Part 618 – Soil Properties and Qualities

Subpart A – General Information

618.0 Definition and Purpose

A. Soil properties are measured or inferred from direct observations in the field or laboratory. Examples of soil properties are particle-size distribution, cation-exchange capacity, and salinity.

B. Soil qualities are behavior and performance attributes that are not directly measured. They are inferred from observations of dynamic conditions and from soil properties. Examples of soil qualities are corrosivity, natural drainage, frost action, and wind erodibility.

C. Soil properties and soil qualities are the criteria used in soil interpretations, as predictors of soil behavior, and for classification and mapping of soils. The soil properties entered in the National Soil Information System (NASIS) must be representative of the soil and the dominant land use for which the interpretations are based.

618.1 Responsibilities

A. Soil property data are collected, tested, and correlated as part of soil survey operations. These data are reviewed, supplemented, and revised as necessary.

B. The soil survey office (SSO) is responsible for collecting, testing, and correlating soil property data and interpretive criteria.

C. The soil survey regional office (SSR) is responsible for the development, maintenance, quality assurance, correlation, and coordination of the collection of soil property data that are used as interpretive criteria. This includes all the data elements listed below.

D. The National Soil Survey Center (NSSC) is responsible for the training, review, and periodic update of soil interpretation technologies.

E. The State soil scientist is responsible for working with the SSR and SSO to ensure soil interpretations are adequate for the field office technical guide and they meet the needs of Federal, State, and local programs.

618.2 Collecting, Testing, and Populating Soil Property Data

A. The collection and testing of soil property data is based on the needs described in the project plans. The collection and testing should conform to the procedures and guides established in this handbook.

B. As aggregated component data, soil properties and qualities that are populated in NASIS are not meant to be site-specific. They represent the component as it occurs throughout the extent of the map unit. Most data entries are developed by aggregating information from point data (pedons) to create low, high, and representative values for the component.

C. Representative value (RV).—For newly populated information in NASIS, the representative value is used to approximate the 50th percentile (median) of a dataset. The 50th percentile is the value where 50% of the data are less than this value.

(1) Low and high values are also populated. These values are meant to convey the spread of the dataset. For example, low and high values may be the 5th and 95th percentiles, where the 5th percentile is the value where 5% of the data are below that value and the 95th percentile is the value where 5% of the data are above that value. Unlike the RV, which is solely meant to approximate the 50th percentile, the low and high values can be tailored to a particular dataset. That is, 5th, 10th, 20th, etc. and 80th, 90th, 95th, etc. can be used according to which percentiles best capture the spread of a particular dataset.

(2) The percentile approach applies only to newly populated datasets in NASIS, not previously populated datasets in NASIS.

(3) The rationale for using the percentile approach is that it provides benchmarks for the spread and central tendency for both normal and non-normal distributions. Values will always fall within the minimum and maximum of the observed dataset. The percentile approach requires a dataset of at least 5 values. For example, the L-RV-H values are shown below for a hypothetical dataset for field-described clay content from the A horizon of 11 pedons:

Clay content: 11, 10, 12, 23, 17, 16, 17, 14, 24, 22, 14
Clay content sorted: 10, 11, 12, 14, 14, 16, 17, 17, 22, 23, 24

Low/10th percentile = 11
RV/50th percentile = 16
High/90th percentile = 23

(4) Of primary importance is the empirical dataset itself regardless of established class limits, such as the particle-size classes or soil component concepts. If a dataset is small, some data points may range beyond established class limits. The representative value (RV), however, must fall within the range of the class (see section 618.3C).

(5) Soil scientists have the flexibility to modify and design new data ranges that reflect the soil component and map unit concepts based on local soil-landscape models supported by field observations, measurements, and laboratory data.

618.3 Soil Properties and Soil Qualities

A. The following sections list soil properties and qualities in alphabetical order and provide some grouping for climatic and engineering properties and classes. A definition, classes, significance, method, and guidance for NASIS database entry are given. The listing includes the soil properties and qualities in the NASIS database. For more details on the NASIS database, refer to part 639 of this handbook. For specifics on data structure, attributes, and choices in NASIS, refer to https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/tools/?cid=nrcs142p2_053552.

B. Previous databases of soil survey information used metric or English units for soil properties and qualities. Values in English units, except for crop yields, were converted into metric units during transfer into the NASIS database. All future edits and entries in NASIS, except yields and acreage, will use metric units.

C. Ranges of soil properties and qualities that are posted in the NASIS database for map unit components may extend beyond the established limits of the taxon from which the component gets its name, but only to the extent that interpretations do not change. However, the representative value (RV) is within the range of the taxon.

618.4 Albedo, Dry

A. Definition.—"Albedo, dry" is the estimated ratio of the incident shortwave (solar) radiation that is reflected by the air-dry, less than 2 mm fraction of the soil surface to that received by it.

B. Significance

(1) Soil albedo, as a function of soil color and angle of incidence of the solar radiation, depends on the inherent color of the parent material, organic matter content, and weathering conditions.
(2) Estimates of the evapotranspiration rates and predictions of soil water balances require albedo values. Evapotranspiration and soil hydrology models that are part of water quality and resource assessment programs require this information.

C. Measurement.—There are instruments that measure albedo.

D. Estimates.—Approximate the values by use of the following formula:

(1) Soil Albedo = 0.069 × (Color Value) - 0.114.
(2) For albedo, dry, use dry color value. Surface roughness has a separate significant impact on the actual albedo. The equation above is the albedo of <2.0 mm smoothed soil condition; if the surface is rough because of tillage, the albedo differs.

E. Entries.—Enter the high, low, and representative values of albedo for the map unit component. The range of valid entries is from 0 to 1, and hundredths (two decimal places) are allowed.

618.5 Artifacts in the Soil

A. Definition.—"Artifacts" are objects or materials created or modified by humans, usually for a practical purpose in habitation, manufacturing, excavation, or construction activities. Examples of artifacts include bitumen (asphalt), brick, concrete, metal, paper, plastic, rubber, and wood products. Artifacts are commonly referred to as "discrete artifacts" if they are 2 mm or larger in diameter and are not compacted into a root-limiting layer that impedes root growth or water movement.

B. Significance.—Artifacts can constitute a significant portion of the soil. The amount and type of particulate artifacts can contribute substantially to various trace metals and total carbon contents of soils. Discrete artifacts that are both cohesive and persistent, defined below, are treated in a similar manner as rock fragments when populating the standard sieves or in calculations involving sieve entries. Discrete artifacts that are noncohesive, nonpersistent, or both are not considered fragments for sieve entries or calculations involving those entries.

C. Measurement.—The fraction from ≥2 to <75 mm in diameter may be measured in the field. However, 50 to 60 kg of sample material may be necessary if there is an appreciable amount of fragments near 75 mm. An alternative means of measuring is to visually estimate the volume of the 20 to 75 mm fraction, then sieve and weigh the 2 to 20 mm fraction. The fraction 75 mm (3 inches) or greater is usually not included in soil samples taken in the field for laboratory testing. Measurements can be made in the field by weighing the dry sample and the portion retained on a 3-inch screen. The smallest dimension of discrete artifacts is used to determine whether these items pass through a sieve. The quantity is expressed as a weight percentage of the total soil. A sample as large as 200 pounds to more than a ton may be needed to assure that the results are representative. Measurements of the fraction from 75 to 250 mm (3 to 10 inches) and the fraction greater than 250 mm (10 inches) in diameter are usually obtained from volume estimates.

D. Estimates

(1) Estimates of discrete artifacts are made similarly to the way estimates of rock fragments are made. These estimates are usually made by visual means and are on the basis of percent by volume. The percent by volume is converted to percent by weight by using the average bulk unit weights for the soil and the specific artifacts. These estimates are made during investigation and mapping activities in the field. They are expressed as ranges that include the estimating accuracy as well as the range of values for a component.
(2) Treated and untreated wood products (e.g., lumber) are considered artifacts. They are not considered wood fragments such as those associated with the woody materials (e.g., tree branches) described in organic soils.
(3) Measurements or estimates of discrete artifacts less than strongly cemented are made prior to any rolling or crushing of the sample.

E. Artifact Cohesion

(1) Definition.—"Artifact cohesion" is the relative ability of the artifact to remain intact after significant disturbance.
(2) Significance.—Artifacts that break down easily are similar to pararock fragments in that these artifacts break down to become part of the fine-earth fraction of the soil. Noncohesive artifacts are excluded from entries for the standards sieves and are not used in sieve calculations.
(3) Entries.—Enter cohesive or noncohesive in the "Component Horizon Human Artifacts" and the "Pedon Horizon Human Artifacts" tables of the NASIS database. Cohesion is based on whether the artifact can be easily broken into <2 mm size pieces either in the hands or with a mortar and pestle. Artifacts that cannot easily be broken are cohesive. All others are considered noncohesive.

F. Artifact Kind

(1) Definition.—"Artifact kind" is the type of object or material being described.
(2) Significance.—Each type of artifact is associated with a combination of other property entries that is used to determine whether the artifact is considered for sieve entries and calculations. The type of artifact also gives clues to the age of the deposit as well as the potential toxicity.

(3) Entries.—Enter the artifact kind in the "Component Horizon Human Artifacts" and "Pedon Horizon Human Artifacts" tables. Enter the appropriate choice for the kind of discrete artifact from the following list:

(i) Bitumen (asphalt)
(ii) Boiler slag
(iii) Bottom ash
(iv) Brick
(v) Cardboard
(vi) Carpet
(vii) Cloth
(viii) Coal combustion by-products
(ix) Concrete
(x) Debitage
(xi) Fly ash
(xii) Glass
(xiii) Metal
(xiv) Paper
(xv) Plasterboard
(xvi) Plastic
(xvii) Potsherd
(xviii) Rubber
(xix) Treated wood
(xx) Untreated wood

G. Artifact Penetrability

(1) Definition.—"Artifact penetrability" is the relative ease with which roots can penetrate the artifact and potentially extract any stored moisture, nutrients, or toxic elements.
(2) Significance.—Artifacts that are penetrable may increase the available water-holding capacity of a soil and should be factored in such calculations. The availability of supplemental nutrients and toxic elements is also greatest in penetrable artifacts.
(3) Entries.—Enter nonpenetrable or penetrable in the "Component Horizon Human Artifacts" and "Pedon Horizon Human Artifacts" tables based on whether roots can penetrate the solid parts of the artifact or between the component parts of the artifact.

H. Artifact Persistence

(1) Definition.—"Artifact persistence" is the relative ability of solid artifacts to withstand weathering and decay over time.
(2) Significance.—Artifacts that decay quickly are similar to pararock fragments and are treated as such in sieve calculations.
(3) Entries.—Enter nonpersistent or persistent in the "Component Horizon Human Artifacts" and "Pedon Horizon Human Artifacts" tables based on whether the artifact is expected to decay in less than a decade or greater than a decade. Nonpersistent artifacts are expected to decay in less than a decade. Persistent artifacts remain intact for a decade or more.

I. Artifact Roundness

(1) Definition.—"Artifact roundness" is an expression of the sharpness of edges and corners of objects.

(2) Significance.—The roundness of artifacts impacts water infiltration, root penetration, and macropore space.

(3) Classes.—The artifact roundness classes follow those used for fragment roundness:

Figure 618-A1

Roundness Class	**Definition**
Very angular	Strongly developed faces with very sharp, broken edges.
Angular	Strongly developed faces with sharp edges (*Soil Survey Manual* (SSM)).
Subangular	Detectable flat faces with slightly rounded corners.
Subrounded	Detectable flat faces with well rounded corners (SSM).
Rounded	Flat faces absent or nearly absent with all corners rounded (SSM).
Well rounded	Flat faces absent with all corners rounded.

(4) Entries.—Enter the appropriate artifact roundness class name for the record of artifacts populated in the "Component Horizon Human Artifacts" and "Pedon Horizon Human Artifacts" tables.

J. Artifact Safety

(1) Definition.—"Artifact safety" is the degree of risk to humans from contact with soils that contain artifacts. Physical contact with soils containing dangerous or harmful artifacts should be avoided unless proper training and protective clothing is available. The risk is based on toxicity to living organisms and not the physical risk that may be present from sharp or heavy objects. Harmful toxicity may be immediate or long-term, through direct or indirect contact. Examples of innocuous artifacts include brick, concrete, glass, plastic, unprinted paper and cardboard, and untreated wood. Some examples of noxious artifacts are batteries, bitumen (asphalt), fly ash, garbage, paper printed with metallic ink, and wood treated with arsenic.

(2) Significance.—Noxious artifacts are dangerous and require special handling when sampling. Areas with noxious artifacts should have restricted human contact.

(3) Entries.—Enter innocuous or noxious in the "Component Horizon Human Artifacts" and "Pedon Horizon Human Artifacts" tables based on whether the artifacts are potentially toxic to living beings.

K. Artifact Shape

(1) Definition.—"Artifact shape" is a description of the overall shape of the object.

(2) Significance.—Artifact shape differs from rock, pararock, and wood fragment shape descriptions and is important for fluid flow in the soil as well as influencing excavation difficulty.
(3) Classes.—The artifact shape classes are: elongated, equidimensional, flat, and irregular.
(4) Entries.—Enter the appropriate artifact shape class name for each record of artifacts populated in the "Component Horizon Human Artifacts" and "Pedon Horizon Human Artifacts" tables.

L. Artifact Size

(1) Definition.—"Artifact size" is based on the cross-sectional diameter of the object.
(2) Significance.—The size of discrete artifacts is significant to the use and management of the soil. Artifact sizes ranging from 2 mm to 75 mm that are both cohesive and persistent are considered when estimating the percent passing the sieves. Artifact size affects equipment use, excavation, construction, and recreational uses.
(3) Entries.—Enter the cross-sectional diameter size of the ≥ 2 mm artifacts described in the "Component Horizon Human Artifacts" and "Pedon Horizon Human Artifacts" tables. The range of valid entries is from 2 to 3,000 millimeters, and only whole numbers (integers) are allowed.

M. Artifact Volume

(1) Definition.—"Artifact volume" is the volume percentage of the horizon occupied by the 2 mm or larger fraction (20 mm or larger for wood artifacts) on a whole soil base.
(2) Significance.—The volume occupied by discrete artifacts (2 mm or larger fraction) is important in selecting appropriate texture modifiers (i.e., artifactual, very artifactual, extremely artifactual). Some soil horizons contain combinations of artifacts and rock fragments. See section 618.72 for guidance in assigning either single (artifact only), compound (artifact and rock fragment), or dual (rock fragment-artifact) texture modifiers for horizons containing artifacts.
(3) Entries.—Enter the high, low, and representative values for the percent volume present of each size class and kind of artifact populated in the "Component Horizon Human Artifacts" and "Pedon Horizon Human Artifacts" tables. The range of valid entries is from 0 to 100 percent, and only whole numbers (integers) are allowed.

618.6 Available Water Capacity

A. Definition.—"Available water capacity" (AWC) is the volume of water that should be available to plants if the soil, inclusive of fragments, were at field capacity. It is commonly estimated as the amount of water held between field capacity and wilting point, with corrections for salinity, fragments, and rooting depth. Available water capacity is determined on each soil layer (horizon) described. AWC differs from the agronomic determination of available water supply (AWS) in that AWS is the weighted sum of AWC for each layer to a specified depth of soil.

B. Classes.—Classes of available water capacity are not normally used except as adjective ratings that reflect the sum of available water capacity in inches to some arbitrary depth. Class limits vary according to climate zones and the crops commonly grown in the areas. The depth of measurement also is variable.

C. Significance.—Available water capacity is an important soil property in developing water budgets, predicting droughtiness, designing and operating irrigation systems, designing drainage systems, protecting water resources, and predicting yields.

D. Estimates.—The most common estimates of available water capacity are made in the field or the laboratory as follows:

(1) Field capacity is determined by sampling the soil moisture content just after the soil has drained following a period of rain and humid weather, after a spring thaw, or after heavy irrigation. Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS, provides more information.
(2) The 15-bar moisture content of the samples is determined with pressure membrane apparatus.
(3) An approximation of soil moisture content at field capacity is commonly made in the laboratory using 1/3-bar moisture percentage for clayey and loamy soil materials and 1/10-bar for sandy materials. Recently, some soil physicists have been using 1/10-bar instead of 1/3-bar for clayey and loamy soil materials and 1/20-bar for sandy soil materials.
(4) Measure the bulk density of the moist soil. Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS, provides more information.
(5) Calculate available water capacity (AWC) using the following formula:

$$AWC = (W1/3 - W15) \times (Db1/3) \times Cm / 100$$

Where—

AWC = volume of water retained in 1 cm3 of whole soil between 1/3-bar and 15-bar tension; reported as cm cm^{-1} [numerically equivalent to inches of water per inch of soil (in in-1)]

W1/3 = weight percentage of water retained at 1/3-bar tension

W15 = weight percentage of water retained at 15-bar tension

Db1/3 = bulk density of <2-mm fabric at 1/3-bar tension

Cm = rock fragment conversion factor derived from: $\frac{\text{volume moist <2-mm fabric (cm3)}}{\text{volume moist whole soil (cm3)}}$

Method 3A2b is used to determine volume moist <2-mm fabric (cm^3).

AWC (cm cm^{-1} or in in^{-1} horizon) = AWC (cm cm^{-1} or in in^{-1}) × horizon thickness

(6) If data are available, estimates are based on available water capacity measurements. If data are not available, data from similar soils are used as a guide. The relationship between available water capacity and other soil properties has been studied by many researchers. Soil properties that influence available water capacity are particle size; size, shape, and distribution of pores; organic matter; type of clay mineral; and structure.
(7) If roots are excluded from a horizon such as a duripan, the amount of water available to plants is nearly zero. Available water capacity values are zero for layers that exclude roots. If roots are restricted but not excluded, estimates of available water capacity are reduced according to the amount of dense material in the layers and the space available for root penetration. Depending on the ability of roots to enter the soil mass and utilize the water, values for the soils with these dense layers may be significantly less than for soils of

similar texture that do not have pans. Entries are made for all soil layers below dense layers only if roots are present.

(8) Depending on their abundance and porosity, rock and pararock fragments reduce available water capacity. Nonporous fragments reduce available water capacity in proportion to the volume they occupy. For example, 50-percent nonporous cobbles reduce available water capacity as much as 50 percent. Porous fragments, such as sandstone, may reduce available water capacity to a lesser extent.

(9) Several factors contribute to a lower amount of plant growth on saline soils. However, as a rough guide, available water capacity is reduced by about 25 percent per 4 mmhos cm^{-1} electrolytic conductivity of the saturated extract.

(10) Soils high in gibbsite or kaolinite, such as Oxisols and Ultisols, may have available water capacity values that are about 20 percent lower than those with equal amounts of 2:1 layer-lattice clays.

(11) Soils high in organic matter have a higher available water capacity than soils low in organic matter if the other properties are the same.

E. Entries.—Enter high, low, and representative values for available water capacity in cm per cm for each horizon. Enter “0” for layers that exclude roots. The range of valid entries is from 0 to 0.7 cm per cm, and hundredths (two decimal places) are allowed.

618.7 Bulk Density, One-Third Bar

A. Definition.—“Bulk density, one-third bar” is the oven-dried weight of the less than 2 mm soil material per unit volume of soil at a water tension of 1/3 bar (33 kPa).

B. Significance.—Bulk density influences plant growth and engineering applications. It is used to convert measurements from a weight basis to a volume basis. Within a family-level particle-size class, bulk density is an indicator of how well plant roots are able to extend into the soil. Bulk density is used to calculate porosity. Bulk density at 33 kPa is used for soil classification in the required characteristics for andic soil properties and in the criteria for Andic, Aquandic, and Vitrandic subgroups.

(1) Plant Growth.—Bulk density is an indicator of how well plant roots are able to extend into the soil. Root restriction initiation and root-limiting bulk densities are shown below for various particle-size classes.

Figure 618-A2

Particle-Size Class	**Bulk Density (g cm^{-3})**	
	Restriction-Initiation	**Root-Limiting**
Sandy	1.69	>1.85
Loamy		
coarse-loamy	1.63	>1.80

Particle-Size Class	Bulk Density (g cm^{-3})	
	Restriction-Initiation	**Root-Limiting**
fine-loamy	1.60	>1.78
coarse-silty	1.60	>1.79
fine-silty	1.54	>1.65
Clayey*		
35-45% clay content	1.49	>1.58
>45% clay content	1.39	>1.47

* Soils with high iron oxide content (e.g., sesquic mineralogy) or with andic soil properties can initiate restriction at lower bulk densities.

(2) Engineering Applications.—Soil horizons with bulk densities less than those indicated below have low strength and would be subject to collapse if wetted to field capacity or above without loading. They may require special designs for certain foundations.
Figure 618-A3

Particle-Size Class	Bulk Density (g cm^{-3})
Sandy	<1.60
Loamy	
coarse-loamy	<1.40
fine-loamy	<1.40
coarse-silty	<1.30
fine-silty	<1.40
Clayey	<1.10

C. Estimates.—The weight applies to the oven-dry soil, and the volume applies to the soil at or near field capacity. Bulk density is a use-dependent property. The entry should represent the dominant use for the soil.

D. Entries.—Enter bulk density at 1/3 bar with the low, high, and representative values for each horizon. The range of valid entries is from 0.02 to 2.6 g cm^{-3}, and hundredths (two decimal places) are allowed.

618.8 Bulk Density, Oven Dry

A. Definition.—“Bulk density, oven dry” (pb_{od}) is the oven-dry weight of the less than 2 mm soil material per unit volume of oven-dry soil.

B. Estimates.—The value pb_{od} is derived by the following formula:

$pbod = [(\text{linear extensibility percent}/100) + 1]^3 \times pb0.33$ bar

Where linear extensibility percent is adjusted to a <2 mm basis.

C. Entries.—Enter the high, low, and representative values for each horizon. The range of valid entries is from 0.02 to 2.6 g cm^{-3}, and hundredths (two decimal places) are allowed.

618.9 Bulk Density, Satiated

A. Definition.—“Bulk density, satiated” (pb_{sat}) is the oven-dry weight of the less than 2 mm soil material per unit volume of soil at a water tension of 0 bar. The measurement is only used for subaqueous soils.

B. Significance.—Coastal wetland and subaqueous soils exist in their environment at saturation. Soils with very low bulk density in submerged environments often contain a large percentage of water, making them very fluid. These soil qualities are important in subaqueous soil interpretations for shellfish and rooted vegetation habitat as well as construction, dredge operations, and the calculation of carbon stocks.

C. Estimates.—The value pb_{sat} is calculated based on the dried weight of a known volume of soil at the field moisture status. Sampling methods can vary depending on environment. For samples taken as vibracores and opened by cutting, a 50-ml plastic syringe with the end removed is used to collect a mini-core. The plunger can be fixed at the 10-ml volume mark and the syringe gently pushed into the split vibracore sample to collect a known volume of sample. This technique is a variation of the field-state core method.

D. Entries.—Enter the high, low, and representative values for each horizon. The range of valid entries is from 0.02 to 2.6 g cm^{-3}, and hundredths (two decimal places) are allowed.

618.10 Calcium Carbonate Equivalent

A. Definition.—“Calcium carbonate equivalent” is the quantity of carbonate in the soil expressed as $CaCO_3$ and as a weight percentage of the less than 2 mm size fraction.

