	7	SD	LOAMY-SKELETAL, PARAMICACEOUS, FRIGID GLOSSIC HAPLUDALFS 62
CATAMOUNT 02/04 1984	6	CO	LOAMY-SKELETAL, PARAMICACEOUS, SHALLOW USTIC DYSTROCRYEPTS 45 48A 49
CATHEDRAL 04/05 1974	6	CO MT UT WY	LOAMY-SKELETAL, PARAMICACEOUS, FRIGID LITHIC HAPLUSTOLLS 34 47 48A 48B
CHASMFALLS 12/99 1999	6	CO	COARSE-LOAMY, PARAMICACEOUS, FRIGID PACHIC HAPLUSTOLLS 48A
T CORPEN 04/05	6	CO	LOAMY, PARAMICACEOUS, FRIGID LITHIC HAPLUSTOLLS 48A
FANNIN 03/03 1923	18	NC GA SC TN	FINE-LOAMY, PARAMICACEOUS, MESIC TYPIC HAPLUDULTS 130
GALUCHE 12/99 1999	6	CO	LOAMY-SKELETAL, PARAMICACEOUS, FRIGID LITHIC DYSTRUSTEPTS 48A
GRIMSTONE 09/00 1973	6	CO WY	FINE-LOAMY, PARAMICACEOUS USTIC GLOSSOCRYALFS 48A 48B
GUANELLA 01/02 2000	6	CO	COARSE-LOAMY, PARAMICACEOUS PACHIC HAPLOCRYOLLS 48A
HERBMAN 02/06 1980	6	CO WY	LOAMY-SKELETAL, PARAMICACEOUS, SHALLOW USTIC HAPLOCRYOLLS 48A
HIAMOVI 12/99 1999	6	CO	LOAMY-SKELETAL, PARAMICACEOUS LITHIC DYSTROCRYEPTS 48A
HISEGA 02/99 1977	7	SD	LOAMY-SKELETAL, PARAMICACEOUS, FRIGID PACHIC HAPLUDOLLS 62

SERIES	DESCR.	ESTAB.	MO	STATE	OTHER STATES USING	SOIL FAMILY	MLRAS USING
HIWAN	07/00	1980	6	CO	MT	SANDY-SKELETAL, PARAMICACEOUS LITHIC CRYORTHENTS	48A
IVYWILD	02/06	1984	6	CO		LOAMY-SKELETAL, PARAMICACEOUS USTIC DYSTROCRYEPTS	48A
KATAKA	12/00	2000	6	CO		LOAMY-SKELETAL, PARAMICACEOUS, FRIGID TYPIC ARGIUSTOLLS	48A
KIBLER	02/05	2004	14	VA		FINE-LOAMY, PARAMICACEOUS, MESIC TYPIC DYSTRUDEPTS	130B
KIGLAUIK	06/05	2005	17	AK		LOAMY-SKELETAL, PARAMICACEOUS, SUBGELIC HUMIC EUTROGELEPTS	240
KITTREDGE	05/00	1980	6	CO		FINE-LOAMY, PARAMICACEOUS USTIC ARGICRYOLLS	48A 48B
LEGAULT	02/06	1980	6	CO		SANDY-SKELETAL, PARAMICACEOUS, SHALLOW TYPIC CRYORTHENTS	48A
LININGER	05/00	1980	6	CO	WY	FINE-LOAMY, PARAMICACEOUS, FRIGID TYPIC ARGIUSTOLLS	48A 49
LUMPYRIDGE	12/99	1999	6	CO		FINE-LOAMY, PARAMICACEOUS, FRIGID TYPIC ARGIUSTOLLS	48A
MAMMOTH	12/00	2000	6	CO		LOAMY-SKELETAL, PARAMICACEOUS LAMELLIC DYSTROCRYEPTS	48A
MCARTHUR	05/02	2002	4	ID		LOAMY-SKELETAL, PARAMICACEOUS, FRIGID VITRANDIC DYSTROXEREPTS	43A
MUMMY	03/06	1999	6	CO		LOAMY-SKELETAL, PARAMICACEOUS HUMIC DYSTROCRYEPTS	48A
OHMAN	12/00	2000	6	CO		LOAMY-SKELETAL, PARAMICACEOUS LAMELLIC DYSTROCRYEPTS	48A
ONAHU	12/99	1999	6	CO		LOAMY-SKELETAL, PARAMICACEOUS, ACID AERIC HUMIC CRYAQUEPTS	48A
PALBOONE	09/98	1995	6	CO		COARSE-LOAMY, PARAMICACEOUS USTIC GLOSSOCRYALFS	48A
PESMORE	02/99	1985	6	WY	UT	LOAMY-SKELETAL, PARAMICACEOUS, FRIGID TORRIORTHENTIC HAPLUSTOLLS	33 34 47
PETTINGELL	12/00	2000	6	CO		LOAMY-SKELETAL, PARAMICACEOUS USTIC HAPLOCRYOLLS	48A
POORMAN	02/03	2003	4	ID	UT	COARSE-LOAMY, PARAMICACEOUS, FRIGID ANDIC HAPLUDALFS	43A 47
PTARMIGAN	03/99	1957	6	CO		COARSE-LOAMY, PARAMICACEOUS HUMIC DYSTROCRYEPTS	45 48A