B. Significance.—The availability of plant nutrients is influenced by the amount of carbonates in the soil. This is a result of the effect that carbonates have on soil pH and of the direct effect that carbonates have on nutrient availability. Nitrogen fertilizers should be incorporated into calcareous soils to prevent nitrite accumulation or ammonium-N volatilization. The availability of phosphorus and molybdenum is reduced by the high levels of calcium and magnesium which are associated with carbonates. In addition, iron, boron, zinc, and manganese deficiencies are common in soils that have a high calcium carbonate equivalent. In some climates, soils that have a high calcium carbonate equivalent in the surface layer are subject to wind erosion. This effect may occur in soils that have a calcium carbonate equivalent of more than 5 percent. A strongly or violently effervescent reaction to cold, dilute hydrochloric acid (HCL) defines calcareous in the wind erodibility groups because of the significance of finely divided carbonates. Calcium carbonate equivalent is used for soil classification in the criteria for several diagnostic horizons (e.g., mollic epipedon), Rendolls suborder, Rendollic Eutrudepts subgroup, and carbonatic mineralogy class.

C. Measurement.—Calcium carbonate equivalent is measured by a method that uses an aqueous solution of 3 normal hydrogen chloride. The method is outlined in Soil Survey Investigations Report No. 42, *Soil Survey Laboratory Methods Manual*, Version 4.0, November 2004, USDA, NRCS. It also may be measured in the field using calcimeters.

D. Entries.—Enter the high, low, and representative values for each horizon listed. Round values to the nearest 5 percent for horizons that have more than 5 percent $CaCO_3$ and to the nearest 1 percent for those with less than 5 percent. Enter 0 if the horizon does not have free carbonates. The range of valid entries is from 0 to 110 percent, and only whole numbers (integers) are allowed.

618.11 Cation-Exchange Capacity NH_4OAc pH 7

A. Definition.—"Cation-exchange capacity" is the amount of exchangeable cations that a soil can adsorb at pH 7.0.

B. Significance.—Cation-exchange capacity is a measure of the ability of a soil to retain cations, some of which are plant nutrients. Soils that have a low cation-exchange capacity hold fewer cations and may require more frequent applications of fertilizer than soils that have a high cation-exchange capacity. Soils that have a high cation-exchange capacity have the potential to retain cations, which reduces the risk of the pollution of ground water. Cation-exchange capacity is used indirectly in soil classification, when recalculated for just the noncarbonate clay fraction, in the required characteristics for kandic and oxic horizons and as a criterion for specific subgroup taxa in Alfisols (e.g., Kandic Paleustalfs), Entisols, Inceptisols, and Mollisols. Cation-exchange capacity is also used in calculating the ratio of cation-exchange capacity to percent noncarbonate clay for classifying certain soils at the family level into cation-exchange activity classes. The latest edition of the Keys to Soil Taxonomy has more information on applying this ratio in classification.

C. Measurement.—Cation-exchange capacity is measured by the methods outlined in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS. The ammonium acetate method gives the cation-exchange capacity value (CEC-7) for soils that have pH >5.5 or contain soluble salts. This method uses a solution of one normal ammonium acetate buffered at pH 7.0 to provide the extracting index cation (NH_4^+). Cation-exchange capacity is reported, on a <2 mm base, in centimoles per kilogram (cmol(+) kg^{-1}), which are equivalent to milliequivalents per 100 grams (meq 100 g^{-1}) of fine-earth soil. If the pH is less than 5.5, use effective cation-exchange capacity (refer to section 618.20).

D. Entries.—Enter the high, low, and representative values of the estimated range in cation-exchange capacity, in meq 100 g^{-1}, for each horizon with pH >5.5. The range of valid entries is from 0 to 400 meq 100 g^{-1}, and tenths (one decimal place) are allowed. A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.99.

618.12 Climatic Setting

A. Climatic setting includes frost-free period, precipitation, temperature, and evaporation. These elements are useful in determining the types of natural vegetation or crops that grow or can grow in an area and in planning management systems for vegetation.

(1) Climatic data are observed nationally by the National Weather Service Cooperative Network, which consists of approximately 10,000 climate stations. The records are available from the Climatic Data Access Facility (CDAF) at Portland, Oregon.
(2) Climatic data are delivered to the field through the Climatic Data Access Network. The Climatic Data Access Network consists of climatic data liaisons established in each State and at National Headquarters.
(3) Climatic data that are input into NASIS are obtained from the respective climatic data liaison. Climatic data may also be obtained from project weather stations or from the State climatologist. NRCS has selected the current standard "normal" period of 1971 to 2000 for climate database entries. Existing entries in the NASIS database may reflect the prior period of 1961 to 1990. Always check with your State's climatic data liaison before using a climate station that has less than 30 years of records or that is located outside a county. Footnote the source of the data, the station, and the starting and ending year of record. Means are given as a range to represent the change of the climate over the geographic extent of the assigned soil.

B. Frost-Free Period

(1) Definition.—"Frost-free period" is the expected number of days between the last freezing temperature (0 °C) in spring (January-July) and the first freezing temperature (0 °C) in fall (August-December). The number of days is based on the probability that the values for the standard "normal" period will be exceeded in 5 years out of 10.
(2) Entries.—Enter the high, low, and representative values for the map unit component. Enter 365 for each value for taxa that are frost-free all year and 0 for those that have no frost-free period. Entries are rounded to the nearest 5 days.

C. Precipitation, Mean Annual

(1) Definition.—"Mean annual precipitation" is the arithmetic average of the total annual precipitation taken over the standard "normal" period. Precipitation refers to all forms of water, liquid or solid, that fall from the atmosphere and reach the ground.
(2) Entries.—Enter the high, low, and representative values in millimeters of water to represent the spatial range for the map unit component. The range of valid entries is from 0 to 11,500 mm, and only whole numbers (integers) are allowed.

D. Air Temperature, Mean Annual

(1) Definition.—"Mean annual air temperature" is the arithmetic average of the daily maximum and minimum temperatures for a calendar year taken over the standard "normal" period.
(2) Entries.—Enter the high, low, and representative values for the map unit component to represent the spatial range in degrees Celsius (centigrade). The range of valid entries is from -50.0 to 50.0 degrees, and tenths (one decimal place) are allowed. Use a minus sign to indicate temperatures below zero.

E. Daily Average Precipitation

(1) Definition.—"Daily average precipitation" is the total precipitation for the month divided by the number of days in the month for the standard "normal" period.
(2) Entries.—Enter the high, low, and representative values, in millimeters. The range of valid entries is from 0 to 750 mm. Record values to the nearest whole number (integer).

F. Daily Average Potential Evapotranspiration

(1) Definition.—"Daily average potential evapotranspiration" is the total monthly potential evapotranspiration divided by the number of days in the month for the standard "normal" period.
(2) Entries.—Enter the high, low, and representative values for daily average potential evapotranspiration in millimeters. The range of valid entries is 0 to 300 mm. Record values to the nearest whole number (integer).

618.13 Continuous Inundation Class, Depth, and Month

A. Free water may occur above the soil. Inundation is the condition when the soil is covered by liquid, free water.

B. Definition.—Continuous inundation is permanent or nearly permanent standing water in a basin or closed depression. This includes depressions, lakes, ponds, estuaries, and seas that are inundated for extended periods with very few or no periods when the soil is not covered with water. The inundation is considered permanent, not temporal, with water on the surface more than 21 hours of each day in all years. The water is removed only by deep percolation, transpiration, evaporation, tidal flows, or by a combination of these processes. Continuous inundation is populated with the frequency of "permanent" in the "Component" table in NASIS. In the "Component month" table, the monthly probability in which standing water occurs, monthly duration, depth of inundation above the soil, and water kind are populated.

C. Continuous Inundation Frequency

"Continuous inundation frequency" is always "permanent" since the soil is nearly permanently or permanently covered with water in every month and every day.

D. Continuous Inundation Monthly Probability

"Continuous inundation month" is the calendar months in which inundation is expected, which is all 12 months since the inundation is permanent or nearly so. The monthly probability class is "extremely high" for all 12 months.

E. Duration Class

(1) "Continuous inundation duration class" is the duration of inundation, which is "constant" for all 12 months because the soils is covered with water every month and every day or almost every day of the year.
(2) Classes.—The continuous inundation duration class is defined below:

Figure 618-A4

Continuous Inundation Duration Class	Duration
Constant	More than 21 hours of each day in all years or almost every day in all years

F. Kind

(1) Definition.—The kind of free water above the soil may be classified as fresh or brackish water.
(2) Entries and classes.—Three classes are entered in the "Component month" table for each month and may vary depending on the time of year. The classes are defined below:

Figure 618-A5

Continuous Inundation Kind	Definition
Fresh water	Water has electrical conductivity < 0.6 dS/m.
Brackish water	Water has electrical conductivity of ≥ 0.6 dS/m.
Not assigned	This entry is used if kind is unknown.

G. Depth of Inundation

(1) Definition.—"Depth of inundation" is the depth of the surface water that continuously covers the soil.
(2) Entries.—Enter the high, low, and representative values for the depth, in centimeters, for the map unit component. The range of valid entries is 0 to 300 cm, and only whole numbers (integers) are allowed. Depth entries may vary by month if findings support it.

H. Significance.—Continuous inundation is an important concern in designs for all kinds of uses. The depth of the water covering the soils is a critical factor in determining plant and animal species.

618.14 Corrosion

A. Various metals and other materials corrode when they are on or in the soil, and some metals and materials corrode more rapidly when in contact with specific soils than when in contact with others. Corrosivity ratings are given for two of the common structural materials, uncoated steel and concrete.

B. Uncoated steel

(1) Definition.—"Risk of corrosion for uncoated steel" is the susceptibility of uncoated steel to corrosion when in contact with the soil.
(2) Classes.—The classes for risk of corrosion to uncoated steel are: low, moderate, and high.
(3) Significance.—Risk of corrosion to uncoated steel pertains to the potential soil-induced electrochemical or chemical action that converts iron into its ions, thereby dissolving or weakening uncoated steel.
(4) Guides.—Part 618, subpart B, section 618.80, gives the relationship of soil water, general texture group, acidity, and content of soluble salts (as indicated by either electrical resistivity at field capacity or electrolytic conductivity of the saturated extract of the soil) to corrosion classes.
  (i) Soil reaction (pH) correlates poorly with corrosion potential; however, a pH of 4.0 or less almost always indicates a high corrosion potential.
  (ii) Ratings, which are based on a single soil property or quality, that place soils in relative classes for corrosion potential must be tempered by knowledge of other properties and qualities that affect corrosion. A study of soil properties in relation to local experiences with corrosion helps soil scientists and engineers to make soil interpretations. Special attention must be given to those soil properties that affect the access of oxygen and moisture to the metal, the electrolyte, the chemical reaction in the electrolyte, and the flow of current through the electrolyte. Special attention must be given to the presence of sulfides or of minerals, such as pyrite, that can be weathered readily and thus cause a high degree of corrosion in metals.
  (iii) The possibility of corrosion is greater for extensive installations that intersect soil boundaries or soil horizons than for installations that are in one kind of soil or in one soil horizon.
  (iv) Using interpretations for corrosion without considering the size of the metallic structure or the differential effects of using different metals may lead to wrong conclusions. Activities that alter the soil, such as construction, paving, fill and compaction, and surface additions, can increase the possibility of corrosion by creating an oxidation cell that accelerates corrosion. Mechanical agitation or excavation that results in aeration and in a discontinuous mixing of soil horizons may also increase the possibility of corrosion.
(5) Entries.—Enter the appropriate class of risk of corrosion for uncoated steel for the whole map unit component. The classes are: low, moderate, and high.

C. Concrete

(1) Definition.—"Risk of corrosion for concrete" is the susceptibility of concrete to corrosion when in contact with the soil.
(2) Classes.—The classes for risk of corrosion to concrete are: low, moderate, and high.
(3) Significance.—Risk of corrosion to concrete pertains to the potential soil-induced chemical reaction between a base (the concrete) and a weak acid (the soil solution). Special cements and methods of manufacturing may be used to reduce the rate of deterioration in soils that have a high risk of corrosion. The rate of deterioration depends on soil texture and acidity; the amount of sodium or magnesium sulfate present in the soil, singly or in combination; and the amount of sodium chloride (NaCl) present in the soil. The presence of NaCl is evaluated because it is used to identify the presence of seawater, rather than because of its corrosive effects on concrete. Seawater contains sulfates, which are one of the principal corrosive agents. A soil that has gypsum or other sulfate minerals

requires a special cement in the concrete mix. The calcium ions in gypsum react with the cement and weaken the concrete.

(4) Guides.—Part 618, subpart B, section 618.81, gives the relationship of soil texture, soil acidity, sulfates, and NaCl to corrosion classes.

(5) Entries.—Enter the appropriate class of risk of corrosion for concrete for the whole map unit component (i.e., low, moderate, or high).

618.15 Crop Name and Yield

A. Definition.—"Crop name" is the common name for the crop. "Crop yield" is crop yield units per unit area for the specified crop.

B. Classes.—The crop names and the units of measure for yields that are allowable as data entries are listed in the NASIS data dictionary. See part 618, subpart B, section 618.82, for the web address of the current NASIS data dictionary.

C. Significance.—Crop names and units of measure are important as records of crop yield. Although the crops and yield often are specific to the time when the soil survey was completed, the ranking and comparison between soils within a soil survey are helpful. These crop and yield data are used to evaluate the soil productive capabilities, cash rent, and land values. Generally, only the most important crops are listed and only the best management is reflected.

D. Estimates

(1) Crop names and yields are specific to the soil survey area. Although the listing of crop names is not limited to any number, only the most important crops in the survey area should be used. The yields are derived in a number of ways but should represent a high level of management by leading commercial farmers, which tends to produce the highest economic return per acre. This level of management includes using the best varieties; balancing plant populations and added plant nutrients to the potential of the soil; controlling erosion, weeds, insects, and diseases; maintaining optimum soil tilth; providing adequate soil drainage; and ensuring timely operations.

(2) Generally, only a representative value is used for each map unit component for non-MLRA soil survey areas. MLRA soil survey areas use the high and low representative values from map unit components of non-MLRA soil survey areas. High and low values represent the range of representative values for a high level of management across the survey area or across several survey areas.

E. Entries.—Enter the common crop name and units of measure. Enter the corresponding irrigated yields, nonirrigated yields, or both, as appropriate for the component. Yields can be posted as high, low, and representative values for the map unit component.

618.16 Diagnostic Horizon Feature – Depth to Bottom

A. Definition.—The diagnostic horizon feature "depth to bottom" is the distance from the top of the soil to the base of the identified diagnostic horizon or to the lower limit of the occurrence of the diagnostic feature.

B. Measurement.—Distance is measured from the top of the soil, which is defined as the top of the mineral soil, or, for soils with "O" horizons, the top of any organic layer that is at least slightly decomposed. For soils that are covered by 80 percent or more rock or pararock fragments, the top of the soil is the mean height of the top of the fragments. See chapter 3 in the *Soil Survey Manual* for a complete discussion.

C. Entries.—The values for the diagnostic horizon feature "depth to bottom" used to populate component data in NASIS are not specific to any one point; they are a reflection of commonly observed values based on field observations and are intended to model the component as it occurs throughout the map unit. Enter the high, low, and representative values in whole centimeters. The high value represents either the greatest depth to which the base of the diagnostic horizon or feature extends or, for horizons for features extending beyond the limit of field observation, is the depth to which observation was made (usually no more than 200 cm). In the case of lithic contact, paralithic contact, and petroferric contact, the entries for depth to the bottom of the diagnostic feature will be the same as the entries for depth to the top of the feature, since the contact has no thickness.

618.17 Diagnostic Horizon Feature – Depth to Top

A. Definition.—The diagnostic horizon feature "depth to top" is the distance from the top of the soil to the upper boundary of the identified diagnostic horizon or to the upper limit of the occurrence of the diagnostic feature.

B. Measurement.—Distance is measured from the top of the soil, which is defined as the top of the mineral soil, or, for soils with "O" horizons, the top of any organic layer that is at least slightly decomposed. For soils that are covered by 80 percent or more rock or pararock fragments, the top of the soil is the mean height of the top of the fragments. See chapter 3 in the *Soil Survey Manual* for a complete discussion.

C. Entries.—The values for the diagnostic horizon feature "depth to top" used to populate component data in NASIS are not specific to any one point; they are a reflection of commonly observed values based on field observations and are intended to model the component as it occurs throughout the map unit. Enter the high, low, and representative values in whole centimeters.

618.18 Diagnostic Horizon Feature – Kind

A. Definition.—The diagnostic horizon feature "kind" is the kind of diagnostic horizon or diagnostic feature present in the soil.

B . Significance.—Diagnostic horizons and features are a particular set of observable or measurable soil properties, defined in Soil Taxonomy, that are used to classify a soil. They have been chosen because they are thought to be the marks left on the soil as a result of the dominant soil-forming processes. In many cases, they are thought to occur in conjunction with other important accessory properties. The utilization of diagnostic horizons and features in the classification process allows the grouping of soils that have formed because of similar genetic processes. The grouping, however, is done based on observable or measurable properties rather than by speculation about the genetic history of a particular soil.

C. Entries.—The diagnostic horizons and features are listed in the latest edition of the *Keys to Soil Taxonomy*. Allowable terms are given in the NASIS data dictionary.

618.19 Drainage Class

A. Definition.—“Drainage class” identifies the natural drainage condition of the soil. It refers to the frequency and duration of wet periods.

B. Classes.—The eight natural drainage classes are listed below. Chapter 3 of the *Soil Survey Manual* provides a description of each natural drainage class.

(1) Excessively drained
(2) Somewhat excessively drained
(3) Well drained
(4) Moderately well drained
(5) Somewhat poorly drained
(6) Poorly drained
(7) Very poorly drained
(8) Subaqueous

C. Significance.—Drainage classes provide a guide to the limitations and potentials of the soil for field crops, forestry, range, wildlife, and recreational uses. The class roughly indicates the degree, frequency, and duration of wetness, which are factors in rating soils for various uses.

D. Estimates.—Infer drainage classes from observations of landscape position and soil morphology. In many soils the depth and duration of wetness relate to the quantity, nature, and pattern of redoximorphic features. Correlate drainage classes and redoximorphic features through field observations of water tables, soil wetness, and landscape position. Record the drainage classes assigned to the series.

E. Entries.—Enter the drainage class name for each map unit component. Use separate map unit components for different drainage class phases or for drained versus undrained phases, where needed.

618.20 Effective Cation-Exchange Capacity

A. Definition.—“Effective cation-exchange capacity” is the sum of ammonium acetate extractable bases plus potassium chloride extractable aluminum (if present). Effective cation-exchange capacity may also be determined as a direct measurement using NH_4Cl.

B. Significance.—Cation-exchange capacity (CEC) is a measure of the ability of a soil to retain cations, some of which are plant nutrients. Soils that have a low cation-exchange capacity hold fewer cations and may require more frequent applications of fertilizer and amendments than soils that have a high cation-exchange capacity. Effective CEC (ECEC) is a measure of CEC that is particularly useful in soils whose ion-exchange capacity is largely a result of variable charge components, such as allophane, imogolite, kaolinite, halloysite, hydrous iron and aluminum oxides, and organic matter. As a result, the CEC of these soils is not a fixed number but is a function of pH. Examples of taxa commonly displaying pH-dependent charge include some Andisols, Histosols, acidic Inceptisols, Oxisols, Spodosols, and weathered Ultisols with kaolinitic or halloysitic mineralogies dominated by iron and aluminum oxyhydroxide minerals.

C. Measurement.—Effective cation-exchange capacity is calculated from the analytical results of two separate laboratory methods. One method measures the basic cations (Ca2+, Mg2+, Na+, K+) extractable in a solution of one normal ammonium acetate buffered at pH 7.0. Another method measures the aluminum extractable in a solution of one normal potassium chloride (for soil horizons with a 1:1 water pH of 5.5 or less). The ECEC value is then calculated and reported for soil horizons that have pH 5.5 or less and that are low in soluble salts. For soils that have a pH of >5.5, the ECEC usually equals only the sum of the NH_4OAc extractable bases. Manual ECEC population in NASIS for soil horizons with pH values between 5.6 and 7.0 is optional and is only needed if there is a significant difference from the populated CEC values (based on NH_4OAc buffered at pH 7.0).

(1) An alternate procedure exists to measure ECEC. It involves a direct measurement by using a neutral unbuffered salt (NH_4Cl) and is an analytically determined value. For a soil with a pH of less than 7.0 (in water, 1:1), the ECEC value should be less than the CEC value measured with a buffered solution at pH 7.0. The ECEC by NH_4Cl is equal to the NH_4OAc extractable bases plus the KCl extractable Al for noncalcareous soils. For more discussion on ECEC, see Soil Soil Survey Investigations Report No. 45, Soil Survey Laboratory Information Manual, Version 2.0, February 2011, USDA, NRCS.

(2) The laboratory methods for both the standard and alternate procedures are outlined in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS.

(3) Effective cation-exchange capacity is reported, on a <2 mm base, in centimoles per kilogram (cmol(+) kg^{-1}) of soil, which are equivalent to milliequivalents per 100 grams (meq 100 g^{-1}) of fine-earth soil.

D. Entries.—Enter the high, low, and representative values of the estimated range in effective cation-exchange capacity at the field pH of the soil, in meq 100 g^{-1}, for the horizon. The range of valid entries is from 0 to 400 meq 100 g^{-1}, and tenths (one decimal place) are allowed. A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.100.

618.21 Electrical Conductivity

A. Definition.—"Electrical conductivity" is the electrolytic conductivity of an extract from saturated soil paste.

B. Classes.—The classes of salinity are listed below:

Figure 618-A6

Salinity Class	**Electrical Conductivity (mmhos cm^{-1})**
Nonsaline	0-2
Very slightly saline	>2-4
Slightly saline	>4-8
Moderately saline	>8-16
Strongly saline	>16

C. Significance.—Electrical conductivity is a measure of the concentration of water-soluble salts in soils. It is used to indicate saline soils. High concentrations of neutral salts, such as sodium chloride and sodium sulfate, may interfere with the absorption of water by plants because the osmotic pressure in the soil solution is nearly as high as or higher than that in the plant cells. Salts may also interfere with the exchange capacity of nutrient ions, thereby resulting in nutritional deficiencies in plants. Electrical conductivity in the extract from a saturated paste is used for soil classification in the required characteristics for the salic horizon and in criteria for certain taxa such as Dystric great groups and Halic subgroups of Vertisols.

D. Measurement.—The electrolytic conductivity of a saturated extract is the standard measure used to express salinity. Units of measure are decisiemens per meter (dS m^{-1}), which are equivalent to millimhos per centimeter (mmhos cm^{-1}), at 25 degrees C. The laboratory procedure used to measure electrical conductivity is described in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS.

E. Estimates.—Field estimates of salinity are made from observations of visible salts on faces of peds, throughout the horizon matrix, on the soil surface, or some combination of the three; from plant growth or productivity; from the presence of native plant indicator species; and from field salinity meters. The occurrences of bare spots, salt-tolerant plants, and uneven crop growth are used as indicators of salinity and high electrical conductivity. When keyed to measurements, these observations help to estimate the amount of salts.

F. Entries.—Enter the high, low, and representative values for the range of electrolytic conductivity of the saturation extract during the growing season for each horizon. If laboratory measurements or accurate field estimates are available, the high and low values do not need to correspond with salinity class limits. However, if data is limited, use the following ranges to represent the high and low values of the salinity classes: 0-2, 2-4, 4-8, 8-16, and 16-32 (or a reasonable high value for the strongly saline class) or use a combination of classes (for example, 2-8 for the high and low values). The range of valid entries is from 0 to 15000 mmhos cm^{-1}, and tenths (one decimal place) are allowed.

648.22 Electrical Conductivity 1:5 (volume)

A. Definition.—"Electrical conductivity 1:5 (volume)" is the electrolytic conductivity of of a diluted, unfiltered supernatant of 1 part soil to 5 parts distilled water as measured by volume. The measurement is only used for subaqueous soils.

B. Classes.—See the salinity classes described above in "Electrical Conductivity" (section 618.21). The traditional salinity classes were designed as phase criteria for terrestrial soils and are not applicable to subaqueous soils.

C. Significance.—Electrical conductivity (EC) 1:5 (volume) is a measure of the concentration of water-soluble salts in soils. It is used to indicate the threshold between freshwater and salt and brackish water subaqueous soils. Measuring EC in this manner is the best approach for subaqueous soils as samples containing reduced sulfide must be kept moist to avoid oxidation and production of sulfate salts that can increase the electrical conductivity. Salinity tolerance in plants is a measure of diminished plant growth at a threshold of 10-percent reduction in biomass. This is not the same as the maximum salinity tolerance which is an LD50 response. Electrical conductivity 1:5 (volume) is used for soil classification in the criteria for the Frasiwassents and Frasiwassists great groups.

D. Measurement.—EC 1:5 (volume) measured in an unfiltered supernatant is the standard measure used to express salinity in subaqueous soils. EC 1:5 (volume) must be measured in a fresh, field wet sample (moisture content at sample collection) that has been refrigerated or even frozen because sulfides may oxidize during drying and form sulfate salts, which can increase the EC value. This method assumes that the salts in subaqueous soils are highly soluble chloride and sulfate salts, in a dissolved state, with no important contributions from minerals such as gypsum. Units of measure are decisiemens per meter (dS m^{-1}), at 25 degrees C. The laboratory procedure used to measure electrical conductivity is described in an addendum to the Soil Survey Investigations Report No. 51, Soil Survey Field and Laboratory Methods Manual, Version 2.0, 2014, USDA, NRCS.

E. Estimates.—Field estimates of salinity are made for subaqueous soils from observations of the presence of native plant indicator species and from measuring the water column with field salinity refractometers. Caution should be used in comparing water column salinity to soil salinity. Ground water discharge can decrease soil salinity, and seasonal evaporation of seawater in barrier salt marshes can produce brine that sinks through the ground water to collect in subsurface coarse-textured lenses. Salinity distributions in mainland-associated soils tend to have a systematic decrease with depth while salinity in other subaqueous soils remain high with depth.

F. Entries.—Enter the high, low, and representative values for the range of electrolytic conductivity 1:5 (volume) of the unfiltered supernatant for each horizon. The range of valid entries is from 0 to 100 dS m^{-1}, and tenths (one decimal place) are allowed.

618.23 Elevation

A. Definition.—"Elevation" is the vertical distance from mean sea level to a point on the Earth's surface.

B. Significance.—Elevation, or local relief, influences the genesis of natural soil bodies. Elevation also may affect soil drainage within a landscape, salinity or sodicity within a climatic area, or soil temperature.

C. Estimates.—Elevation is normally obtained from U.S. Geological Survey topographic maps or measured using altimeters or global positioning systems.

D. Entries.—Enter the high, low, and representative values for elevation in meters for each map unit component. The range of valid entries is from -300 to 8550 meters, and tenths (one decimal place) are allowed.

618.24 Engineering Classification

A. AASHTO Group Classification

(1) Definition.—"AASHTO group classification" is a system that classifies soils specifically for geotechnical engineering purposes that are related to highway and airfield construction. It is based on particle-size distribution and Atterberg limits, such as liquid limit and plasticity index. This classification system is covered in Standard No. M 145-82, published by the American Association of State Highway and Transportation Officials (AASHTO), and consists of a symbol and a group index. The classification is based on that portion of the soil that is smaller than 3 inches in diameter.

(2) Classes.—The AASHTO classification system identifies two general classifications: granular materials having 35 percent or less, by weight, particles smaller than 0.074 mm in diameter and silt-clay materials having more than 35 percent, by weight, particles smaller than 0.074 mm in diameter. These two divisions are further subdivided into seven main group classifications. Part 618, subpart B, section 618.83, shows the criteria for classifying soil in the AASHTO classification system. The group and subgroup classifications are based on estimated or measured grain-size distribution and on liquid limit and plasticity index values.

(3) Significance.—The group and subgroup classifications of this system aid in the evaluation of soils for highway and airfield construction. The classifications can help to make general interpretations relating to performance of the soil for engineering uses, such as highways and local roads and streets.

(4) Measurements.—Measurements involve sieve analyses for the determination of grain-size distribution of that portion of the soil between a 3 inch and 0.074 mm particle size. ASTM Designations D 422, C 136, and C 117 have applicable procedures for the determination of grain-size distribution. The liquid limit and plasticity index values (ASTM Designation D 4318) are determined for that portion of the soil having particles smaller than 0.425 mm in diameter (no. 40 sieve). Measurements, such as laboratory tests, are made on most benchmark soils and on other representative soils in survey areas.

(5) Estimates.—During soil survey investigations and field mapping activities, the soil is classified by field methods. This classification involves making estimates of particle-size fractions by a percentage of the total soil, minus the greater-than-3-inch fraction. Estimates of liquid limit and plasticity index are based on clay content and mineralogy relationships. Estimates are expressed in ranges that include the estimating accuracy as well as the range of values for the taxon.

(6) Entries.—Enter classes and separate them by commas for each horizon, for example, A-7, A-6. The acceptable entries for AASHTO group are A-1, A-l-a, A-l-b, A-2, A-2-4, A-2-5, A-2-6, A-2-7, A-3, A-4, A-5, A-6, A-7, A-7-5, A-7-6, and A-8.

B. AASHTO Group Index

(1) Definition.—The AASHTO group and subgroup classifications may be further modified by the addition of a group index value. The empirical group index formula was devised for approximate within-group evaluation of the "clayey granular" materials and the "silty-clay" materials.
(2) Significance.—The group index aids in the evaluation of the soils for highway and airfield construction. The index can help to make general interpretations relating to performance of the soil for engineering uses, such as highways and local roads and streets.
(3) Measurement.—The group index (GI) is calculated from an empirical formula:

$$GI = (F-35)\,[0.2 + 0.005\,(LL-40)] + 0.01\,(F-15)\,(PI-10)$$

Where—

F = percentage passing sieve No. 200 (75 micrometer), expressed as a whole number LL = liquid limit

PI = plasticity index

In calculating the group index of A-2-6 and A-2-7 subgroups, only the PI portion of the formula is used.

(4) Entries.—The group index is reported to the nearest integer. If the calculated group index is negative, the group index value is zero. The minimum group index value is 0, and the maximum is 120. A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.98.

C. Unified Soil Classification

(1) Definition.—The Unified soil classification is a system that classifies mineral and organic mineral soils for engineering purposes based on particle-size characteristics, liquid limit, and plasticity index.
(2) Classes
   (i) The Unified soil classification system identifies three major soil divisions:
      - Coarse-grained soils having less than 50 percent, by weight, particles smaller than 0.074 mm in diameter.
      - Fine-grained soils having 50 percent or more, by weight, particles smaller than 0.074 mm in diameter.
      - Highly organic soils that demonstrate certain organic characteristics. These divisions are further subdivided into a total of 15 basic soil groups.
   (ii) The major soil divisions and basic soil groups are determined on the basis of estimated or measured values for grain-size distribution and Atterberg limits. ASTM Designation D 2487 shows the criteria chart used for classifying soil in the Unified system, the 15 basic soil groups of the system, and the plasticity chart for the system.
(3) Significance.—The various groupings of this classification have been devised to correlate in a general way with the engineering behavior of soils. This correlation provides a useful first step in any field or laboratory investigation for engineering purposes. It can be used to

make some general interpretations relating to probable performance of the soil for engineering uses.

(4) Measurement.—The methods for measurement are provided in ASTM Designation D 2487. Measurements involve sieve analysis for the determination of grain-size distribution of that portion of the soil between 3 inches and 0.074 mm in diameter (no. 200 sieve). ASTM Designations D 422, C 136, and C 117 have applicable procedures that are used, where appropriate, for the determination of grain-size distribution. Values for the Atterberg limits (liquid limit and plasticity index) are also used. Specific tests are made for that portion of the soil having particles smaller than 0.425 mm in diameter (no. 40 sieve) according to ASTM Designations D 423 and D 424. Measurements, such as laboratory tests, are made on most benchmark soils and on other representative soils in survey areas.

(5) Entries for Measured Data.—For measured Unified data, enter up to four classes for each horizon. ASTM Designation D 2487 provides flow charts for classifying the soils. Separate the classes by commas, for example, CL-ML, ML. Acceptable entries are: GW, GP, GM, GC, SW, SP, SM, SC, CL, ML, OL, CH, MH, OH, PT, CL-ML, GW-GM, GW-GC, GP-GM, GP-GC, GC-GM, SW-SM, SW-SC, SP-SM, SP-SC, and SC-SM.

(6) Estimates.—The methods for estimating are provided in ASTM Designation D 2488. During all soil survey investigations and field mapping activities, the soil is classified by field methods. The methods include making estimates of particle-size fractions by a percentage of the total soil. The Atterberg limits are also estimated based on the wet consistency, ribbon or thread toughness, and other simple field tests. These tests and procedures are explained in ASTM Designation D 2488. If samples are later tested in the laboratory, adjustments are made to field procedures as needed. Estimates are expressed in ranges that include the estimating accuracy as well as the range of values from one location to another within the map unit. If an identification is based on visual-manual procedures, it must be clearly stated so in reporting.

(7) Entries for Estimated Soils.—For estimated visual-manual Unified data, enter up to four classes for each horizon. ASTM Designation D 2488 provides flow charts for classifying the soils. Separate the classes by commas, for example, CL, ML, SC. Acceptable entries are: GW, GP, GM, GC, SW, SP, SM, SC, CL, ML, OL, CH, MH, OH, PT, CL-ML, GW-GM, GW-GC, GP-GM, GP-GC, GC-GM, SW-SM, SW-SC, SP-SM, SP-SC, and SC-SM.

618.25 Erosion Accelerated, Kind

A. Definition.—“Erosion accelerated, kind” is the type of detachment and removal of surface soil particles that is largely affected by human activity.

B. Significance.—The type of accelerated erosion is important in assessing the current health of the soil and in assessing its potential for different uses. Erosion, whether natural or induced by humans, is an important process that affects soil formation and may remove all or parts of the soils formed in the natural landscape.

C. Classes.—There are five kinds of accelerated erosion:

(1) Water erosion, sheet
(2) Water erosion, rill
(3) Water erosion, gully
(4) Water erosion, tunnel

(5) Wind erosion

D. Entries.—Enter the appropriate class for each map unit component. Multiple entries are allowable, but a representative value should be indicated.

618.26 Erosion Class

A. Definition.—“Erosion class” is the class of accelerated erosion.

B. Significance

(1) The degree of erosion that has taken place is important in assessing the health of the soil and in assessing the soil’s potential for different uses. Erosion is an important process that affects soil formation and may remove all or parts of the soils formed in natural landscapes.
(2) Removal of increasing amounts of soil increasingly alters various properties and capabilities of the soil. Properties and qualities affected include bulk density, organic matter content, tilth, and water infiltration. Altering these properties affects the productivity of the soil.

C. Estimates.—During soil examinations, estimate the degree to which soils have been altered by accelerated erosion. The *Soil Survey Manual* describes the procedures involved.

D. Classes.—There are five erosion classes:

(1) None – deposition
(2) Class 1
(3) Class 2
(4) Class 3
(5) Class 4

E. Entries.—Enter the appropriate class for each map unit component.

618.27 Excavation Difficulty Classes

A. Definition.—“Excavation difficulty classes” are used for soil layers, horizons, pedons, or geologic layers and estimate the difficulty of making an excavation into them. Excavation difficulty, in most instances, is strongly controlled by water state, which should be specified.

B. Classes.—The excavation difficulty classes are defined below:

Figure 618-A7

Class	Definition
Low	Excavations can be made with a spade using arm-applied pressure only. Neither application of impact energy nor application of pressure with the foot to a spade is necessary.

Class	Definition
Moderate	Arm-applied pressure to a spade is insufficient. Excavation can be accomplished quite easily by application of impact energy with a spade or by foot pressure on a spade.
High	Excavation with a spade can be accomplished with difficulty. Excavation is easily possible with a full-length pick, using an over-the-head swing.
Very high	Excavation with a full-length pick, using an over-the-head swing, is moderately to markedly difficult. Excavation is possible in a reasonable period of time with a backhoe mounted on a 40 to 60 kW (50-80 hp) tractor.
Extremely high	Excavation is nearly impossible with a full-length pick using an over-the-head arm swing. Excavation cannot be accomplished in a reasonable time period with a backhoe mounted on a 40 to 60 kW (50-80 hp) tractor.

C. Significance.—Excavation difficulty classes are important for evaluating the cost and time needed to prepare shallow excavations.

D. Estimates.—Estimates of excavation difficulty classes are made from field observations.

E. Entries.—Enter the appropriate class for each horizon. The allowable entries are: low, moderate, high, very high, and extremely high.

618.28 Exchangeable Sodium

A. Definition.—“Exchangeable sodium” is a measure of soil exchangeable sodium ions that may become active by cation exchange. It is the fraction of the cation-exchange capacity of a soil that is occupied by sodium ions, expressed as a percentage.

B. Significance.—Exchangable sodium percentage (ESP) is used for soil classification in the required characteristics for the natric horizon, in the key to soil orders and key to suborders of Inceptisols and Mollisols, and in criteria for certain taxa such as Sodic subgroups. Soils that have values for exchangeable sodium of 15 percent or more may have an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity and aeration, and a general degradation of soil structure.

C. Measurement.—The ESP is calculated by several methods which use the results of separate procedures to measure the sodium extractable by NH_4OAc and the cation-exchange capacity by NH_4OAc, pH 7.0 (CEC-7) as outlined in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS. Units of measure for extractable sodium and cation-exchange capacity are centimoles per kilogram (cmol(+) kg^{-1}) of soil, which are equivalent to milliequivalents per 100 grams (meq 100 g^{-1}) of soil. In some soils with high salt content (i.e., >20 dS m^{-1}) the ESP is calculated using the sodium extractable by NH_4OAc, the cation-exchange capacity by NH_4OAc, pH 7.0 (CEC-7), the water saturation percentage, and the water-soluble sodium (mmol (+) L^{-1}).

D. Entries.—Enter high, low, and representative values as percentages for each horizon for which data is available. The range of valid entries is from 0 to 100 percent, and only whole numbers (integers) are allowed.

618.29 Extractable Acidity

A. Definition.—"Extractable acidity" is a measure of soil exchangeable hydrogen ions that may become active by cation exchange.

B. Significance.—Extractable acidity is important for certain evaluations of soil nutrient availability or of the effect of waste additions to the soil. Extractable acidity is indirectly important data for soil classification because it is needed to calculate cation-exchange capacity by sum of cations (at pH 8.2). The cation-exchange capacity by the sum of cations method is used to calculate percent base saturation by sum of cations.

C. Measurement.—Extractable acidity is determined by a method using a solution of barium chloride-triethanolamine buffered at pH 8.2, as outlined in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS. Units of measure are centimoles per kilogram (cmol(+) kg^{-1}) of soil, which are equivalent to milliequivalents per 100 grams (meq 100 g^{-1}) of soil.

D. Entries.—Enter the range of extractable acidity in milliequivalents per 100 grams (meq 100 g^{-1}) of soil for the horizon. The range of valid entries is from 0 to 250 meq 100 g^{-1}, and tenths (one decimal place) are allowed. A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.101.

618.30 Extractable Aluminum

A. Definition.—"Extractable aluminum" is the amount of aluminum that approximates the aluminum considered exchangeable. It is a measure of the "active" acidity present in soils with a 1:1 water pH ≤ 5.5.

B. Significance.—Extractable aluminum is important for certain evaluations of soil nutrient availability and of toxicities. An aluminum saturation of about 60 percent is usually regarded as toxic to most plants. It may be a useful measurement for assessing potential lime needs for acid soils. Extractable aluminum is used for soil classification in the criteria for Alic and some Eutric subgroups of Andisols.

C. Measurement.—Extractable aluminum is determined by a method using a solution of one normal potassium chloride, as outlined in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS. Units of measure are centimoles per kilogram (cmol(+) kg^{-1}) of soil, which are equivalent to milliequivalents per 100 grams (meq 100 g^{-1}) of soil.

D. Entries.—Enter the range of extractable aluminum as milliequivalents per 100 grams (meq 100 g^{-1}) of soil for the horizon. The range of valid entries is from 0 to 150 meq 100 g^{-1}, and hundredths (two decimal places) are allowed.

318.31. Flooding Frequency Class, Duration Class, Inundation Type, and Month

A. Free water may occur above the soil. Inundation is the condition when the soil area is covered by liquid, free water.

B. Definition.—"Flooding" is the temporary inundation by flowing water from any source, such as streams overflowing their banks, runoff from adjacent or surrounding slopes, inflow from high tides, or any combination of sources. Chapter 3 of the *Soil Survey Manual* provides additional information. Standing water (ponding) or water that forms a permanent covering is excluded from the definition.

C. Classes.—Estimates of flooding class are based on the interpretation of soil properties and other evidence gathered during soil survey fieldwork. Flooding hazard is expressed by flooding frequency class, flooding duration class, flooding inundation type, and time of year that flooding occurs. Not considered here, but nevertheless important, are velocity and depth of floodwater. Frequencies used to define classes are generally estimated from evidence related to the soil and vegetation. They are expressed in wide ranges that do not indicate a high degree of accuracy. Flooding frequencies that are more precise can be calculated by performing complex analyses used by engineers. The class "very frequent" is used for areas subject to daily and monthly high tides.

(1) Flooding Frequency Class.—"Flooding frequency class" indicates the number of times flooding occurs over a period of time. The classes of flooding are defined as follows:

Figure 618-A8

Flooding Frequency Class	Definition
None	No reasonable possibility of flooding; less than 0.2 percent chance of flooding in any year or less than 1 time in 500 years.
Very rare	Flooding is very unlikely but is possible; 0.2 to less than 1 percent chance of flooding in any year, or 1 time or more in 500 years but less than 1 time in 100 years.
Rare	Flooding is unlikely but is possible; 1 to less than 5 percent chance of flooding in any year, or 1 time or more in 100 years but less than 5 times in 100 years.
Occasional	Flooding is expected infrequently; 5 to less than 50 percent chance of flooding in any year, or 5 times or more in 100 years but less than 50 times in 100 years.
Frequent	Flooding is likely to occur often; 50 percent or more chance of flooding in any year, or 50 times or more in 100 years but less than 50 percent in all months of any year.
Very frequent	Flooding is likely to occur very often; more than 50 percent chance of flooding in all months of any year.

(2) Flooding Duration Class.—The average duration of inundation per flood occurrence is given only for the occasional, frequent, and very frequent classes (defined above).

Figure 618-A9

Flooding Duration Class	Duration
Extremely brief	0.1 to < 4 hours
Very brief	4 hours to < 2 days
Brief	2 days to < 7 days
Long	7 days to < 30 days
Very long	≥ 30 days

(3) Flooding Inundation Type.—The type of water flow or flooding event that causes inundation of the soil. The three inundation types that are populated in the NASIS database are defined below. Definitions of terms follow.

Figure 618-A10

Flooding Inundation Type	Definition
Overbank flow	Inundation by a stream flowing above and outside of its normal channel.
Overland flow	Inundation by runoff water coming from surrounding or adjacent slopes; water flow is not concentrated in any form of stream channel.
Tidal flow	Inundation as a result of flows from astronomical tides, such as solar and lunar times, storm surges, storm tides, wind tides, and tsunami waves.

(4) Terms

(i) Overbank flow and overland flow.—Flooding that originates on the land and inundates terrestrial soils, subaqueous soils, and water bodies.

(ii) Tidal flow.—Flooding that originates in water bodies, such as bays, estuaries, seas, and lakes, and inundates terrestrial soils, subaqueous soils, and water; it includes tidal flow, solar tide, lunar tide, storm surge, storm tide, wind tide, and tsunami.

(iii) Solar tide.—Normal rise in water level produced by the gravitational pull of the sun.

(iv) Lunar tide.— Normal rise in water level produced by the gravitational pull of the moon.

(v) Storm surge.—An abnormal rise in water level during a storm, measured as the height of the water above the normal predicted astronomical tide.

(vi) Storm tide.—An abnormal rise in water level during a storm, resulting from the combination of storm surge and the astronomical tides.

(vii) Wind tide.—An abnormal rise in water level produced by the wind.
(viii) Tsunami.—An abnormal rise in water level or a wave caused by seismic activity, including underwater earthquakes, volcanic eruptions, and landslides.

D. Assignment

(1) Yearly flooding frequency classes are assigned to months and indicate the months of likely occurrence in the year and not the frequency of the flooding during the month, except for the very frequent class. The time period expressed includes 70 percent of the occurrences. Only in the very frequent and none classes are all 12 months populated with a frequency.
(2) Only the dominant flooding inundation type and the highest frequency are populated for soils that have more than one type of flooding. For example, some soils that are flooded by overbank flow from rivers are also subject to storm tides. The three types populated in the NASIS database are overbank flow, overland flow, and tidal flow, as defined above.
(3) Flooding duration classes are assigned to months. Time period and duration of flooding are the most critical factors that determine the growth and survival of a given plant species. Flooding during the dormant season has few if any harmful effects on plant growth or mortality and may improve the growth of some species. If inundation from floodwater occurs for long periods during the growing season, the soil becomes oxygen deficient and plants may be damaged or killed.

E. Significance.—The susceptibility of soils to flooding is an important consideration for building sites, sanitary facilities, and other uses. Floods may be less costly per unit area of farmland as compared to that of urban land, but the loss of crops and livestock can be disastrous.

F. Estimates.—The most precise evaluation of flood-prone areas for stream systems is based on hydrologic studies. The area subject to inundation during a flood of a given frequency, such as one with a 1 percent or 2 percent chance of occurrence, is generally determined by one of two basic methods.