SERIES / DESCR. ESTAB.	MO	STATE / OTHER STATES USING	SOIL FAMILY / MLRAS USING
RALEIGH 05/00 1980	6	CO	LOAMY-SKELETAL, PARAMICACEOUS, SHALLOW USTIC HAPLOCRYOLLS 48A
RARICK 03/99 1975	6	CO	COARSE-LOAMY, PARAMICACEOUS HUMIC DYSTROCRYEPTS 48A 48B
RATAKE 02/99 1975	6	CO WY	LOAMY-SKELETAL, PARAMICACEOUS, FRIGID, SHALLOW TYPIC HAPLUSTOLLS 48A 48B
RESORT 09/00 1980	6	CO	SANDY-SKELETAL, PARAMICACEOUS, FRIGID, SHALLOW ENTIC HAPLUSTOLLS 48A
ROFORK 12/99 1999	6	CO	LOAMY-SKELETAL, PARAMICACEOUS, FRIGID, SHALLOW ENTIC HAPLUSTOLLS 48A
SIEBERT 02/99 1973	6	CO	LOAMY-SKELETAL, PARAMICACEOUS LAMELLIC HAPLOCRYALFS 48A 48B
SINUKTUK 06/05 2005	17	AK	LOAMY-SKELETAL, PARAMICACEOUS, SUBGELIC TYPIC EUTROGELEPTS 240
SINUKTUT 2005	17	AK	LOAMY-SKELETAL, PARAMICACEOUS, SUBGELIC TYPIC EUTROGELEPTS 240
SPRUCEDALE 09/00 1981	6	CO	LOAMY, PARAMICACEOUS, SHALLOW USTIC ARGICRYOLLS 48A
SUTTLER 12/01 1976	4	ID	COARSE-LOAMY, PARAMICACEOUS LAMELLIC DYSTROCRYEPTS 43B
TAHANA 12/00 2000	6	CO	SANDY-SKELETAL, PARAMICACEOUS USTIC EUTROCRYEPTS 48A
TIGARAHA 06/05 2005	17	AK	LOAMY-SKELETAL, PARAMICACEOUS, SUBGELIC TYPIC DYSTROGELEPTS 240
TOLLAND 12/00 2000	6	CO	SANDY-SKELETAL, PARAMICACEOUS USTIC EUTROCRYEPTS 48A
TRAILRIDGE 12/99 1999	6	CO	LOAMY-SKELETAL, PARAMICACEOUS, SHALLOW HUMIC DYSTROCRYEPTS 48A
TROUTDALE 09/00 1979	6	CO	FINE-LOAMY, PARAMICACEOUS USTIC ARGICRYOLLS 48A 48B
WATAUGA 07/01 1939	18	NC GA SC TN VA	FINE-LOAMY, PARAMICACEOUS, MESIC TYPIC HAPLUDULTS 130

Soil Family Report based on Micaceous Mineralogy

SERIES	MO	STATE	SOIL FAMILY	DESCR.	ESTAB.	OTHER STATES USING	MLRAS USING
ALBUS	2	CA	LOAMY-SKELETAL, MICACEOUS, FRIGID ULTIC HAPLOXERALFS	06/92	1984		5
CASHIERS	18	NC	FINE-LOAMY, MICACEOUS, MESIC TYPIC DYSTRUDEPTS	07/01	1990		130
CHANDLER	18	NC	COARSE-LOAMY, MICACEOUS, MESIC TYPIC DYSTRUDEPTS	07/01	1907	GA MD SC TN	130 147
CHICKAMAN	4	MT	COARSE-SILTY, MICACEOUS ANDIC DYSTROCRYEPTS	03/02	1985		43A
GROVER	14	NC	FINE-LOAMY, MICACEOUS, THERMIC TYPIC HAPLUDULTS	09/03	1951	AL GA SC VA	136
HULLS	2	CA	FINE-LOAMY, MICACEOUS, MESIC ULTIC HAPLOXEROLLS	12/71	1952		15
T KINSEYRIDGE	2	CA	LOAMY-SKELETAL, MICACEOUS, MESIC HUMIC DYSTROXEREPTS				5
T LAUADA	18	NC	FINE-LOAMY, MICACEOUS, MESIC TYPIC HAPLUDULTS	01/06		TN	130
LOUISA	14	GA	LOAMY, MICACEOUS, THERMIC, SHALLOW RUPTIC-ULTIC DYSTRUDEPTS	09/03	1909	AL NC SC VA	136
MANOR	13	MD	COARSE-LOAMY, MICACEOUS, MESIC TYPIC DYSTRUDEPTS	03/99	1900	DE NC PA VA	130 148 149A
MASTERSON	2	CA	LOAMY-SKELETAL, MICACEOUS, MESIC HUMIC DYSTROXEREPTS	07/98	1957		5
MICAVILLE	18	NC	COARSE-LOAMY, MICACEOUS, MESIC TYPIC DYSTRUDEPTS	07/01	1993		130
MOUNTAIN PARK	14	GA	FINE-LOAMY, MICACEOUS, THERMIC TYPIC HAPLUDULTS	03/06	2006	AL	
MT. AIRY	13	MD	LOAMY-SKELETAL, MICACEOUS, MESIC TYPIC DYSTRUDEPTS	01/06	1965		148
RACE	2	CA	FINE-LOAMY, MICACEOUS, FRIGID TYPIC DYSTROXEREPTS	03/01	1984		5
SODACREEK	1	WA	MEDIAL OVER LOAMY-SKELETAL, MICACEOUS TYPIC VITRICRYANDS	04/92	1995		6
SWEETAPPLE	14	GA	COARSE-LOAMY, MICACEOUS, THERMIC TYPIC DYSTRUDEPTS	07/99	1979	VA	136