(1) The first method is used if stream flow data are available. In this method, the data are analyzed to determine the magnitude of floods of different frequencies. Engineering studies are made to determine existing channel capacities and flow on the flood plain by the use of valley cross sections and water-surface profiles.
(2) The second method is used if stream flow data are not available. In this method, hydrologists make an estimate of flood potential from recorded data on rainfall. They consider such factors as—
Size, slope, and shape of the contributing watershed.
(3) Hydrologic characteristics of the soil.
(4) Land use and treatment.
(5) Hydraulic characteristics of the valley and channel system.
(6) With the use of either method, soil surveys can aid in the delineation of flood-prone areas. Possible sources of flooding information are—
    - NRCS project-type studies, such as those arising from Public Law 556, flood protection, river basin, or resource conservation and development projects.
    - Flood hazard analyses.
    - Corps of Engineers (COE) flood plain information reports.
    - Special flood reports.
    - Local flood-protection and flood-control project reports.
    - Department of Housing and Urban Development flood-insurance study reports.

- Maps by the U.S. Geological Survey (USGS), NRCS, Tennessee Valley Authority, COE, or National Oceanic and Atmospheric Administration.
- Studies by private firms and other units of Government.
- USGS quadrangle sheets and hydrologic atlases of flood-prone areas and stream gauge data.
- The online FEMA Flood Map Service Center: http://msc.fema.gov/portal.

(7) General estimates of flooding frequency and duration are made for each soil. However, in intensively used areas where construction has materially altered the natural water flow, flood studies are needed to adequately reflect present flooding characteristics.

(8) Soil scientists collect and record evidence of flood events during the course of the soil survey. The extent of flooded areas, flood debris in trees, damage to fences and bridges, and other signs of maximum water height are recorded. Information that is helpful in delineating soils that have a flood hazard is also obtained. Hydrologists may have flood stage predictions that can be related to kinds of soil or landscape features. Conservationists and engineers may have recorded elevations of high flood marks. Local residents may have recollections of floods that can help to relate the events to kinds of soil, topography, and geomorphology.

(9) Certain landscape features have developed as the result of past and present flooding and include former river channels, oxbows, point bars, alluvial fans, meander scrolls, sloughs, natural levees, backswamps, sand splays, and terraces. Most of these features are easily recognizable on aerial photographs when the photo image is compared to on-the-ground observations. Different kinds of vegetation and soils are normally associated with these geomorphic features.

(10) The vegetation that grows in flood areas may furnish clues to past flooding. In the central and southeastern United States, the survival of trees in flood-prone areas depends on the frequency, duration, depth, and time of flooding and on the age of the tree.

(11) Past flooding may sometimes leave clues in the soil, such as—

(i) Thin strata of material of contrasting color, texture, or both.

(ii) An irregular decrease in organic matter content, not due to human-alteration by mixing or transportation of material, which is an indication of a buried genetic surface horizon.

(iii) Soil layers that have abrupt boundaries to contrasting kinds of material, which indicate that the materials were laid down suddenly at different times and were from different sources or were deposited from stream flows of different velocities.

(iv) Artifacts which are easily moved and deposited by flood waters (e.g., plastic bottles).

(12) Laboratory analyses of properly sampled layers are often helpful in verifying these observations. Organic carbon and particle-size analyses are particularly useful in verifying flood deposits. Microscopic observations may detect preferential horizontal orientation of plate-like particles; microlayering, which indicates water-laid deposits; or mineralogical differences between layers.

G. Entries.—If a map unit component floods, then the annual flooding frequency and duration are populated, as stated above in section 618.31B, for the specific months in which the flooding events most commonly occur. All other months have records in the “Component Month” table but the data elements for frequency and duration are left as “NULL.” Flooding entries reflect the current existing and mapped condition with consideration for dams, levees, and other human-induced changes affecting flooding frequency and duration. Only in very frequent and none classes are all 12 months populated with a frequency.

(1) Enter the flooding frequency class name: none, very rare, rare, occasional, frequent, or very frequent.
(2) Enter the flooding duration class name that most nearly represents the soil component: extremely brief, very brief, brief, long, or very long.

618.32 Fragments in the Soil

A. Definition.—"Fragments" are unattached, cemented pieces of bedrock, bedrock-like material, durinodes, concretions, nodules, or pedogenic horizons (e.g., petrocalcic fragments) 2 mm or larger in diameter and unprocessed woody material 20 mm or larger in diameter in organic soils. Fragments are separated into three types: rock fragments, pararock fragments (which are distinguished by cementation class), and wood fragments. The words "rock" and "pararock" are used here in the broad sense and do not connote only natural fragments of geologic material. Some artifacts behave in a similar manner to fragments in the soil. See section 618.5 for detailed information on the measurement, classes, and data entries for artifacts.

(1) Rock fragments are unattached pieces of geologic or pedogenic material 2 mm in diameter or larger that are strongly cemented or more resistant to rupture. Rock fragments ≥2 mm to <75 mm (3 inches)* are considered when estimating the percent passing sieves, as discussed in section 618.48.
(2) Pararock fragments are unattached, cemented pieces of geologic or pedogenic material 2 mm in diameter or larger that are extremely weakly cemented to moderately cemented. These fragments are not retained on sieves because they are crushed by grinding during sample preparation.
(3) Wood fragments are unprocessed (i.e., naturally occurring) woody materials that cannot be crushed between the fingers when moist or wet and are 20 mm or larger in size. Wood fragments are only used in organic soils. They are comparable to rock and pararock fragments in mineral soils. Processed wood products, whether treated or untreated, are considered artifacts and not wood fragments.

B. Significance

(1) The fraction of the soil 2 mm or larger in diameter has an impact on the behavior of the whole soil. Soil properties, such as available water capacity, cation-exchange capacity, saturated hydraulic conductivity, structure, and porosity, are affected by the volume, composition, and size distribution of rock fragments in the soil. Fragments also affect the management of the soil and are used as interpretation and classification criteria (e.g., particle-size and substitute classes). Terms related to volume, size, and hardness of fragments are used as texture modifier terms.
(2) Generally, the fraction of soil ≥75 mm (3 inches) in diameter is not included in the engineering classification systems. However, it can be added as a descriptive term to the group name, for example, poorly graded gravel with silt, sand, cobbles, and boulders. Estimates of the percent of cobbles and boulders are presented in the soil descriptions for a group name (see ASTM Designation D 2487, Appendix X1.1). A small amount of these larger particles generally has little effect on soil properties. The particles may, however, have an effect on the use of a soil in certain types of construction. Often, the larger portions of a soil must be removed before the material can be spread in thin layers, graded, or compacted and graded to a smooth surface. As the quantity of this "oversized" fraction increases, the properties of the soil can be affected. If the larger particles are in contact

with each other, the strength of the soil is very high and the compressibility very low. If voids exist between the larger particles, the soil will likely have high saturated hydraulic conductivity and may undergo some internal erosion as a result of the movement of water through the voids. Most of the smaller and more rapid construction equipment normally used in excavating and earthmoving cannot be used if the oversize fraction of a soil is significant.

C. Measurement.—The fraction from ≥2 to <75 mm in diameter may be measured in the field. However, 50 to 60 kg of sample material may be necessary if there is an appreciable amount of fragments near 75 mm. An alternative means of measuring is to visually estimate the volume of the 20- to 75-mm fraction, then sieve and weigh the ≥2- to <20-mm fraction. The fraction ≥75 mm (3 inches) or greater is usually not included in soil samples taken in the field for laboratory testing. Measurements can be made in the field by weighing the dry sample and the portion retained on a 3-inch screen. The quantity is expressed as a weight percentage of the total soil. A sample as large as 200 pounds to more than a ton may be needed to assure that the results are representative. Measurements of the fraction from ≥75 to <250 mm (3 to 10 inches) and the fraction greater than or equal to 250 mm (10 inches) in diameter are usually obtained from volume estimates.

D. Estimates

(1) Estimates are usually made by visual means and are on the basis of percent by volume. The percent by volume is converted to percent by weight by using the average bulk unit weights for soil and rock. These estimates are made during investigation and mapping activities in the field. They are expressed as ranges that include the estimating accuracy as well as the range of values for a component.

(2) Measurements or estimates of fragments less than strongly cemented are made prior to any rolling or crushing of the sample.

E. Rock Fragments Greater Than 10 Inches (250 mm)

(1) Definition.—"Rock fragments greater than 10 inches" is the percent by weight of the horizon occupied by rock fragments greater than or equal to 10 inches (250 mm) in diameter. Although the upper limit is undefined, for practical purposes it generally is no larger than a pedon, up to 10 meters square. For flat rock fragments, the intermediate dimension is used for the 250 mm (10 inch) measurement. For example, a flat-shaped rock fragment that is 100 mm × 250 mm × 380 mm has an intermediate dimension of 250 mm and is not counted as greater than 250 mm. A flat-shaped rock fragment that is 100 mm × 275 mm × 380 mm has an intermediate dimension of 275 mm and is counted as greater than 250 mm.

(2) Entries.—Enter the high, low, and representative values in the "Component Horizon" table in the NASIS database as whole number percentages for each horizon, as appropriate.

F. Rock Fragments ≥3 to <10 Inches (75 to 250 mm)

(1) Definition.—"Rock fragments 3 to 10 inches" is the percent by weight of the horizon occupied by rock fragments ≥3 to <10 inches (75 to 250 mm) in diameter.

(2) Entries.—Enter the high, low, and representative values in the "Component Horizon" table in the NASIS database as whole number percentages for each horizon, as appropriate.

G. Fragment Kind

(1) Definition.—"Fragment kind" is the lithology or composition of the 2 mm or larger fraction of the soil (20 mm or larger for wood fragments).
(2) Entries.—Enter the appropriate fragment kind name for the record of fragments populated in the "Component Horizon Fragments" tables in the NASIS database. The class names appear in a choice list and can also be viewed in the NASIS data dictionary.

H. Fragment Roundness

(1) Definition.—"Fragment roundness" is an expression of the sharpness of edges and corners of fragments.
(2) Significance.—The roundness of fragments impacts water infiltration, root penetration, and macropore space.
(3) Classes.—The fragment roundness classes are given below:

Figure 618-A11

Roundness Class	**Definition**
Very angular	Strongly developed faces with very sharp, broken edges.
Angular	Strongly developed faces with sharp edges (SSM).
Subangular	Detectable flat faces with slightly rounded corners.
Subrounded	Detectable flat faces with well rounded corners (SSM).
Rounded	Flat faces absent or nearly absent with all corners rounded (SSM).
Well rounded	Flat faces absent with all corners rounded.

(4) Entries.—Enter the appropriate fragment roundness class name for the record of fragments populated in the "Component Horizon Fragments" table in the NASIS database.

I. Fragment Hardness

(1) Definition.—"Fragment hardness" is equivalent to the "rupture resistance cemented" of a fragment of specified size that has been air dried and then submerged in water.
(2) Measurements.—Measurements are made using the procedures and classes of cementation that are listed with the rupture resistance classes in the *Soil Survey Manual*. Classes are described for block-like specimens about 25-30 mm on edge, which are air dried and then submerged in water for at least 1 hour. The specimen is compressed between an extended thumb and forefinger, between both hands, or between a foot and a nonresilient flat surface. If the specimen resists compression, a weight is dropped onto it from progressively greater heights until it ruptures. Failure is considered at the initial detection of deformation or rupture. Stress applied in the hand should be over a 1-second period. The tactile sense of the class limits may be learned by applying force to top-loading scales and sensing the pressure through the tips of the fingers or through the ball of the foot. Postal scales may be used for the resistance range that is testable with the fingers. A bathroom scale may be used for the higher rupture resistance range.
(3) Significance.—The hardness of a fragment is significant where the rupture resistance class is strongly cemented or greater. These classes can impede or restrict the movement of soil

water vertically through the soil profile and have a direct impact on the quality and quantity of ground water and surface water.

(4) Classes.—The fragment hardness (rupture resistance) classes are—
  (i) Extremely weakly cemented
  (ii) Very weakly cemented
  (iii) Weakly cemented
  (iv) Moderately cemented
  (v) Strongly cemented
  (vi) Very strongly cemented
  (vii) Indurated

(5) Entries.—Enter the appropriate class name for each record of fragments populated in the "Component Horizon Fragments" table in the NASIS database. Choose the term without the word "cemented" (i.e., choose "moderately" to represent the moderately cemented class).

J. Fragment Shape

(1) Definition.—"Fragment shape" is a description of the overall shape of the fragment.

(2) Significance.—Fragment shape is important for fragments that are too large to be called channers or flagstones.

(3) Classes.—The fragment shape classes are: flat and nonflat.

(4) Entries.—Enter the appropriate fragment shape class name for each record of fragments populated in the "Component Horizon Fragments" table in the NASIS database.

K. Fragment Size

(1) Definition.—"Fragment size" is based on the multiaxial dimensions of the fragment.

(2) Significance.—The size of fragments is significant to the use and management of the soil. Fragment size is used as a criterion in naming map units. It affects equipment use, excavation, construction, and recreational uses.

(3) Classes.—Classes of fragment size are subdivided as flat or nonflat, based on the shape of the fragments (described above).

  (i) Flat fragment classes are given below:

Figure 618-A12

Flat Fragment Class	**Length of Fragment (mm)**
Channers	≥2 to <150
Flagstones	≥150 to <380
Stones	≥380 to <600
Boulders	≥600

  (ii) Nonflat fragment classes are given below:

Figure 618-A13

Nonflat Fragment Class	Diameter (mm)
Gravel	≥2 to <75
fine gravel	≥2 to <5
medium gravel	≥5 to <20
coarse gravel	≥20 to <75
Cobbles	≥75 to <250
Stones	≥250 to <600
Boulders	≥600

(iii) Gravel is a collection of fragments having a diameter ranging from ≥2 to <75 mm. Individual fragments in this size range are properly referred to as "pebbles," not "gravels." For fragments that are less than strongly cemented, "para" is used as a prefix to the above terms (e.g., paracobbles).

(4) Entries.—Enter the high, low, and representative values of each size class populated in the "Component Horizon Fragments" table in the NASIS database. The range of valid entries is from 2 to 3,000 millimeters, and only whole numbers (integers) are allowed.

L. Fragment Volume

(1) Definition.—"Fragment volume" is the volume percentage of the horizon occupied by the 2 mm or larger fraction (20 mm or larger for wood fragments) on a whole soil base.

(2) Significance.—The volume occupied by the 2 mm or larger fraction is important in selecting texture modifiers (i.e., gravelly, very gravelly, extremely paragravelly).

(3) Entries.—Enter the high, low, and representative values for the percent volume present of each size class and kind of fragment populated in the "Component Horizon Fragments" table in the NASIS database. The range of valid entries is from 0 to 100 percent, and only whole numbers (integers) are allowed.

618.33 Free Iron Oxides

A. Definition.—"Free iron oxides" are secondary iron oxides, such as goethite, hematite, ferrihydrite, lepidocrocite, and maghemite. These forms of iron may occur as discrete particles, as coatings on other soil particles, or as cementing agents between soil mineral grains. They consist of iron extracted by dithionite-citrate from the fine-earth fraction.

B. Significance.—The amount of iron that is extractable by dithionite-citrate is used in the ferritic, ferruginous, parasesquic, and sesquic mineralogy classes defined in Soil Taxonomy. The ratio of dithionite-citrate (free) iron to total iron in a soil is a measure of the degree of soil weathering. Free iron oxides are important in the soil processes of podzolization and laterization and play a significant role in the phosphorous fixation ability of soils.

C. Measurement.—Free iron oxides are measured as the amount extracted by a solution of sodium dithionite and sodium citrate using a method outlined in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS.

D. Entries.—Enter high, low, and representative values as percentages for each horizon for which data is available. The range of valid entries is from 0 to 100 percent, and hundredths (two decimal places) are allowed.

618.34 Frost Action, Potential

A. Definition.—"Potential frost action" is a rating of the susceptibility of the soil to upward or lateral movement by the formation of segregated ice lenses. It rates the potential for frost heave and the subsequent loss of soil strength when the ground thaws.

B. Classes.—Classes are used in regions where frost action is a potential problem. Refer to part 618, subpart B, section 618.84, for more information. The classes are: low, moderate, and high. They are defined below:

Figure 618-A14

Potential Frost Action Class	**Definition**
Low	Soils are rarely susceptible to the formation of ice lenses.
Moderate	Soils are susceptible to the formation of ice lenses, which results in frost heave and subsequent loss of soil strength.
High	Soils are highly susceptible to the formation of ice lenses, which results in frost heave and subsequent loss of soil strength.

C. Significance.—Damage from frost action results from the formation of segregated ice crystals and ice lenses in the soil and the subsequent loss of soil strength when the ground thaws. Frost heave damages highway and airfield pavements. It is less of a problem for dwellings and buildings that have footings which extend below the depth of frost penetration. In cold climates, unheated structures that have concrete or asphalt floors can be damaged by frost heave. Driveways, patios, and sidewalks can heave and crack. The thawing of the ice causes a collapse of surface elevation and produces free-water perches on the still-frozen soil below. Soil strength is reduced. Backslopes and side slopes of cuts and fills can slough during thawing. Seedlings and young plants of clover, alfalfa, wheat, and oats can be raised out of the soil or have their root systems damaged by frost heave.

D. Estimates

(1) Freezing temperatures, soil moisture, and susceptible soils are needed for the formation of segregated ice lenses. Ice crystals begin to form in the large pores first. Water in small pores or water that was adsorbed on soil particles freezes at lower temperatures. This supercooled water is strongly attracted to the ice crystals, moves toward them, and freezes on contact with them. The resulting ice lens continues to grow in width and thickness until all available water that can be transported by capillary has been added to the ice lens and a further supply cannot be made available because of the energy requirements.

(2) Soil temperatures must drop below 0° C for frost action to occur. Generally, the more slowly and deeply the frost penetrates, the thicker the ice lenses are and the greater the resulting frost heave is. Part 618, subpart B, section 618.85, is a map that shows the design freezing index values in the continental United States. The values are the number of degree days below 0° C for the coldest year in a period of 10 years. The values indicate duration and intensity of freezing temperatures. The 250 isoline is the approximate boundary below which frost action ceases to be a problem. Except on the West Coast, the frost action boundary corresponds closely to the functional boundary between the mesic and thermic soil temperature regimes as defined in Soil Taxonomy. More information is provided in the U.S. Army Engineer School, Student Reference, 1967, Soil Engineering, Section I, Volume II, Chapters VI-IX, Fort Belvoir, VA.

(3) Water necessary for the formation of ice lenses may come from a high water table or from infiltration at the surface. Capillary water in voids and adsorbed water on particles also contribute to ice lens formation but, unless this water is connected to a source of free water, the amount generally is insufficient to produce significant ice segregation and frost heave.

(4) The potential intensity of ice segregation is dependent to a large degree on the effective soil pore size and soil saturated hydraulic conductivity, which are related to soil texture. Ice lenses form in soils in which the pores are fine enough to hold quantities of water under tension but coarse enough to transmit water to the freezing front. Soils that have a high content of silt and very fine sand have this capacity to the greatest degree and hence have the highest potential for ice segregation. Clayey soils hold large quantities of water but have such slow saturated hydraulic conductivity that segregated ice lenses are not formed unless the freezing front is slow moving. However, sandy soils have large pores and hold less water under lower tension. As a result, freezing is more rapid and the large pores permit ice masses to grow from pore to pore, entombing the soil particles. Thus, in coarse grained soils, segregated ice lenses are not formed and less displacement can be expected.

(5) Estimates of potential frost action generally are made for soils in mesic or colder temperature regimes. Exceptions are on the West Coast, where the mesic-thermic temperature line crosses below the 250 isoline, as displayed in part 618, subpart B, section 618.85, and along the East Coast, where the soil climate is moderated by the ocean. Mesic soils that have a design freezing index of less than 250 degree days should not be rated because frost action is not likely to occur. The estimates are based on bare soil that is not covered by insulating vegetation or snow. They are also based on the moisture regime of the natural soil. The ratings can be related to manmade modifications of drainage or to irrigation systems on an onsite basis. Frost action estimates are made for the whole soil to the depth of frost penetration, to bedrock, or to a depth of 2 meters (6.6 feet), whichever is shallowest. Part 618, subpart B, section 618.84, is a guide for making potential frost action estimates. It uses the soil moisture regimes and taxonomic family particle-size classes as defined in *Soil Taxonomy*.

E. Entries.—Enter one of the following classes for the whole soil: low, moderate, or high. If frost action is not a problem, enter “none.”

618.35 Gypsum

A. Definition.—“Gypsum” is the percent, by weight, of hydrated calcium sulfates in the <20 mm fraction of soil.

B. Significance.—Gypsum is partially soluble in water and can be dissolved and removed by water. Soils with more than 10 percent gypsum may collapse if the gypsum is removed by percolating water. Gypsum is corrosive to concrete. Corrosion of concrete is most likely to occur in soils that are more than about 1 percent gypsum when wetting and drying occurs. Gypsum percentage is used for soil classification in the required characteristics for gypsic and petrogypsic horizons, the gypseous substitute classes, several strongly contrasting particle-size classes, and the hypergypsic, gypsic, and carbonatic mineralogy classes.

C. Measurement.—Gypsum percentage is measured by a method that uses precipitation in acetone, as outlined in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS.

D. Entries.—Enter the high, low, and representative values to represent the range in gypsum content as a weight percent of the soil fraction less than 20 mm in size. Round values to the nearest 5 percent for layers that are more than 5 percent gypsum and to the nearest 1 percent for layers that are less than 5 percent gypsum (for example, 0-1, 1-5, 5-10). If the horizon does not have gypsum, enter “0.” The range of valid entries is from 0 to 120 percent, and only whole numbers (integers) are allowed.

618.36 Horizon Depth to Bottom

A. Definition.—“Horizon depth to bottom” is the distance from the top of the soil to the base of the soil horizon.

B. Measurement.—Distance is measured from the top of the soil, which is defined as the top of the mineral soil, or, for soil with “O” horizons, the top of any organic layer that is at least slightly decomposed. For soils that are covered by 80 percent or more rock or pararock fragments, the top of the soil is the mean height of the top of the fragments. See chapter 3 in the *Soil Survey Manual* for a complete discussion. Measurement should be estimated to a depth of 200 cm for most soils and to a depth at least 25 cm below a lithic contact if the contact is above 175 cm. For soils, including those that have a root-restricting contact such as a paralithic contact, the lowest horizon bottom should extend to a depth of at least 25 cm below the contact or to a depth of 200 cm, whichever is shallower.

C. Entries.—Values for horizon depth to bottom that are used to populate component data in NASIS are not specific to any one point but rather are a reflection of commonly observed values based on field observations and are intended to model the component as it occurs throughout the map unit. Enter the high, low, and representative values in whole centimeters. The high value represents either the greatest depth to which the base of the horizon extends or, for horizons extending beyond the limit of field observation, is the depth to which observation was made (usually no more than 200 cm but at least 150 cm).

618.37 Horizon Depth to Top

A. Definition.—"Horizon depth to top" is the distance from the top of the soil to the upper boundary of the soil horizon.

B. Measurement.—Distance is measured from the top of the soil, which is defined as the top of the mineral soil, or, for soils with "O" horizons, the top of any organic layer that is at least slightly decomposed. For soils that are covered by 80 percent or more rock or pararock fragments, the top of the soil is the mean height of the top of the fragments. See chapter 3 in the *Soil Survey Manual* for a complete discussion.

E. Entries.—Values for depth to top that are used to populate component data in NASIS are not specific to any one point but rather are a reflection of commonly observed values based on field observations and are intended to model the component as it occurs throughout the map unit. Enter the high, low, and representative values in whole centimeters. See section 618.38, "Horizon Designation," for a discussion on how to list E/B and E and Bt type horizons.

618.38 Horizon Designation

A. Definition.—"Horizon designation" is a concatenation of three kinds of symbols used in various combinations to identify layers of soil that reflect the investigator's interpretations of genetic relationships among layers within a soil.

B. Significance.—Soils vary widely in the degree to which horizons are expressed. The range is from little or no expression to strong expression. Layers of different kinds are identified by symbols. Designations are provided for layers that have been changed by soil formation and for those that have not. Designations are assigned after comparison of the observed properties of the layer with properties inferred for the material before it was affected by soil formation. Designations of genetic horizons express a qualitative judgment about the kind of changes that are believed to have taken place. A more detailed discussion can be reviewed in the latest edition of the Keys to Soil Taxonomy and in the *Soil Survey Manual*, chapter 3. Horizon designations shown in field pedon descriptions (point data) represent a specific location on the landscape. Horizon designations used to populate component data in NASIS are not specific to any one point but rather are a reflection of commonly observed horizon sequences based on field observations and are intended to model the component as it occurs throughout the map unit so that accurate interpretations can be derived.

C. Entries.—Enter combinations of symbols to reflect master horizons and their vertical subdivisions. Commonly occurring master horizon sequences, identified in field pedon descriptions (e.g., A-Bt1-Bt2-Btk-2Bk-2C), are used for soil components in NASIS. Generalized horizon layer designations (e.g., H1-H2-H3) may be used instead of genetic horizon designations. Users of generalized horizon layer designations must be cognizant of the fact that certain master horizon designations, such as O, Cr, and R, are still required entries in NASIS for proper soil interpretations.

(1) It is not possible to include all master horizon sequences observed in individual pedon descriptions when populating the interpretive horizons of soil components. For example, if

an Ap horizon is present and the former E horizon is incorporated into the Ap horizon, a sequence of Ap-E should not be used because the horizons would not normally occur together. Judgment is required when determining how much detail is required to represent the component adequately for interpretations. Care must be taken to maintain important differences between genetic horizons whose range in properties are specified separately on the official series descriptions. Some general guidance follows. Master horizons (i.e., O, A, E, B) represent unique sets of pedogenic processes and therefore should not be combined when aggregating data, even if their basic properties are similar.

(2) Transitional horizons, such as EB and BC, should be recorded if they are commonly more than about 10 cm thick. After applying careful judgment, some horizons may be combined in order to avoid overly complex horizon sequences representing map unit components. Keep in mind, however, that once combined, any useful information gained by their separation is lost. Transitional horizons thinner than about 10 cm may be combined with an adjacent master horizon if they are not considered important to the interpretation of the component. Master horizon subdivisions showing genetic variations not deemed significant to interpretations may be combined. For example, a horizon sequence of Bt1-Bt2-Bt3, based solely on color variation and having no other significant differences, may be combined and shown simply as Bt. Master horizon subdivisions showing genetic variations that are deemed significant to interpretations should not be combined. For example, a horizon sequence of Bt-Btx-BC should not be combined. Do not combine horizons that straddle the criteria break to a diagnostic horizon. For example, a Bk1 with insufficient calcium carbonate content to qualify as a calcic horizon should not be combined with a Bk2 that is a calcic horizon. Enter only what the documentation can support.

(3) Combination horizons (E and Bt, Btn/E, E/Bt, etc.) should be entered as two separate horizon records, such as one for the E part of the horizon and the second for the Bt part of the horizon. Both records must have the same horizon designations assigned (e.g., E/Bt). But these separate horizon records must have different RV depth values for the top and bottom depths. The RV horizon depths must be completely in sync with no duplication, overlaps, or gaps. For example, the E part of a E/Bt horizon could have RV depths of 20 to 35 cm and the Bt part of the E/Bt horizon could have RV depths of 35 to 50 cm. The depth values for the "Low" and "High" columns of the horizon top and bottom depths may be populated to identify the overlapping nature of the horizon (e.g., both records may have the same low value for the top depth of 10 cm). Soil property data elements would be populated for each part to describe the characteristics of that separate part of the combination horizon.

(4) Allowable codes are listed in the NASIS data dictionary (https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1247050&ext=pdf). The rules for use of horizon designations are in the latest edition of the *Keys to Soil Taxonomy* and in the *Soil Survey Manual*, chapter 3.

618.39 Horizon Thickness

A. Definition.—"Horizon thickness" is a measurement from the top to bottom of a soil horizon throughout its areal extent.

B. Measurement.—Soil horizon thickness varies on a cyclical basis. Measurements should be made to record the range in thickness as it normally occurs in the soil.

C. Entries.—Horizon thickness values used to populate component data in NASIS are not specific to any one point but rather are a reflection of commonly observed values based on field observations and are intended to model the component as it occurs throughout the map unit. Enter the high, low, and representative values in whole centimeters. The minimum allowable entry is 1 cm. For horizons extending beyond the limit of field observation, thickness is only populated to the depth at which an observation was made.

618.40 Hydrologic Group

A. Definition

(1) The complete definition and official criteria for hydrologic soil groups are available online at (Title 210, National Engineering Handbook, part 630, chapter 7, "Hydrologic Soil Groups").

(2) "Hydrologic group" is a group of soils having similar runoff potential under similar storm and cover conditions. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to a seasonal high water table, saturated hydraulic conductivity after prolonged wetting, and depth to a layer with a very slow water transmission rate. Changes in soil properties caused by land management or climate changes also cause the hydrologic soil group to change. The influence of ground cover is treated independently.

B. Classes.—The soils in the United States are placed into four groups, A, B, C, and D, and three dual classes, A/D, B/D, and C/D.

C. Significance.—Hydrologic groups are used in equations that estimate runoff from rainfall. These estimates are needed for solving hydrologic problems that arise in planning watershed-protection and flood-prevention projects and for planning or designing structures for the use, control, and disposal of water.

D. Measurements.—The original classifications assigned to soils were based on the use of rainfall-runoff data from small watersheds and infiltrometer plots. From these data, relationships between soil properties and hydrologic groups were established.

E. Estimates.—Assignment of soils to hydrologic groups is based on the relationship between soil properties and hydrologic groups. Wetness characteristics, water transmission after prolonged wetting, and depth to very slowly permeable layers are properties used in estimating hydrologic groups.

F. Entries.—Enter the soil hydrologic group, such as A, B, C, D, A/D, B/D, or C/D.

618.41 Landscape, Landform, Microfeature, Anthroscape, Anthropogenic Landform, and Anthropogenic Microfeature

A. Definition.— the geomorphic description is nested to describe largest to smallest setting.

1. (1) "Landscape" is a broad or unique land area comprised of a collection of related landforms that define a general geomorphic form or setting.
2. (2) "Landform" is any physical, recognizable form or feature of the Earth's surface having a characteristic shape, internal composition, and produced by natural causes; a distinct individual produced by a set of processes.
3. (3) "Microfeatures" are small, local, natural forms on the land surface that are too small to delineate on a topographic or soils map at commonly used map scales.
4. (4) "Anthroscapes" are human-modified landscapes of substantial and permanent alterations formed by the removal, addition, or reorganization of the physical shape and/or internal stratigraphy of the land, associated with management for habitation, commerce, food or fiber production, recreation, or other human activities that have permanently and substantively altered water flow and sediment transport across or within the regolith.
5. (5) "Anthropogenic landforms" are discrete, human-made landforms on the Earth's surface or in shallow water that have characteristic shape and range of internal composition of unconsolidated earthy, organic, human-transported materials, or rock that is the direct result of human manipulation or activities and are mappable at common soil survey scales (e.g., Order 2: > 1:10,000 and < 1:24,000). Anthropogenic landforms can be either constructional (accumulations; e.g., artificial levee) or destructional (voids; e.g., quarry) in origin.
6. (6) "Anthropogenic microfeatures" are discrete, individual, human-derived forms on the Earth's surface or in shallow water that have a characteristic shape and range in composition of unconsolidated earthy, organic, human-transported materials, or rock, and are too small to delineate on a topographic or soils map at commonly used map scales. Anthropogenic microfeatures can be either constructional accumulations (e.g., railroad bed) or destructional voids (e.g., ditch) in origin.

B. Significance.— Geographic patterns suggests natural relationships. Running water, with weathering and gravitation, commonly sculpts landforms within a landscape. Over the ages, earthy material is removed from some landforms and deposited on others. Landforms are interrelated. An entire area has unity through the interrelationships of its landform. Typically, microfeatures and anthropogenic microfeatures are nested within landforms or anthropogenic landforms. In turn, landforms and anthropogenic landforms are nested within landscapes or anthroscapes.

1. (1) Each landform or anthropogenic landform may have one kind of soil present or several. Climate, vegetation, and time of exposure to weathering of the parent materials are commonly about the same throughout the extent of the landform, depending on the relief of the area. Position on the landform may have influenced the soil-water relationships, microclimate, and vegetation.
2. (2) The anthropogenic landform typically has straight-line boundaries or geometric shape and is the result of human deposition or removal activities.
3. (3) The proper identification of the geomorphic setting is an important part of understanding the formative history of the soil and the materials from which the soil formed and dictate the dynamics operating in a given area. Understanding these geoforms, materials, and interactions aid in the development of the soil mapping model and in the consistent transfer of information between areas.
4. (4) Landform terms are also used as local phase criteria for separating components or uniquely naming soil map units. See part 627 of this handbook for more information on naming physiographic phases, features, and materials.

(5) A term should only be used once in a geomorphic descriptive string (e.g., microfeature/landform/landscape, or anthropogenic microfeature/anthropogenic landform/anthroscape). If a term is used at one level, it should not be repeated at another level in the same string (e.g., an outwash plain on an outwash plain is not acceptable). A different term that conveys additional information should be used at each level (e.g., an outwash plain on a till plain is more informative).

(6) Describe and record what you see. Not all levels are present at all sites. If there are no microfeatures present, none should be recorded for that site. If anthropogenic landforms are found, but are not part of a larger anthropogenically modified area (no anthroscape), then a natural landscape should be identified.

C. Classes.—The allowable list of terms is included in the NASIS data dictionary. Definitions of the terms are included in part 629 of this handbook.

D. Entries.—Enter the appropriate class name for the landforms on which each map unit component occurs. A representative value (term) may be indicated. It is possible to indicate the presence of one landform occurring on another landform (e.g., a dune on a flood plain).

618.42 Linear Extensibility Percent

A. Definition.—"Linear extensibility percent" is the linear expression of the volume difference of natural soil fabric at 1/3-bar or 1/10-bar water content and oven dryness. The volume change is reported as percent change for the whole soil.

B. Classes.—Shrink-swell classes are based on the change in length of an unconfined clod as moisture content is decreased from a moist to a dry state. If this change is expressed as a percent, the value used is LEP, linear extensibility percent. If it is expressed as a fraction, the value used is COLE, coefficient of linear extensibility. The shrink-swell classes are defined as follows:

Figure 618-A15

Shrink-Swell Class	LEP	COLE
Low	<3.0	<0.03
Moderate	3.0–5.9	0.03–0.06
High	6.0–8.9	0.06–0.09
Very High	≥9.0	≥0.09

C. Significance.—If the shrink-swell class is rated moderate to very high, shrinking and swelling can damage buildings, roads, and other structures. The high degree of shrinkage associated with high and very high shrink-swell classes can damage plant roots. Linear extensibility (expressed as cm of extension per meter of soil) is used for soil classification in the required characteristics for Vertic subgroups. Such soils will typically have LEP values of 6 or more.

D. Measurement.—Coefficient of linear extensibility is measured directly as the change in clod dimension from moist to dry conditions and is expressed as a percentage of the volume change to the dry length:

$$\text{COLE} = \frac{\text{moist length - dry length}}{\text{dry length}}$$

When expressed as LEP (linear extensibility percent):

$$\text{LEP} = \text{COLE} \times 100$$

Linear extensibility may be determined by any of the following methods:

(1) For the core method of measurement, select a sample core from a wet or moist soil. Carefully measure the wet length of the core and set the core upright in a dry place. If the core shrinks in a symmetrical shape without excessive cracking or crumbling, its length can be measured and linear extensibility percent calculated. If the core crumbles or cracks, measurements cannot be accurately determined by this method.

(2) In the coated clod method of measurement, shrink-swell potential can be estimated from the bulk density of soil measured when moist and when dry. The coated clod method is widely used and is the most versatile procedure for determining the bulk density of coherent soils. Procedures and calculations are given in Soil Survey Investigations Report No. 42, *Soil Survey Laboratory Methods Manual*, Version 4.0, November 2004, USDA, NRCS.

(3) Linear extensibility percent can be calculated from bulk density moist (Dbm) and bulk density dry (Dbd) using the following formula:

$$\text{LEP} = 100\ [(\text{Dbd}/\text{Dbm})^{1/3}\ -1]\ [1-(\text{Volume }\% > 2\text{ mm}/100)]$$

This equation is used to simplify the determination of shrink-swell potential classes. The classes are as follows:

Figure 618-A16

Dbd/Dbm	Shrink-Swell Potential
< 1.10	Low
1.10 - 1.20	Moderate
1.20 - 1.30	High
≥ 1.30	Very high

E. Estimates.—Field estimates of shrink-swell potential can be made by observing desiccation cracks, slickensides, gilgai, soil creep, and leaning utility poles. Shrink-swell potential correlates closely with the kind and amount of clay. The greatest shrink-swell potential occurs in soils that have high amounts of 2:1 lattice clays, such as clay minerals in the smectite group. Illitic clays are intermediate, and kaolinitic clays are least affected by volume change as the content in moisture changes.

F. Entries.—Enter the low, high, and representative linear extensibility percent values. If laboratory measurements or accurate field estimates are available, the high and low values do not need to correspond with shrink-swell class limits. However, if data is limited, the high and low values may correspond to the high and low limits of the appropriate shrink-swell class. The range of valid entries is from 0 to 30 percent, and tenths (one decimal place) are allowed.

618.43 Liquid Limit

A. Definition.—“Liquid limit” is the water content of the soil material, which passes a no. 40 sieve, at the change between the liquid and plastic states.

B. Significance.—The plasticity chart, given in ASTM Designation D 2487, is a plot of liquid limit (LL) versus plasticity index (PI) and is used in classifying soil in the Unified soil classification system. The liquid limit is also a criterion for classifying soil in the AASHTO classification system, as shown in part 618, subpart B, section 618.83. Generally, the amount of clay- and silt-sized particles, the organic matter content, and the type of minerals determine the liquid limit. Soils that have a high liquid limit have the capacity to hold a lot of water while maintaining a plastic or semisolid state.

C. Measurement.—Tests are made on thoroughly puddled soil material that has passed a no. 40 (.425 mm) sieve. The measurement is expressed on a dry weight basis, according to ASTM Designation D 4318. This procedure requires the use of a liquid limit device, a special tool designed to standardize the arbitrary boundary between a liquid and plastic state of a soil. Estimates of liquid limit are made on soils during soil survey investigations and mapping activities. The liquid limit is usually inferred from clay mineralogy and clay content. If soils are tested later in the laboratory, adjustments are made to the field estimates as needed. Generally, experienced personnel can estimate these values with a reasonable degree of accuracy.

D. Estimates.—The formula in part 618, subpart B, section 618.86, is used in the NASIS database to provide default calculated values if no measurements are available.

E. Entries.—Enter the high, low, and representative values as a range for each horizon. The range of valid entries is from 0 to 400 percent, and tenths (one decimal place) are allowed. However, entries should be rounded to the nearest 5 percent unless they represent measured values or a calculation is used. Enter “0” for nonplastic soils. The liquid limit for organic soil material is not defined and is assigned “null.” A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.102.

618.44 Organic Matter

A. Definition.—“Organic matter percent” is the weight of decomposed plant and animal residue and expressed as a weight percentage of the soil material less than 2 mm in diameter.

B. Significance

(1) Organic matter influences the physical and chemical properties of soils far more than the proportion to the small quantities present would suggest. The organic fraction influences plant growth through its influence on soil properties. It encourages granulation and good tilth, increases porosity and lowers bulk density, promotes water infiltration, reduces plasticity and cohesion, and increases the available water capacity. It has a high capacity to

adsorb and exchange cations and is important to pesticide binding. It furnishes energy to micro-organisms in the soil. As it decomposes, it releases nitrogen, phosphorous, and sulfur. The distribution of organic carbon according to depth indicates different episodes of soil deposition or soil formation.

(2) Soils that are very high in organic matter have poor engineering properties and subside upon drying.

C. Measurement.—Laboratory measurements are made using a dry combustion method to determine percent total carbon. For an estimate of organic carbon in calcareous soils, the carbon present in carbonate compounds, such as $CaCO_3$, must be calculated and then subtracted from the total carbon. This is done using the equation:

percent organic carbon = percent total carbon - [% <2 mm $CaCO_3 \times 0.12$].

The results are given as the percent of organic carbon in dry soil. To convert the figures for organic carbon to those for organic matter, multiply the organic carbon percentage by 1.724. The detailed procedures are outlined in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS.

D. Estimates.—Color and "feel" are the major properties used to estimate the amount of organic matter. Color comparisons in areas of similar materials can be made against laboratory data so that a soil scientist can make estimates. In general, black or dark colors indicate high amounts of organic matter. The contrast of color between the A horizon and subsurface horizons is also a good indicator.

E. Entries.—Enter the high, low, and representative values for the range in organic matter in each horizon. The range of valid entries is from 0 to 100 percent, and hundredths (two decimal places) are allowed.

618.45 Parent Material, Kind, Modifier, and Origin

A. Definition.—Parent material is the unconsolidated material, mineral or organic, from which the soil develops. The soil surveyor considers parent material in developing a model to be used for soil mapping. Soil scientists and specialists in other disciplines use parent material data to help interpret soil boundaries and project performance of the material below the soil. Many soil properties relate to parent material. Among these properties are proportions of sand, silt, and clay; chemical content; bulk density; structure; and the kinds and amounts of fragments. These properties affect interpretations and may be criteria used to separate soil series. Soil properties and landscape information infer parent material. Three data elements—parent material kind, parent material modifier, and parent material origin—describe parent material.

B. Parent Material Kind

(1) Definition.—"Parent material kind" is a term describing the general physical, chemical, and mineralogical composition of the material, mineral or organic, from which the soil develops. Mode of deposition, weathering, or both may be implied or implicit.

(2) Classes.—The list of allowable entries is included in the NASIS data dictionary. Definitions of many of these terms are included in part 629 of this handbook.

(3) Entries.—Enter the applicable class names for each map unit component. Multiple entries are permissible. Multiple rows of parent materials may also be indicated for a single component, such as loess over till over residuum.

C. Parent Material Modifier

(1) Definition.—“Parent material modifier” is the general description of the texture of the parent material. Class limits correspond to those of the general texture groupings defined in the *Soil Survey Manual* and the family category particle-size classes defined in Soil Taxonomy.
(2) Classes.—The classes of parent material modifiers are as follows:
  (i) Clayey
  (ii) Coarse-loamy
  (iii) Coarse-silty
  (iv) Fine-loamy
  (v) Fine-silty
  (vi) Gravelly
  (vii) Loamy
  (viii) Sandy
  (ix) Sandy and gravelly
  (x) Sandy and silty
  (xi) Silty
  (xii) Silty and clayey
(3) Entries.—Enter the appropriate class name to modify the corresponding row of parent material kind.

D. Parent Material Origin

(1) Definition.—“Parent material origin” is the type of bedrock from which the parent material is derived.
(2) Classes.—The allowable class names are included in the NASIS data dictionary and are the same as for the “bedrock kind” data element.
(3) Entries.—Enter the appropriate parent material origin class names that correspond to each parent material kind. Although this data element is intended to be used when “residuum” is the chosen parent material kind, it may also be used with other kinds of parent material.

618.46 Particle Density

A. Definition.—“Particle density” is the mass per unit of volume of the solid soil particle, either mineral or organic. It is also known as specific gravity.

B. Significance.—Particle density is used in the calculation of weight and volume for soil (porosity). The relationship between bulk density, percent pore space, and the rate of sedimentation of solid particles in a liquid depends on particle density. The term “particle density” indicates wet particle density or specific gravity.

C. Measurement.—The standard methods of measurement for particle density are: the ASTM standard test method for specific gravity of soils, ASTM Designation D 854-92, which uses soil materials passing a no. 4 sieve; the method described by Blake and Hartge in Methods of Soil

Analysis, Part 1, Agronomy 9; or the method for volcanic soils described by Bielders and others in Soil Science Society of America Journal 54, pages 822-826.

D. Estimates

(1) Particle density is often assumed to be 2.65 g cm^{-3}; however, many minerals and material of various origins have particle densities less than or greater than this standard. Particle density (Dp) may be calculated using the extractable iron and the organic carbon percentages in the following formula:

$$Dp = \frac{100}{\frac{(1.7 \times OC)}{Dp1} + \frac{(1.6 \times Fe)}{Dp2} + \frac{100 - [(1.7 \times OC) + (1.6 \times Fe)]}{Dp3}}$$

(2) OC is the organic carbon percentage and Fe is the percent extractable iron determined by dithionite-citrate extraction, or by an equivalent method. The particle density of the organic matter (Dp1) is assumed to be 1.4 g cm^{-3}, that of the minerals from which the extractable iron originates (Dp2) is assumed to be 4.2 g cm^{-3}, and that of the material exclusive of the organic matter and the minerals contributing to the extractable Fe (Dp3) is assumed to be 2.65 g cm^{-3}.

E. Entries.—Enter the representative value for the horizon. The range of valid entries is from 0.01 to 5 g cm^{-3}, and hundredths (two decimal places) are allowed.

618.47 Particle Size

A. Definition.—"Particle size" is the effective diameter of a particle as measured by sedimentation, sieving, or micrometric methods. Particle sizes are expressed as classes with specific effective diameter class limits. The broad classes are clay, silt, and sand, ranging from the smaller to the larger of the less than 2 mm mineral soil fraction. It includes fragments of weathered or poorly consolidated fragments that disperse to particles less than 2 mm in diameter.

B. Significance.—The physical behavior of a soil is influenced by the size and percentage composition of the size classes. Particle size is important for most soil interpretations, for determination of soil hydrologic qualities, and for soil classification.

C. Measurement.—Particle size is measured by sieving and sedimentation. The method used is method 3A1, which is outlined in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS. A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.103.

D. Classes.—The USDA uses the following size separates for the <2 mm mineral material:

Figure 618-A17

USDA Particle Size Separates	Size (mm)
Clay, total	<0.002
Silt, total	≥0.002 to <0.05

USDA Particle Size Separates	Size (mm)
Silt, fine	≥0.002 to <0.02
Silt, coarse	≥0.02 to <0.05
Sand total	≥0.05 to <2.00
Very fine sand	≥0.05 to <0.10
Fine sand	≥0.10 to <0.25
Medium sand	≥0.25 to <0.50
Coarse sand	≥0.50 to <1.00
Very coarse sand	≥1.00 to <2.00

Part 618, subpart B, section 618.87, compares the USDA system with the AASHTO and Unified soil classification systems and shows the U.S. standard sieve sizes.

E. Clay Percentage

(1) Definition.—“Total clay percentage” is the weight percentage of the mineral particles less than 0.002 mm in equivalent diameter in the less-than-2-mm soil fraction. Most of the material is in one of three groups of clay minerals or in a mixture of these clay minerals. The groups are kaolinite, smectite, and hydrous mica, the best-known member of which is illite.

(2) Significance.—Physical and chemical activities of a soil are related to the kind and amount of clay minerals. Clay particles may have thousands of times more surface area per gram than silt particles and nearly a million times more surface area than very coarse sand particles. Thus, clay particles are the most chemically and physically active part of mineral soil.

(i) Clay mineralogy and clay percentage have a strong influence on engineering properties and the behavior of soil material when it is used as construction or foundation material. They influence linear extensibility, compressibility, bearing strength, and saturated hydraulic conductivity.

(ii) The kind and amount of clay influence plant growth indirectly by affecting available water capacity, water intake rate, aeration, cation-exchange capacity, saturated hydraulic conductivity, erodibility, and workability. Up to a certain point, an increase in the amount of clay in the subsoil is desirable. Clay can increase the amount of water and nutrients stored in that zone. By slightly slowing the rate of water movement, it can reduce the rate of nutrient loss through leaching. If the amount of clay is great, it can impede water and air movement, restrict root penetration, increase runoff, and, on sloping land, result in increased erosion.

(iii) Clay particles are removed by percolating water from surface and subsurface horizons and deposited in the subsoil horizons. The amount of clay accumulation and its location in the profile provide clues for the soil scientist about soil genesis. Irregular clay distribution as related to depth may indicate lithologic discontinuities, especially if accompanied by irregular sand distribution.

(3) Measurement.—Clay content is measured in the laboratory by the pipette or hydrometer methods after the air-dry soil is pretreated to remove organic matter and soluble salts.

Field estimates of clay content are made by manual methods. The way a wet soil ribbons (develops a long continuous ribbon) when pressed between the thumb and fingers gives a good idea of the amount of clay present. Excessive amounts of sodium can toughen the soil, making the soil feel more clayey. Care should be taken not to overestimate the amount of clay in sodic soils. Accuracy depends largely on frequent and attentive observation. Texture reference samples determined in the laboratory are used by soil scientists to calibrate the feel of soils with various percentages of clay.

(4) Entries.—Enter the high, low, and representative values of the clay total separate as a percent of the material less than 2 mm in size for each horizon. Enter a "0" if the amount is not significant, as in organic layers or in some andic soil materials. The range of valid entries is from 0 to 100 percent, and tenths (one decimal place) are allowed. The representative value chosen should equate to a valid clay total content for the representative texture class posted for each horizon.

F. Sand Percentage

(1) Definition.—"Sand percentage" is the weight percentage of the mineral particles less than 2 mm and greater than or equal to 0.05 mm in equivalent diameter in the less than 2 mm soil fraction. The sand separates recognized are very coarse, coarse, medium, fine, very fine, and total. Respective size limits are shown in section 618.47D above. Much of the sand fraction is composed of fragments of rocks and primary minerals, especially quartz. Therefore, the sand fraction is quite chemically inactive.

(2) Significance.—Physical properties of the soil are influenced by the amounts of total sand and of the various sand fractions present in the soil. Sand particles, because of their size, have a direct impact on the porosity of the soil. This impact influences other properties, such as saturated hydraulic conductivity, available water capacity, water intake rates, aeration, and compressibility related to plant growth and engineering uses.

(3) Measurement.—Sand content is measured in the laboratory by the wet sieving method and then fractionated by dry sieving. Field estimates are made by manual methods. The degree of grittiness in a wet soil sample, when worked between the thumb and forefinger, gives an estimate of the sand content. The size of sand grains may be observed with the naked eye or with the aid of a hand lens.

(4) Entries.—Enter the high, low, and representative value of the sand total separate and each sand size separate (sand very coarse separate, sand coarse separate, sand medium separate, sand fine separate, and sand very fine separate) as a percent of the material less than 2 mm in size for each horizon. The sum of the representative values for the five sand size fractions must equal the representative value for the sand total separate. The range of valid entries is from 0 to 100 percent, and tenths (one decimal place) are allowed. Enter a "0" if the amount is not significant, as in organic layers or in some andic soil materials. The representative values chosen should equate to a valid sand total content and sand size fraction content for the representative texture class posted for each horizon.

G. Silt Percentage

(1) Definition.—"Silt percentage" is the weight percentage of the mineral particles greater than or equal to 0.002 mm but less than 0.05 mm in the less than 2 mm soil fraction. The silt separates recognized are fine, coarse, and total. The respective size limits are listed in paragraph 618.46D above. The silt separate is dominated by primary minerals, especially quartz, and therefore has a low chemical activity.

(2) Significance.—The silt separate possesses some plasticity, cohesiveness, and absorption, but to a much lesser degree than the clay separate. Silt particles act to slow water and air movement through the soil by filling voids between sand grains. A very high content of silt in a soil may be physically undesirable for some uses unless supplemented by adequate amounts of sand, clay, and organic matter.

(3) Measurement

(i) The silt content is measured in the laboratory in two phases. The fine silt is measured using the pipette method on the suspension remaining from the wet sieving process. Aliquots of the diluted suspension are removed at predetermined intervals based on Stokes Law. The aliquots are then dried and weighed. The coarse silt fraction is the difference between 100 percent and the sum of the sand, clay, and fine silt percentages.

(ii) The silt content may be estimated in the field using the ribbon test as described for clay. The content of silt is usually estimated by first estimating the clay and sand portions and then subtracting that number from 100 percent. Silt tends to give the soil a smooth feel.

(4) Entries.—Enter the high, low, and representative value of the silt total separate and each silt size separate (silt coarse separate and silt fine separate) as a percent of the material less than 2 mm in size for each horizon. The sum of the representative values for the two silt size fractions must equal the representative value for the silt total separate. The range of valid entries is from 0 to 100 percent, and tenths (one decimal place) are allowed. Enter a "0" if the amount is not significant, as in organic layers or in some andic soil materials. The representative value chosen should equate to a valid silt total content for the representative texture class posted for each horizon.

618.48 Percent Passing Sieves

A. Definition.—The percent passing sieve numbers 4, 10, 40, and 200 is the weight of material that passes through these sieves, based on the material less than 3 inches (75 mm)* in size and expressed as a percentage.

B. Significance.—Data for the percent passing sieves are used to classify the soil in the engineering classifications and to make judgments on soil properties and performance. Many soil characteristics are influenced by the depth distribution of grain sizes for the soil as well as the soil's mode of deposition, stress history, density, and other features.

C. Measurement.—Measurements involve sieve analysis for the determination of grain size distribution of that portion of the soil having particle diameters between 3 inches and 0.074 mm (no. 200 sieve). ASTM Designations D 422, C 136, and C 117 are applicable procedures. Measurements are made on most benchmark soils and other representative soils in survey areas.

D. Estimates

(1) Estimates of the content of sand, silt, clay, and rock fragments that are made for soils during soil survey investigations and mapping activities are used to estimate percent passing sieves. If samples are tested later in a laboratory, adjustments are made to the field estimates as needed. Generally, experienced personnel can estimate these values with a

high degree of accuracy. Estimates for percent passing sieves can be made from soil texture using the following general guidance:

(i) Percent passing #200 = clay + silt + 1/2 very fine sand.

(ii) Percent passing #40 = 1/2 very fine sand + fine sand + 1/2 medium sand + percent passing #200.

(2) The percent passing #10 equals the less-than-2-mm fraction, and soil texture is based on the less-than-2-mm fraction. Since sieves represent the less-than-3-inch fraction, the #40 and #200 sieve estimates must be adjusted when the percent passing #10 is less than 100 percent. The percent passing #40 and #200 that is determined by texture must be adjusted by multiplying the percent passing #40 and percent passing #200 by the percent passing #10. Pararock fragments are not cemented strongly enough to be retained on sieves. They are crushed and estimated into percent passing sieves. ASTM procedures use a roller crusher as a pretreatment of the soil material prior to sieving. Field estimates should try to replicate this procedure. Discrete artifacts which are either noncohesive or nonpersistent (e.g., paper) are not considered in estimating sieve values.

E. Entries.—Enter the high, low, and representative values to represent the range of percent passing each sieve size for each horizon. The range includes the estimating accuracy as well as the range of values for a soil. The range of valid entries is from 0 to 100 percent, and tenths (one decimal place) are allowed. A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.104.

618.49 Plasticity Index

A. Definition.—“Plasticity index” is the numerical difference between the liquid limit and the plastic limit. It is the range of water content in which a soil exhibits the characteristics of a plastic solid. The plastic limit is the water content that corresponds to an arbitrary limit between the plastic and semisolid states of a soil.

B. Significance.—The plasticity index, when used in connection with the liquid limit, serves as a measure of the plasticity characteristics of a soil. The plasticity chart, given in ASTM Designation D 2487, is a plot of the liquid limit (LL) versus the plasticity index (PI) and is used in classifying soil in the Unified soil classification system. The plasticity index is also a criterion for classifying soil in the AASHTO classification system, as shown in part 618, subpart B, section 618.83. Soils that have a high plasticity index have a wide range of moisture content in which the soil performs as a plastic material. Highly and moderately plastic clays have large PI values.

C. Measurements.—Tests are made on that portion of the soil having particles passing the no. 40, (425 micrometer) sieve, according to ASTM Designation D 423. Measurements are made on most benchmark soils and on other representative soils in survey areas. Estimates of plasticity index are made on all soils during soil survey investigations and mapping activities. The plasticity index is usually not estimated directly: a position on the plasticity chart in ASTM Designation D 2487 is estimated and the plasticity index is determined from the chart. If soils are later tested in the laboratory, adjustments are made to the field procedures as needed. Generally, experienced personnel can estimate these values with a reasonable degree of accuracy. Estimates are expressed in ranges that include the estimating accuracy as well as the range of values from one location to another within the map unit.

D. Estimates.—The formula in part 618, subpart B, section 618.86, is used in the NASIS database to provide default calculated values if no measurements are available.

E. Entries.—Enter the high, low, and representative values to represent the range of plasticity index for each horizon. The range of valid entries is from 0 to 130 percent, and tenths (one decimal place) are allowed. However, entries should be rounded to the nearest 5 percent unless they represent measured values or a calculation is used. Enter "0" for nonplastic soils. The plasticity index for organic soil material is not defined and is assigned "null." A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.102.

618.50 Ponding Depth, Duration Class, Frequency Class, and Month

A. Free water may occur above the soil. Inundation is the condition when the soil is covered by liquid, free water.

B. Definition.—Ponding is the temporary inundation by standing water in a closed depression, including potholes, sloughs, backswamps, playas, and ponds. The water is removed only by deep percolation, transpiration, evaporation, or by a combination of these processes. Ponding of soils is classified according to depth, frequency, duration, and the months in which standing water is most likely to occur.

C. Ponding Depth

(1) Definition.—"Ponding depth" is the depth of the surface water that is ponding inundation on the soil.
(2) Entries.—Enter the high, low, and representative values for the ponding depth, in centimeters, for the map unit component. The range of valid entries is from 0 to 185 cm, and only whole numbers (integers) are allowed.

D. Ponding Duration Class

(1) Definition.—"Ponding duration class" is the average duration, or length of time, of the ponding occurrence.
(2) Classes.—The ponding duration classes are listed below:

Figure 618-A18

Ponding Duration Class	Duration of the Ponding Occurrence
Very brief	0.1 hour to < 48 hours
Brief	48 hours to < 7 days
Long	7 to < 30 days
Very long	≥ 30 days

(3) Entries.—Enter “very brief,” “brief,” “long,” or “very long” for the map unit component. Only use entries if ponding frequency (defined below) occurs more often than “rare.” Ponding duration classes are assigned to months.

E. Ponding Frequency Class

(1) Definition.—“Ponding frequency class” indicates the range in the number of times ponding occurs over a period of time, or the range in the percent probability of a ponding event in any year.
(2) Classes.—The ponding frequency classes are listed below:

Figure 618-A19

Ponding Frequency Class	Definition
None	No reasonable possibility of ponding; less than 0.2 percent chance of ponding in any year or less than 1 time in 500 years.
Rare	Ponding is unlikely but possible; 0.2 percent to less than 5 percent chance of ponding in any year; or 1 time or more in 500 years but less than 5 times in 100 years.
Occasional	Ponding is expected infrequently; 5 to less than 50 percent chance of ponding in any year, or 5 times or more in 100 years but less than 50 times in 100 years.
Frequent	Ponding is likely to occur often; 50 percent or more chance in any year; 50 times or more in 100 years but less than a 100 percent chance of ponding in all months of any year.

(3) Entries.—Enter “none,” “rare,” “occasional,” or “frequent” as appropriate for the map unit component. Yearly ponding frequency classes are assigned to months, indicating the months of most likely occurrence and not the frequency of the ponding during the month. The time period expressed includes 70 percent of the occurrences.

F. Ponding Month

(1) Definition.—“Ponding month” is the calendar months in which ponding is expected.
(2) Classes.—The time of year when ponding is likely to occur is expressed in months for the expected beginning to expected end of the ponding period. The time period expressed includes 70 percent of the occurrences.
(3) Entries.—Yearly ponding frequency classes are assigned to months and indicate the months of occurrence and not the frequency of the ponding during the month. Enter annual frequency in each month of the year in which ponding is expected, as defined above.

G. Significance.—The susceptibility of soils to ponding is important for homes, building sites, and sanitary facilities. Time and duration of the ponding are critical factors in determining plant species. Ponding during the dormant season has few if any harmful effects on plant growth or mortality and may even improve growth.

H. Estimates.—Generally, estimates of ponding frequency and duration can be made for each soil. Where the natural infiltration, saturated hydraulic conductivity, and surface and subsurface drainage of soils is altered, ponding studies are needed to reflect present ponding characteristics.

(1) Evidence of ponding events should be gathered during soil survey fieldwork. High water lines and other signs of maximum water height are recorded. Other records may also exist.
(2) Certain landform features are subject to ponding. These features are characteristics of closed drainage systems with concave, concave slope shape and include potholes, playas, sloughs, and backswamps. Most of these features are recognizable when correlating features on aerial photographs with ground observations. Different kinds of vegetation and soils are normally associated with these geomorphic features.
(3) The vegetation that grows in ponded areas may furnish clues to past ponding and indicate the potential for ponding in the future. Generally, native vegetation in ponded areas consists of obligate and facultative wet hydrophytes. Some plant species are intolerant of ponding and do not grow in areas that are ponded.
(4) The soil provides clues to past ponding, but characteristics vary according to climate and soil conditions. Some of the clues (alone or in any combination) are—
  (i) A dark surface horizon or layer overlying a gleyed subsoil.
  (ii) Many prominent redoximorphic features that have low value and chroma.
  (iii) Capillary transport and concentrations of carbonates or sulfates, or both, in the upper soil horizons.
  (iv) Dark colors and high levels of organic matter throughout the profile.

618.51 Pores

A. Definition.—Pores are small openings or voids ("pore space") between soil particles and aggregates in the soil material. The term includes matrix, nonmatrix, and interstructural pore space. For water movement at low suction and conditions of satiation, the nonmatrix and interstructural porosity have particular importance.

(1) Matrix Pores.—Matrix pores are formed by the agents that control the packing of the primary soil particles (i.e., primary packing voids). These pores are usually smaller than nonmatrix pores. Additionally, their aggregate volume and size can change markedly according to water state for soil horizons or layers with high extensibility.
(2) Nonmatrix Pores.—Nonmatrix pores are relatively large voids that are expected to be present both when the soil is moderately moist or wetter as well as in drier states. The voids are not bounded by the planes that delimit structural units. Nonmatrix pores may be formed by roots, animals, the action of compressed air, and other agents. The size of the distribution of nonmatrix pores usually bears no relationship to the particle-size distribution and the related matrix pore-size distribution.
(3) Interstructural Pores.—Interstructural pores are delimited by structural units. Inferences as to the interstructural porosity may be obtained from the structure description. Commonly, interstructural pores are at least crudely planar.

B. Description of Pores.—Nonmatrix pores are described by quantity, size, shape, and vertical continuity (generally in that order).

(1) Pore Quantity
  (i) Definition.—"Pore quantity" is defined by classes that pertain to the number of a selected size of pores per unit area of undisturbed soils. The unit area that is evaluated varies according to the size class of the pores: 1 cm^2 for very fine and fine pores, 1 dm^2 for medium and coarse pores, and 1 m^2 for very coarse pores.
  (ii) Classes.—The pore quantity classes are described below:

Figure 618-A20

Pore Quantity Class	Number of Pores per Unit Area
Few	<1
Common	≥1-5
Many	≥5

(iii) Entries.—Enter pore quantity as pores/area. Enter the high, low, and representative values as whole numbers between 0 and 99 for the horizon.

(2) Pore Size

(i) Definition.—“Pore size” is the average diameter of the pore.

(ii) Classes.—The pore size classes are described below:

Figure 618-A21

Pore Size Class	Pore Size (mm)
Very fine	<1
Fine	≥1 to <2
Medium	≥2 to <5
Coarse	≥5 to <10
Very Coarse	≥10

(iii) Entries.—Enter a single class or classes for the horizon.

(3) Pore Shape

(i) Definition.—“Pore shape” is a description of the multi-areal shape of the pore. The shapes of nonmatrix pores are dendritic tubular (approximately cylindrical, elongated, and branching), irregular (nonconnected cavities or chambers), tubular (approximately cylindrical and elongated), or vesicular (approximately spherical or elliptical). The primary packing voids between soil particles or rock fragments are referred to as interstitial pores.

(ii) Classes.—The pore shape classes are:

- Dendritic tubular
- Interstitial
- Irregular
- Tubular
- Vesicular

(iii) Entries.—Enter one of the classes from the pore shape list for the horizon.

(4) Vertical Continuity

(i) Definition.—“Vertical continuity” is the average vertical distance through which the minimum pore diameter exceeds 0.5 mm when the soil layer is moist or wetter.

(ii) Classes.—The vertical continuity classes are described below:

Figure 618-A22

Vertical Continuity Class	Vertical Distance (cm)
Low	<1
Moderate	≥1 to <10
High	≥10

(iii) Entries.—Enter one of the vertical continuity classes.

618.52 Reaction, Soil (pH)

A. Definition.—"Soil reaction" is a numerical expression of the relative acidity or alkalinity of a soil.

B. Classes.—The descriptive terms for reaction and their respective and inclusive ranges in pH are given below:

Figure 618-A23

Reaction Class	Range in pH
Ultra acid	1.8–3.4
Extremely acid	3.5–4.4
Very strongly acid	4.5–5.0
Strongly acid	5.1–5.5
Moderately acid	5.6–6.0
Slightly acid	6.1–6.5
Neutral	6.6–7.3
Slightly alkaline	7.4–7.8
Moderately alkaline	7.9–8.4
Strongly alkaline	8.5–9.0
Very strongly alkaline	9.1–11.0

C. Significance

(1) A principal value of soil pH is the information it provides about associated soil characteristics. Two examples are phosphorus availability and base saturation. Soils that have a pH of approximately 6 or 7 generally have the most ready availability of plant nutrients. Strongly acid or more acid soils have low extractable calcium and magnesium; a high solubility of aluminum, iron, and boron; and a low solubility of molybdenum. In addition, these soils may possibly have organic toxins and generally have a low availability of nitrogen and phosphorus. At the other extreme are alkaline soils. Calcium, magnesium, and molybdenum are abundant where there is little or no toxic aluminum and nitrogen is readily available. If pH is above 7.9, the soils may have an inadequate availability of iron, manganese, copper, zinc, and especially phosphorus and boron.

(2) Soil reaction is one of several properties used as a general indicator of soil corrosivity or the soil's susceptibility to dispersion. In general, soils that are either highly alkaline or highly acid are likely to be corrosive to steel. Soils that have pH <5.5 are likely to be corrosive to concrete. Soils that have pH >8.5 are likely to be highly dispersible and may have a piping problem.

(3) Soil reaction is used for soil classification in the required characteristics for sulfidic materials, in the key to calcareous and reaction classes for mineral soils, in the key to reaction classes for Histosols and Histels, and in criteria for certain taxa such as Sulfic subgroups.

D. Measurement.—The most common soil laboratory measurement of pH is the 1:1 water method. In this method, a crushed and sieved soil sample is mixed with an equal amount of water and a measurement is made of the suspension using a pH meter. Another common method, used for mineral and organic soils, is the 0.01M calcium chloride method. A new method to indicate the possible presence of sulfidic materials is the hydrogen peroxide test, delta pH for acid sulfate soils. This method uses hydrogen peroxide to rapidly oxidize sulphur compounds, which releases elemental sulphur and quickly decreases the pH. In NASIS, the pH values derived from these three methods are populated in separate data elements.

(1) The pH values derived from water suspension are affected by field applications of fertilizer or other salts in the soil, the content of carbon dioxide in the soil, and the moisture content at the time of sampling. The 0.01M calcium chloride method reduces these influences.
(2) The laboratory procedure for measuring pH by the 1:1 water and 0.01M calcium chloride methods are described in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS.
(3) The procedure for measuring pH by the hydrogen peroxide test, delta pH for acid sulphate soils method is described in Soil Survey Investigations Report No. 51, *Soil Survey Field and Laboratory Methods Manual*, Version 2.0, 2014, USDA, NRCS.

E. Estimates.—A variety of field test kits are available for determination of pH in the field. The methods include a water-soluble dye, which is mixed with soil and thus produces a color that is compared with a chart; a dye-impregnated paper, which changes color according to differences in pH; and portable glass electrodes. Each State office can recommend a suitable pH method for the soils in the State. If requested, the NSSC Kellogg Soil Survey Laboratory makes suggestions for suitable methods for field measurements and furnishes NRCS soil scientists with the proper chemicals.

F. Entries.—Soil reaction (pH) is time and moisture dependent, and water pH can vary up to a whole unit during the growing season. The range of pH should reflect the variations. The 1:1 water method generally is used with mineral soils. Mineral and organic soils are measured in a 1:2 0.01M calcium chloride solution and with the hydrogen peroxide test, delta pH method. Separate entries are made by horizon for pH 1:1 water, pH 1:2 0.01M calcium chloride, and final pH oxidized, as needed. Enter the high, low, and representative values of the appropriate estimated pH range for each horizon. If laboratory measurements or accurate field estimates are available, the high and low values do not need to correspond with reaction class limits. However, if data is limited, then pH values may reflect reaction class limits, such as 1.8-3.4, 3.5-4.4, etc., or a combination of reaction classes, such as 4.5-5.5, can be entered.

618.53 Restriction Kind, Depth, Thickness, and Hardness

A. Restriction Kind

(1) Definition.—“Restriction kind” is the type of nearly continuous layer that has one or more physical, chemical, or thermal properties that significantly reduce the movement of water and air through the soil or that otherwise provide an unfavorable root environment. Bedrock (e.g., limestone), cemented horizons (e.g., duripan), densic material (e.g., dense till), frozen horizons or layers (e.g., permanent ground ice), and horizontally oriented, human-manufactured materials (e.g., concrete) are examples of subsurface layers that are kinds of restrictions.
(2) Significance.—Restrictive layers limit plant growth by restricting the limits of the rooting zone. They also impede or restrict the movement of soil water vertically through the soil

profile and have a direct impact on the quality and quantity of ground water and surface water. Restrictions are important for both soil interpretations and soil classification.

(3) Measurement.—Identify and describe restrictive soil layers in the field. Observe, measure, and record the restriction kind along with their depth, thickness, and hardness (defined below). When describing pedons, identify types or kinds of restrictions by suffix symbols, such as "d," "f," "m," "r," "v," or "x," or by the master layers "M" or "R." Use measurements or observations made throughout the extent of occurrence of a soil as a basis for estimates of restriction kind.

(4) Entries.—Enter the appropriate choice for the kind of restrictive horizon or layer from the following list:

- (i) Abrupt textural change
- (ii) Bedrock, densic
- (iii) Bedrock, lithic
- (iv) Bedrock, paralithic
- (v) Cemented horizon
- (vi) Densic material
- (vii) Duripan
- (viii) Fragipan
- (ix) Manufactured layer
- (x) Natric
- (xi) Ortstein
- (xii) Permafrost
- (xiii) Petrocalcic
- (xiv) Petroferric
- (xv) Petrogypsic
- (xvi) Placic
- (xvii) Plinthite
- (xviii) Salic
- (xix) Strongly contrasting textural stratification
- (xx) Sulfuric

B. Restriction Depth

(1) Definition.—"Restriction depth" is the vertical distance from the soil surface to the upper and lower boundaries of the restriction.

(2) Measurement.—Use measurements or observations made throughout the extent of occurrence of a soil as a basis for estimates of restriction depth.

(3) Entries.—Restriction depth values used to populate component data in NASIS are not specific to any one point. They are a reflection of commonly observed values based on field observations and are intended to model the component as it occurs throughout the map unit. Enter the high, low, and representative values for the top and bottom restriction depths in centimeters using whole numbers (integers).

C. Restriction Thickness

(1) Definition.—"Restriction thickness" is the distance from the top to the bottom of a restrictive layer.

(2) Significance.—Restriction thickness has a significant impact on the ease of mechanical excavation.

(3) Measurement.—Use observations made throughout the extent of occurrence of a soil as a basis for estimates of restriction thickness.

(iv) Entries.—Restriction thickness values used to populate component data in NASIS are not specific to any one point. They are a reflection of commonly observed values based on field observations and are intended to model the component as it occurs throughout the map unit. Enter the high, low, and representative values for the thickness in centimeters. The range of valid entries is from 1 to 999, and only whole numbers (integers) are allowed.

D. Restriction Hardness

(1) Definition.—"Restriction hardness" is the rupture resistance cemented of an air-dried, then submerged block-like specimen of mineral material. Ice is not applicable.

(2) Significance.—Restriction hardness has a significant impact on the ease of mechanical excavation. Use excavation difficulty classes (defined above) to evaluate the relationships of restriction layers to excavations.

(3) Measurement.—Use observations made throughout the extent of occurrence of a soil as a basis for estimates of restriction hardness. For measurements of the restriction hardness, use the procedures and classes of cementation listed with the rupture resistance classes. Classes are described for like specimens about 25-30 mm on edge that are air-dried and then submerged in water for at least 1 hour. Compress the specimen between extended thumb and forefinger, between both hands, or between the foot and a nonresilient flat surface. If the specimen resists compression, drop a weight onto it from progressively greater heights until it ruptures. Failure is the point of the initial detection of deformation or rupture. Stress applied in the hand should be over a 1-second period. Learn the tactile sense of the class limits by applying force to top-loading scales and sensing the pressure through the tips of the fingers or through the ball of the foot. Use postal scales for the resistance range that is testable with the fingers. Use a bathroom scale for the higher rupture resistance range.

(4) Classes.—Restriction hardness is rated using the classes and operation descriptions listed below:

Figure 618-A24

Restriction Hardness (Rupture Resistance) Class	Operation Description*
Noncemented	Fails under very slight force applied slowly between thumb and forefinger (<8N).
Extremely weakly cemented	Fails under slight force applied slowly between thumb and forefinger (8 to 20N).
Very weakly cemented	Fails under moderate force applied slowly between thumb and forefinger (20 to 40N).
Weakly cemented	Fails under strong force applied slowly between thumb and forefinger (about 80N maximum force can be applied) (40 to 80N).
Moderately cemented	Cannot be failed between thumb and forefinger but can be failed between both hands or by placing specimen on a nonresilient surface and applying gentle force underfoot (80 to 160N).

Restriction Hardness (Rupture Resistance) Class	**Operation Description***
Strongly cemented	Cannot be failed in hands but can be failed underfoot by full body weight (about 800N) applied slowly (160 to 800N).
Very strongly cemented	Cannot be failed underfoot by full body weight but can be failed by <3J blow (800N to 3J).
Indurated	Cannot be failed by blow of 3J (> 3J).

* Both force (Newtons, N) and energy (joules, J) are employed. The number of Newtons is 10 times the kilograms of force. One joule is the energy delivered by dropping a 1 kg weight a distance of 10 cm.

618.54 Saturated Hydraulic Conductivity

A. Definition.—"Saturated hydraulic conductivity" is the ease with which pores of a saturated soil transmit water. Formally, it is the proportionality coefficient that expresses the relationship of the rate of water movement to hydraulic gradient in Darcy's Law (a law that describes the rate of water movement through porous media). It is expressed in micrometers per second. To convert micrometers per second to inches per hour, multiply micrometers per second by 0.1417. The historical definition of "saturated hydraulic conductivity" is the amount of water that would move vertically through a unit area of saturated soil in unit time under unit hydraulic gradient.

B. Significance.—Saturated hydraulic conductivity is used in soil interpretations. It is also known as K_{sat}. Saturated hydraulic conductivity is used for soil classification in criteria for certain taxa, such as the Albaqualfs and Albaquults great groups.

C. Measurement.—Means of measurement, such as the Amoozemeter and double-ring infiltrometers, provide some basis for estimation of saturated hydraulic conductivity. No method has been accepted as a standard. Since measurements are difficult to make and are only available for relatively few soils, estimates of saturated hydraulic conductivity are based on soil properties.

D. Estimates.—The soil properties that affect saturated hydraulic conductivity are distribution, continuity, size, and shape of pores. Since the pore geometry of a soil is not readily observable or measurable, observable properties related to pore geometry are used to make estimates of saturated hydraulic conductivity. These properties are texture, structure, pore size, density, organic matter content, and mineralogy. Part 618, subpart B, section 618.88, provides a guide for estimating saturated hydraulic conductivity according to soil texture and bulk density or according to specified overriding conditions.

(1) In making estimates, the soil characteristic that exerts the greatest control for many soils is texture.

(2) The general relationships shown in part 618, subpart B, section 618.88, are adjusted up or down depending on bulk density. Structure, pore size, organic matter content, clay mineralogy, and other features observed within the soil profile, such as consistency, dry layers in wet seasons, root mats or absence of roots, and evidence of perched water levels or standing water, are good field indicators for adjusting estimates.

(3) Water movement through bedrock for layers designated as R and Cr can be estimated from the guide in part 618, subpart B, section 618.89, of this handbook.

E. Entries.—Enter the high, low, and representative values of saturated hydraulic conductivity for each horizon. The range of valid entries is from 0 to 705 µm s^{-1}, and four decimal places are allowed.

618.55 Slope Aspect

A. Definition.—"Slope aspect" is the direction toward which the surface of the soil faces.

B. Significance.—Slope aspect may affect soil temperature, evapotranspiration, winds received, and snow accumulation.

C. Measurement.—Slope aspect is measured clockwise from true north as an angle between 0 and 360 degrees. Tools such as geographic information systems (GIS) can be used to consistently predict and identify slope aspect.

D. Entries.—For map unit components that are aspect dependent, enter the slope aspect counterclockwise, slope aspect clockwise, and slope aspect representative. The range of valid entries is from a minimum of 0 degrees to a maximum of 360 degrees. Record values to the nearest whole number (integer). The fields may be left NULL for those components that are not aspect dependent.

(1) "Slope aspect counterclockwise" is one end of the range in characteristics for the slope aspect of a component. This end of the range is expressed in degrees measured clockwise from true north, but in the direction counterclockwise from the representative slope aspect.
(2) "Slope aspect clockwise" is one end of the range in characteristics for the slope aspect of a component. This end of the range is expressed in degrees measured clockwise from true north, but in the direction clockwise from the representative slope aspect.
(3) "Slope aspect representative" is the common, typical, or expected direction toward which the surface of the soil faces, measured in degrees clockwise from true north.

618.56 Slope Gradient

A. Definition.—"Slope gradient" is the difference in elevation between two points and is expressed as a percentage of the distance between those points. For example, a difference in elevation of 1 meter over a horizontal distance of 100 meters is a slope of 1 percent.

B. Significance.—Slope gradient influences the retention and movement of water, the potential for soil slippage and accelerated erosion, the ease with which machinery can be used, soil-water states, and the engineering uses of the soil. Slope is used for soil classification in criteria for certain taxa, such as the Fluvents suborder, Fluvaquents great group, Fluvaquentic and Fluventic subgroups, and several Cumulic subgroups.

C. Measurement.—Slope gradient is usually measured in the field with a hand level or clinometer. The range is determined by summarizing data from several sightings. Slope gradient may also be determined through the use of a digital elevation model (DEM) and geospatial software. A DEM is a digital file format that is the representation of the elevation values over a topographic surface by a regular array of z-values.

(1) DEMs are available in many resolutions and sources. Resolution refers to the smallest measurement unit represented by the data. A resolution is selected to capture and represent the soil resource of concern for the project area. Resolution will typically be 5 or 10 meters to a side. Resolutions larger than 10 meters are not used except in special circumstances, such as remote, wildland surveys where higher resolution data is unavailable.

(2) DEM sources are developed using light detection and ranging (LiDAR), interferometric synthetic aperture radar (IFSAR) and older methods, including electronic image correlation, manual profiling on stereoplotters, and contour-to-grid interpolation. USGS is the largest provider of DEMs with sources derived from all methods except IFSAR. DEMs produced using older methods may have artifacts that preclude it from use.

(3) A project area may have DEMs of multiple resolutions with overlapping extents. This process is resampling and should proceed from finer to coarser resolutions. In these cases, a seamless DEM is developed at a common resolution that meets the objectives of the project. For example, data at 3-meter and 5-meter resolution is resampled to match adjacent 10-meter DEMs.Two common methods are available, resample and aggregate. Resample will convert from an input resolution to any output resolution with elevation values assigned using bilinear or cubic convolution. Aggregate will convert to output resolutions that are evenly divisible by the input resolution with output values assigned using the mean or median of the aggregation. There is no practical difference in the output produced from these methods.

(4) Slope gradient is calculated from a DEM using geospatial software based on two common algorithms, Evans and Young (see Evans, 1979, in subpart B, section 618.106) and Zevenbergen and Thorne (1987) (see subpart B, section 618.106). The Evans and Young algorithm is often the sole method available. The output unit for slope gradient is percent for soil survey purposes. Differences in the output between these methods is not of practical significance for soil survey purposes.

(5) Slope gradient is determined based on a neighborhood. Neighborhood size may be thought of as analogous to the length parameter in a conventional slope measurement. The common implementation in geospatial software uses a 3 x 3 neighborhood, typically a range of 10 to 40 meters. This neighborhood works well for larger cell resolutions like 10 or 30 meters, but results in noisy slope gradients when using small cell resolutions like 1 or 3 meters. Software that allows setting neighborhood size as a parameter is an important option for derivation of slope gradient as resampling is not required. Smaller neighborhoods emphasize local variation, while larger neighborhoods emphasize broad trends. Neighborhood size is based on the terrain and soil mapping objectives.

(6) Neighborhood shape is a parameter available with some software. Most implementations of slope gradient use a square neighborhood explicitly defined by the cell resolution. A circular neighborhood has been shown to provide a more accurate representation of slope gradient (see Shi et.al., 2007, 2012, in subpart B, section 618.106).

(7) The slope gradient calculation will produce a layer containing floating point data type. Converting the original slope gradient layer to an integer data type is acceptable. Integer data types result in smaller file sizes and quicker processing operations. Statistical parameters like majority and median are available automatically from some geospatial software when integer data types are used as inputs.

D. Entries.—Enter the high, low, and representative values to represent the range of slope gradient as a percentage for the map unit component. The range of valid entries is to the nearest integer from 0 to 99 percent. Tenths (one decimal place) are allowed but are only used for representative values less than 1 percent. These values may be determined by a statistical summary of the slope gradient layer for a given map unit layer. Slope gradient distributions are seldom normal, eliminating the use of conventional statistical parameters like mean and standard deviation as tools for determining the high, low and representative values. These values should be based on the robust parameters of percentiles. The representative value is based on the median. The low and high should be based on ranges that capture a majority of the area represented in a map unit. Using the 10th and 90th percentiles as the low and high represents 80 percent of the area.

618.57 Slope Length, USLE

A. Definition.—"Slope length" is the horizontal distance from the origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or runoff becomes concentrated in a defined channel. Refer to Agriculture Handbook 703.

B. Significance.—Slope length has considerable control over runoff and potential accelerated water erosion. Slope length is combined with slope gradient in erosion prediction equations to account for the effect of topography on erosion.

C. Measurement

(1) Slope length is measured from the point of origin of overland flow to the point where the slope gradient decreases enough that deposition begins or runoff becomes concentrated in a defined channel. In cropland, defined channels are usually ephemeral gullies or, in rare cases where they are near a field edge, are a classic gully or stream. Surface runoff will usually concentrate in less than 400 feet (120 meters), although longer slope lengths of up to 1000 feet are occasionally found. The maximum distance allowed in erosion equations is 1000 feet (305 meters). Conversion to the horizontal distance is made in the conversion process within the equation model.

(2) Assume no support practices. Ignore practices such as terraces or diversions. Slope length is best determined by pacing or measuring in the field. Do not use contour maps to estimate slope lengths unless contour intervals are 1 foot or less. Slope lengths estimated from contour maps are usually too long because most maps do not have the detail needed to indicate all ephemeral gullies and concentrated flow areas that end the slope lengths. Refer to figures 4-1 through 4-10 within Agriculture Handbook 703 for more landscape guidance.

D. Entries.—Enter the high, low, and representative values for the range for each map unit component. Enter a whole number that represents the slope length in meters, from the point of origin of overland flow to the point of deposition or concentrated flow, of the slope on which the component lies. The slope length may be fully encompassed within one map unit or may cross several map units. The minimum value is 0, and the maximum value used in erosion equations is 305 meters. The NASIS database allows valid entries from 0 to 4000 meters.

618.58 Sodium Adsorption Ratio

A. Definition.—"Sodium adsorption ratio" (SAR) is a measure of the amount of sodium (Na^+) relative to calcium (Ca^{2+}) and magnesium (Mg^{2+}) in the water extracted from a saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration. SAR is calculated from the following equation:

$$SAR = Na^+ / [(Ca^{2+} + Mg^{2+})/2]^{0.5}$$

B. Significance.—Sodium adsorption ratio is used for soil classification in the required characteristics for the natric horizon, in the key to soil orders and key to suborders of Inceptisols and Mollisols, and in criteria for certain taxa such as Sodic subgroups. Soils that have values for sodium adsorption ratio of 13 or more may have an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity and aeration, and a general degradation of soil structure.

C. Measurement.—The concentration of Na, Ca, and Mg ions is measured in a water extract from a saturated soil paste. The method is described in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS. The sodium adsorption ratio is then calculated from the molar concentrations of the three cations using the equation shown above in section 618.58A.

D. Entries.—Enter the high, low, and representative values for the range of sodium adsorption ratio for each horizon. Enter "0" where SAR is negligible. The range of valid entries is from 0 to 9999, and tenths (one decimal place) are allowed.

618.59 Soil Erodibility Factors, USLE, RUSLE2

A. Definition.—Soil erodibility factors Kw and Kf quantify soil detachment by runoff and raindrop impact. These erodibility factors are indexes used to predict the long-term average soil loss from sheet and rill erosion under crop systems and conservation techniques. Factor Kw applies to the whole soil, and factor Kf applies only to the fine-earth (less than 2.0 mm) fraction. The procedure for determining the Kf factor is outlined in Agriculture Handbook 703, "Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)," USDA, Agricultural Research Service, 1997. The K factors for soils in Hawaii and the Pacific Basin were extrapolated from local research. The nomograph, shown in part 618, subpart B, section 618.91, was not used to determine K factors for soils in Hawaii.

B. Classes.—Experimentally measured Kw factors vary from 0.02 to 0.69. For soil interpretations, the factors are grouped into 14 classes. The classes are identified by a representative class value as follows: 0.02, 0.05, 0.10, 0.15, 0.17, 0.20, 0.24, 0.28, 0.32, 0.37, 0.43, 0.49, 0.55, and 0.64.

C. Significance.—Soil erodibility factors Kw or Kf are used in the erosion prediction equations USLE and RUSLE.

(1) Soil properties that influence rainfall erosion are those that affect—
  (i) Infiltration rate, movement of water through the soil, and water storage capacity.
  (ii) Dispersion, detachability, abrasion, and mobility by rainfall and runoff.

(2) Some of the most important properties are texture, organic matter content, structure size class, and the saturated hydraulic conductivity of the subsoil.

D. Estimates

(1) The Kw factor is measured by applying a series of simulated rainstorms on freshly tilled plots. Direct measurement of K factors is both costly and time consuming and is conducted only for a few selected soils.
(2) Reliable estimates of Kf factor are obtained from the soil erodibility nomograph, which is presented on page 11 of Agriculture Handbook 537 and reproduced in part 618, subpart B, section 618.91, or by using the soil erodibility equation. The nomograph integrates the relationship between the Kf factor and the following five soil properties:
(3) Percent silt plus very fine sand
 (i) Percent sand greater than or equal to 0.10 mm
 (ii) Organic matter content
 (iii) Soil structure
 (iv) Saturated hydraulic conductivity
(4) The soil erodibility equation which follows also provides an estimate of Kf.

$$\text{K factor} = \{2.1 \times M^{1.14} \times 10^{-4} \times (12\text{-}a) + 3.25 \times (b\text{-}2) + 2.5 \times (c\text{-}3)\} /100$$

where: M = (percent si + percent vfs) × (100 - percent clay)

<u>Example</u>: For a soil with 29.0% silt, 12.3% very fine sand, and 36% clay

M = (29.0+12.3) × (100-36) = 2,643.20.

a = percent organic matter (0, 1, 2, 3, or 4).

b = soil structure code (1, = very fine granular, 2, = fine granular, 3, = med or coarse granular, or 4 = blocky, platy, or massive)

c = profile saturated hydraulic conductivity code (1, 2, 3, 4, 5, or 6).

Use the layer with the lowest K_{sat} RV (representative value) in the permeability control section. The permeability control section is the zone from the top of the mineral soil layer being evaluated to a depth of 50 cm below the top of that soil layer but should not exceed a profile depth of 200 cm. The permeability control section guarantees that a specific zone is only considered relative to the mineral soil layer being evaluated. Include the permeability of any bedrock or other nonsoil layers in the permeability control section. Note that the codes were initially established using the 1951 edition of the *Soil Survey Manual*. The codes correspond to the following saturated hydraulic conductivity ranges.

Figure 618-A25

Profile permeability class code	Permeability class of 1951	Saturated hydraulic conductivity range µm/sec	Saturated hydraulic conductivity classes (1993)
6	Very slow	<0.30	very low or mod. low
5	Slow	≥0.30 to <1.20	mod. low
4	Slow or mod.	≥1.20 to <4.80	mod. high
3	Moderate	≥4.80 to <15.00	mod. high or high
2	Mod. or rapid	≥15.00 to <30.00	high
1	Rapid	≥30.00	high or very high

(5) The accuracy of the nomograph and equation has been demonstrated for a large number of soils in the United States. However, the nomograph and the equation may not be applicable to some soils having properties that are uniquely different from those used in developing the nomograph. For example, the nomograph does not accurately predict Kf factors for certain Oxisols in Puerto Rico or the Hawaiian Islands; some soils with andic soil properties, organic soil materials, or low activity clays; and some calcareous or micaceous soils. In these cases, Kf factors are estimated using the best information at hand and knowledge of the potential for rainfall erosion. See Agriculture Handbook 703 for more information.

(6) When using the nomograph and the equation, care should be taken to select an organic matter percentage that is most representative of the horizon being considered, assuming long-term cultivation. It is acceptable to use linear interpolations between plotted lines on the nomograph and values in hundredths (two decimal places) for organic matter content in the equation. For horizons that have organic matter content greater than 4 percent, use the 4-percent curve in the nomograph and exactly 4 percent in the equation.

(7) Rock or pararock fragments are not taken into account in the nomograph or the soil erodibility equation. If fragments are substantial, they have an armoring effect. Pararock fragments are assumed to break down with cultivation or other manipulation and so are not used in determining Kw factors. If a soil has mixtures of rock and pararock fragments, the Kw factor should reflect the degree of protection afforded only by the rock fragments. Guidelines for determining Kw factors are as follows:

   (i) First, use the soil erodibility nomograph shown in part 618, subpart B, section 618.91, or the soil erodibility equation shown above to determine the Kf factor for the soil material less than 2 mm in diameter.

   (ii) Then use the table in part 618, subpart B, section 618.92, to convert the Kf value of the soil fraction less than 2 mm in diameter, which is derived from either the nomograph in part 618, subpart B, section 618.91, or from the soil erodibility equation, to a Kw factor adjusted for the total volume of rock fragments. The Kw factor is adjusted only when the total content of rock fragment values in the layer, by volume, is equal to or greater than 15 percent. If total rock fragment content, by volume, is less than 15 percent, the Kw factor equals the Kf factor. In practice, the representative values (RVs) for rock fragment volume, as populated in the NASIS "Horizon Fragments" table, are summed for each size fraction to compute the total rock fragment content for the layer.

   (iii) If the soil on site contains more or less rock fragments than the mean of the range reported, adjustments can be made in Kf by using part 618, subpart B, section 618.92. Select the estimates of total rock fragment volume percentages, then use part 618, subpart B, section 618.92. In part 618, subpart B, section 618.92, go to the line with the rock fragment volume percentage and find, in the appropriate line, the nearest value to the Kf factor. Within that column, read the Kw factor on the line with the percentage of rock fragments of the soil for which you are making the estimate. Round the K factor displayed in the table to the closest acceptable K factor class entry, as shown below. This is the new Kw factor adjusted for rock fragments on site.

E. Entries.—Enter the coordinated values for Kw and Kf factor classes for each horizon posted, except organic horizons.

(1) The acceptable entries for Kw and Kf classes are: 0.02, 0.05, 0.10, 0.15, 0.17, 0.20, 0.24, 0.28, 0.32, 0.37, 0.43, 0.49, 0.55, and 0.64. Use the comparison reports and calculation

script in NASIS for help in populating Kf and Kw factors. Use the reports to print or export the currently stored values for Kf and Kw factor classes for each component in a selected set for comparison with the computed Kf and Kw factor classes using the calculation script formulas. The comparison reports give a preview of the results of the K factor calculations and should be used before the decision is made to run the calculation and save the new data.

(2) Soil horizons that do not have rock fragments are assigned equal Kw and Kf factors. In horizons where total rock fragments are 15 percent or more, by volume, the Kw factor is always less than the Kf factor. For example:

Figure 618-A26

Depth (in)	USDA Texture	Kw	Kf
0-5	GR-L	0.20	0.32
0-5	L	0.32	0.32
0-5	GRV-L	0.10	0.32
0-46	CL	0.28	0.28
46-60	SL	0.20	0.20

(3) Soils that have similar properties and erosivity should be grouped in similar K factor classes.

618.60 Soil Erodibility Factors for WEPP

A. Definition.—Soil erodibility factors for WEPP include interrill erodibility (Ki), rill erodibility (Kr), and critical shear stress (Tc). These erodibility factors for the WEPP erosion model quantify the susceptibility of soil detachment by water. They predict the long-term average soil loss which results from sheet and rill erosion under various alternative combinations of crop systems and conservation techniques.

B. The Ki, Kr, and Tc factors are used in a continuous simulation computer model that predicts soil loss and deposition on a hillslope. Reference NSERL Report No. 9, USDA, Agricultural Research Service, National Erosion Research Laboratory, August 1994, documentation version 94.7. This procedure does not include data for soils with highly weathered material (e.g., oxic horizons) and those with andic soil properties. These factors are quantitative and calculated using experimental equations. They are different from the soil erodibility factors used in USLE and RUSLE.

(1) Interrill Erodibility (Ki)

(i) Definition.—“Interrill erodibility (Ki)” is the susceptibility of detachment and transport of soil particles by water. It is the susceptibility of the soil to movement to a rill carrying runoff.

(ii) Significance.—Interrill erodibility (Ki) is a measure of sediment delivery rate to rills as a function of rainfall intensity. The Ki values for soil need to be adjusted if factors that influence the resistance of soil to detachment occur. These factors include live and dead root biomass, soil freezing and thawing, and mechanical and livestock compaction.

(iii) Measurement.—Interrill erodibility (Ki) measurements are determined from rainfall simulation experiments. These experiments require the use of specialized equipment and specialized measurement techniques in a research setting.

(iv) Calculations.—Use the following equations:

- For cropland soils with 30 percent or more sand:

  Ki = 2,728,000 + 192,100 × (% very fine sand)

  Where very fine sand must be less than or equal to 40 percent; if very fine sand is greater, use 40 percent.

- For cropland soils with less than 30 percent sand:

  Ki = 6,054,000 - 55,130 × (% clay)

  Where clay must not exceed 50 percent; if clay is greater, use 50 percent.

(v) Entries.—The computer generates entry values using the above formulas. Allowable Ki values range from 2,000,000 to 11,000,000.

(2) Rill Erodibility (Kr)

(i) Definition.—"Rill erodibility (Kr)" is a measure of the susceptibility of a soil to detachment by flowing water. As rill erodibility (Kr) increases, rill erosion rates increase.

(ii) Significance.—Rill erodibility (Kr) is often defined as the soil detachment per unit increase in shear stress of clear water flow. The rate of soil detachment in rills varies because of a number of factors, including soil disturbance by tillage, living root biomass, incorporated residue, fragments, soil consolidation, freezing and thawing, and wheel and livestock compaction.

(iii) Measurement.—Rill erodibility (Kr) measurements are determined by rainfall simulation and flow simulation experiments. These experiments require the use of specialized equipment and specialized measurement techniques in a research setting.

(iv) Calculations.—Use the following equations:

- For cropland soils with 30 percent or more sand:

  Kr = 0.00197 + 0.00030 × (% very fine sand) + 0.03863 × EXP(-1.84 × ORGMAT)

  Where—

  - Organic matter (ORGMAT) is the organic matter in the surface soil (assuming that organic matter equals 1.724 times organic carbon content). Organic matter must exceed 0.35 percent; if less, use 0.35 percent.
  - Very fine sand must be less than or equal to 40 percent; if greater, use 40 percent.

- For cropland soils with less than 30 percent sand:

  Kr = 0.0069 + 0.134 × EXP(-0.20 × % Clay)

- Where clay must be 10 percent or greater; if less, use 10 percent.

(v) Entries.—The computer generates the value by using the above formulas. Allowable Kr values range from 0.002 to 0.045 s/m.

(3) Critical Shear Stress (Tc)

(i) Definition.—“Critical shear stress (Tc)” is the hydraulic shear that must be exceeded before rill erosion can occur.

(ii) Significance.—Critical shear stress (Tc) is important in the rill detachment equation. It is the shear stress below which no soil detachment occurs. Critical shear stress (Tc) is the shear intercept on a plot of detachment by clear water versus shear stress in rills.

(iii) Measurements.—Critical shear stress (Tc) is derived from a specialized research project.

(iv) Calculations.—Use the following equations:

- For cropland soils with 30 percent or more sand:

  Tc = 2.67 + 0.065 × (% clay) - 0.058 × (% very fine sand)

  Where very fine sand must be less than or equal to 40 percent; if greater, use 40 percent.

- For cropland soils with less than 30 percent sand:

  Tc = 3.5

(v) Entries.—No manual entry is needed. The value is computer generated using the above formulas. Allowable Tc values range from 1 to 6 N/m^2.

618.61 Soil Moisture Status

A. Definition.—“Soil moisture status” is the mean monthly soil water state at a specified depth.

B. Classes.—The water state classes used in soil moisture status are: dry, moist, and wet. These classes are defined as follows:

Figure 618-A27

Water State Class	Definition
Dry	≥15 bar suction
Moist	< 15 bar to ≥ 0.0 bar (moist plus nonsatiated wet)
Wet	< 0.0 bar; free water present (satiated wet)

C. Significance.—Soil moisture status is a recording of the generalized water states for a soil component. Soil moisture greatly influences vegetation response, root growth, excavation difficulty, albedo, trafficability, construction, conductivity, soil chemical interactions, workability, chemical transport, strength, shrinking and swelling, frost action, seed germination, and many other properties, qualities, and interpretations. Soil moisture states are significant to soil taxonomic classification, wetland classification, and other classification systems. The recording of soil moisture states helps to document the soil classification as well as convey information useful for crop and land management models.

D. Measurement

(1) Soil water status can be measured using tensiometers or moisture tension plates. Soil water status also can be field estimated. Chapter 3 of the *Soil Survey Manual* provides more

information. It is important to note that the three water state classes and eight subclasses described in the *Soil Survey Manual* are used to describe the moisture state at a point in time for individual pedons (spatial and temporal point data), while the water state classes discussed here are used to estimate the mean monthly aggregated moisture conditions for a map unit component. As a consequence, only three classes are used and the definitions for the moist and wet classes are modified from the definitions in the *Soil Survey Manual*. The wet class used here includes only the satiated wet class and corresponds to a free water table. The moist class is expanded to include the nonsatiated wet class given in the *Soil Survey Manual*.

(2) Dry is separated from moist at 15 bar suction. Wet satiated has a tension of 0.0 bar or less (zero or positive pore pressure).

(3) Changes in natural patterns of water movement from dams and levees are considered in evaluating and entering soil moisture status. Infiltration, saturated hydraulic conductivity, and organic matter, which affect soil moisture movement, are strongly impacted by land cover and land use. Land use and land cover should be considered as a mapping tool for separating map units or map unit components. The difference in soil moisture status resulting from differences in land use and land cover constitute a difference in soil properties. However, conservation practices, such as irrigating and fallowing the land, alter the soil moisture status but are not considered in the map unit component data. Use-dependent databases may allow entries for these altered states in the future. Permanent installations, such as drainage ditches and tile, affect soil moisture status, and the drained condition should be reflected in the soil moisture status entries for map unit components that are mapped as "drained." Undrained areas are mapped as "undrained" components, and the entries for soil moisture status reflect the undrained condition.

(4) Irrigation and drainage canals are shown on soil maps; their effects on the soil should be shown in the properties of the soils in mapping and in the property records. Soils that are now wet because of excessive irrigation and leaking canals should be mapped, and their properties should reflect the current soil moisture status.

E. Guiding Concepts

(1) The intent is to describe a mean moisture condition, by month, for a soil component. Layer depths may or may not be the same as horizon depths in the "Component Horizon" table. Layers define the zone having a specific soil moisture state. If the soil is wet throughout 0 to 200 cm, then one entry ("wet") is made for 0 to 200 cm for that month.

(2) For frozen soils, enter the appropriate soil moisture state that the soil would have if thawed. For example, if the soil is frozen and then determined to be wet when thawed, enter "wet."

(3) The horizons can be subdivided or combined, as appropriate, into layers for the various soil moisture states as needed. Remember that these are monthly averages for the extent of the component across the landscape.

(4) The entries are expected to come from the best estimates that local knowledge can provide. When possible, use documented measurements. The information as aggregated data is not expected to be exact but should be generalized and reflect an average condition.

(5) Entries for the representative values (RV) on distance to the upper and lower boundary of the moisture layer should reflect the soil moisture conditions expected in a normal year, as defined in the latest edition of the Keys to Soil Taxonomy.

(6) Make entries for each month by layer. Enter the dominant condition for the month. This is the condition that exists for more than 15 days on the long-term average. The low and high

values represent the depth range within the component for the normal year; they should not represent the extremes, such as years of drought.

(7) If the depth to free water fluctuates during the month, use the depth for the average between the high and low levels.

F. Entries.—Enter the soil moisture status as “dry,” “moist,” or “wet” for each soil layer for each month. Enter only one soil moisture state for a given layer. The number of layers depends upon the number of changes of soil moisture status in the profile. Enter the values for component soil moisture depth to top and depth to bottom that represents the distance, in whole centimeters, from the soil surface to the top and bottom respectively, of each soil layer for each month. Part 618, subpart B, section 618.97, contains examples of entries in a worksheet format that graphs soil moisture status by month and depth.

618.62 Soil Slippage Potential

A. Definition.—“Soil slippage potential” is the hazard that a mass of soil will slip when vegetation is removed, soil water is at or near saturation, and other normal practices are applied. Conditions that increase the hazard of slippage but are not considered in this rating are undercutting lower portions or loading the upper parts of a slope or altering the drainage or offsite water contribution to the site, such as through irrigation. The publication “Landslides Investigation and Mitigation Special Report 247” (Transportation Research Board, National Research Council, 1996) provides additional information on landscape slippage.

B. Significance.—Slippage is an important consideration for engineering practices, such as constructing roads and buildings, and for forestry practices.

C. Estimates.—Soil slippage potential classes are estimated by observing slope; lithology, including contrasting lithologies; strike and dip; surface drainage patterns; and occurrences of such features as slip scars and slumps.

D. Guides.—Use part 618, subpart B, section 618.96, “Key Landforms and Their Susceptibility to Slippage,” as a guide for rating the hazard of slippage.

E. Entries.—Enter one of the following soil slippage potential classes for the component:

(1) High (unstable)
(2) Medium (moderately unstable)
(3) Low (slightly unstable to stable)

618.63 Soil Temperature

A. Definition.—“Soil temperature” is the temperature calculated as both the mean annual temperature at a single depth in the soil and the mean monthly temperature calculated at a specified depth range for each month of the year.

B. Significance.—Soil temperature is important to many biological and physical processes that occur in the soil. Plant germination and growth are closely related to soil temperature. Cold soil temperatures effectively create a thermal pan in the soil. Roots cannot uptake moisture or nutrients below the threshold temperatures specific to plant species. Chemical reactions are temperature sensitive. Pesticide breakdown, residue breakdown, microbiological activity in the soil, and nutrient conversions relate to soil temperature. Soil temperature gradients affect soil moisture and salt movement. Soil temperatures below freezing especially affect soil saturated hydraulic conductivity, excavation difficulty, and construction techniques. Soil temperature is used in soil classification and hydric soil determinations. Additional information on soil temperature is provided in chapter 3 of the *Soil Survey Manual* and chapter 4 of Soil Taxonomy.

C. Estimates.—Soil temperature according to depth can be estimated from measured soil temperatures of the vicinity. Air temperature fluctuations, soil moisture, aspect, slope, color, snow cover, plant cover, and residue cover affect soil temperature. Estimates of soil temperature should take these factors into account when soil temperatures are extrapolated from one soil map unit component to another.

D. Measurement.—Soil temperature can be measured by many types of thermometers, including mercury, bimetallic, thermisters, and thermocouples. Many types of thermometers can be configured for remote, unattended operation.

E. Mean Annual Soil Temperature (MAST)

(1) Definition.—“Mean annual soil temperature (MAST)” is the temperature generally determined at a depth of 50 cm below the soil surface or at the upper boundary of a root-limiting layer as defined in Soil Taxonomy, whichever is shallower.
(2) Entries.—Enter the high, low, and representative values for the range of mean annual soil temperature for the component as the long-term average of the mean monthly soil temperatures in the “Component” table. The long-term average is generally considered to be a 30-year average. The range of valid entries is from -40 to 50 degrees Celsius, and tenths (one decimal place) are allowed.

F. Mean Monthly Soil Temperature

(1) Definition.—“Mean monthly soil temperature” is the long-term monthly average of the mean daily high and daily low soil temperatures at a specified depth for the month in question. Long-term is generally considered to be a 30-year average.
(2) Entries.—Enter soil temperature for the component as the long-term monthly average of the mean daily soil temperature at a specified depth for the month in question in the “Component Soil Temperature” table. The long-term average is generally considered to be a 30-year average. The range of valid entries is from -25 to 50 degrees Celsius, and only whole numbers (integers) are allowed. The number of layers populated depends upon the number of changes of soil temperature status in the profile.

G. Soil Temperature, Depth to Top

(1) Definition.—“Soil temperature, depth to top” is the distance from the top of the soil to the upper boundary of the soil temperature layer.
(2) Entries.—Enter the value for “soil temperature, depth to top” that represents the distance, in centimeters, from the soil surface to the top of each soil temperature layer for each month in the “Component Soil Temperature” table.

H. Soil Temperature, Depth to Bottom

(1) Definition.—“Soil temperature, depth to bottom” is the distance from the top of the soil to the lower boundary of the soil temperature layer.
(2) Entries.—Enter the value for “soil temperature, depth to bottom” that represents the distance, in centimeters, from the soil surface to the bottom of each soil temperature layer for each month in the “Component Soil Temperature” table.

618.64 Subsidence, Initial and Total

A. Definition.—“Subsidence” is the decrease in surface elevation as a result of the drainage of wet soils that have organic layers or semifluid, mineral layers. Initial subsidence is the decrease of surface elevation that occurs within the first 3 years of the drainage of these wet soils. Total subsidence is the potential decrease of surface elevation as a result of the drainage of these wet soils.

B. Significance

(2) The susceptibility of soils to subsidence is an important consideration for organic soils that are drained. If these soils are drained for community development, special foundations are needed for buildings. Utility lines, sidewalks, and roads that lack special foundations may settle at different rates, thus causing breakage, high maintenance costs, and inconvenience. If the soils are drained for farming, the long-term effects of subsidence, the possible destruction of land if it subsides below the water table, and possible legal implications where the soils are in wetlands must be considered.
(3) Subsidence as a result of drainage is attributed to the factors in the following list. The first three factors are responsible for the initial subsidence that occurs rapidly, specifically within about 3 years after the water table is lowered.
    (i) Shrinkage from drying
    (ii) Consolidation because of the loss of ground-water buoyancy
    (iii) Compaction from tillage or manipulation
    (iv) Wind erosion
    (v) Burning
    (vi) Biochemical oxidation
(4) After the initial subsidence, a degree of stability is reached and the loss of elevation declines to a steady rate, primarily because of oxidation. The oxidation and subsidence continue at this slower rate until stopped by the water table or underlying mineral material.
    (i) The rate of subsidence depends on—
    (ii) Ground-water depth
    (iii) Amount of organic matter
    (iv) Kind of organic matter
    (v) Soil temperature
    (vi) pH
    (vii) Biochemical activity

C. Estimates

(1) A number of studies have been made to measure actual subsidence. Other useful studies have measured the bulk density of organic soils after drainage. Based on these studies, some general guidelines can be given for initial and total subsidence.

(2) Initial subsidence generally is about half of the depth to the lowered water table or to mineral soil, whichever is shallower. It occurs within about 3 years after drainage. Total subsidence is the total depth to the water table or the thickness of the organic layer, whichever is shallower. It is rarely reached, except where organic layers are thin or where drainage systems have been installed for a long time.

D. Measurement.—After organic soils have been drained and cultivated for a number of years, they reach a nearly steady rate of subsidence that is reflected by the rather stable bulk density. Unpublished studies by the NSSC Kellogg Soil Survey Laboratory have shown that the bulk density of the organic component, such as that with the percent mineral calculated out, stabilizes at around 0.27 g/cc for surface layers and 0.18 g/cc for subsurface layers. These values can be used to calculate the amount of subsidence at some time in the future as compared to the thickness of soil at the time of observation or measurement. The procedure is as follows:

(1) Sample the surface and subsurface layers for field state bulk density. Methods are described in the Handbook of Soil Survey Investigations Field Procedures, I 4-2, 1971, USDA, Soil Conservation Service, and in Soil Survey Investigations Report No. 42, *Soil Survey Laboratory Methods Manual*, Version 4.0, November 2004, USDA, NRCS.

(2) Calculate out the weight contribution of the mineral component to obtain the bulk density of the organic component (DbOM). This manipulation allows bulk densities to be on a common base so that various layers can be compared. The formula for the computation is as follows: $DbOM = Db\,(1 - \text{percent mineral}/100)$, where Db is the field state bulk density.

(3) Calculate the subsidence percent (SP) for surface and subsoil horizons as follows:

(i) For surface horizons:

$$SP = 100 - [(DbOM/0.27) \times 100]$$

(ii) For subsurface horizons:

$$SP = 100 - [(DbOM/0.18) \times 100]$$

Where DbOM is obtained from step (2).

(4) Convert initial subsidence percent to depth of subsidence in inches as follows:

$$S = SPsur \times Tsur + SPsub \times Tsub$$

Where—

S = depth of subsidence in inches

SPsur = subsidence percent of the surface horizon

Tsur = thickness of the surface horizon

SPsub = subsidence percent of the subsurface horizon

Tsub = thickness of the subsurface horizon above the water table or the mineral soil, whichever is shallower

E. Entries.—Enter the high, low, and representative values that represent the range for initial and total subsidence, in centimeters, for the map unit component. The range of valid entries is from 0 to 999, and only whole numbers (integers) are allowed. If subsidence is not a concern, enter “0.”

618.65 Sum of Bases

A. Definition.—"Sum of bases" is the sum of the basic cations calcium, magnesium, potassium, and sodium that are extractable from the <2 mm soil fraction using a solution of ammonium acetate (NH_4OAc, pH 7).

B. Significance.—Sum of bases is important for certain evaluations of soil nutrient availability or of the effect of waste additions to the soil. Sum of extractable bases is used directly in soil classification as a criterion to classify soils in most of the Eutric subgroups of Andisols. It is also used indirectly in soil classification to calculate percent base saturation by the sum of cations method. Base saturation by sum of cations is used as a criterion for Ultisols; Ultic subgroups of Alfisols, Andisols, and Mollisols; Alfic and Dystric subgroups of Inceptisols; and Alfic subgroups of Spodosols.

C. Measurement.—Sum of bases is calculated from the results of methods outlined in Soil Survey Investigations Report No. 42, *Soil Survey Laboratory Methods Manual*, Version 4.0, November 2004, USDA, NRCS. Sum of bases is reported in centimoles per kilogram (cmol(+) kg^{-1}), which are equivalent to milliequivalents per 100 grams (meq 100 g^{-1}) of soil.

D. Entries.—Enter the range of sum of bases as milliequivalents per 100 grams (meq 100 g^{-1}) of soil for the horizon. The range of valid entries is from 0 to 300, and tenths (one decimal place) are allowed.

618.66 Surface Fragments

A. Definition.—"Surface fragments" are unattached, cemented pieces of bedrock, bedrocklike material, durinodes, concretions, nodules, or pedogenic horizons (e.g., petrocalcic fragments) 2 mm or larger in diameter and woody material 20 mm or larger in diameter that are exposed at the surface of the soil. Surface fragments can be rock fragments, pararock fragments, or wood fragments, as defined in section 618.32. Vegetal material other than wood fragments, whether live or dead, is not included.

B. Surface Fragment Cover Percent

(1) Definition.—"Surface fragment cover percent" is the percent of ground covered by fragments 2 mm or larger in diameter (20 mm or larger in diameter for wood fragments).
(2) Significance.—Fragments on the soil surface are used as map unit phase criteria and greatly affect the use and management of the soil. They affect equipment use, erosion, excavation, and construction. They act as mulch, slowing evaporation and armoring the soil against rainfall impact. They also affect the heating and cooling of soils.
(3) Estimates.—An estimation of cover by surface fragments can be made visually without quantitative measurement, by transect techniques, or by some combination of visual and quantitative measures. Chapter 3 of the *Soil Survey Manual* provides more information.
(4) Entries.—Enter the high, low, and representative values for the percent of the surface covered by each size class and kind of fragment populated in the "Component Surface Fragments" table in the NASIS database. The range of valid entries is from 0 to 100 percent, and hundredths (two decimal places) are allowed.

C. Surface Fragment Kind

(1) Definition.—"Surface fragment kind" is the lithology or composition of the surface fragments 2 mm or larger in diameter (20 mm or larger in diameter for wood fragments).
(2) Significance.—Fragments vary according to their resistance to weathering. Consequently, fragments of some lithologies are more suited than others for use as building stone, road building material, or riprap to face dams and stream channels.
(3) Entries.—Enter the appropriate fragment kind name for the record of fragments populated in the "Component Surface Fragments" table in the NASIS database. The class names are present in a choice list and can also be viewed in the NASIS data dictionary.

D. Surface Fragment Size

(1) Definition.—"Surface fragment size" is the size based on the multiaxial dimensions of the surface fragments.
(2) Significance.—The size of surface fragments is significant to the use and management of the soil. The adjective form of fragment size is used as phase criteria for naming map units. The size affects equipment use, excavation, construction, and recreational uses.
(3) Classes

Classes of surface fragment size are subdivided based on the shape of the fragments (described below).

- Flat fragment classes are described below:

Figure 618-A28

Flat Fragment Class	**Length of Fragment (mm)**
Channers	≥2 to <150
Flagstones	≥150 to <380
Stones	≥380 to <600
Boulders	≥600

- Nonflat fragment classes are described below:

Figure 618-A29

Nonflat Fragment Class	**Diameter (mm)**
Gravel	≥2 to <75*
Fine gravel	≥2 to <5
Medium gravel	≥5 to <20
Coarse gravel	≥20 to <75

Cobbles	≥75 to <250
Stones	≥250 to <600
Boulders	≥600

(4) Gravel is a collection of fragments having a diameter ranging from ≥2 to <75 mm. Individual fragments in this size range are properly referred to as pebbles, not "gravels." For fragments that are less than strongly cemented, "para" is used as a prefix to the above terms (e.g., paracobbles).

(5) Entries.—Enter the high, low, and representative values for each size class populated in the "Component Surface Fragments" table in the NASIS database. Valid entries are values of 2 millimeters (mm) or larger, and only whole numbers (integers) are allowed.

E. Mean Distance Between Rocks

(1) Definition.—"Mean distance between rocks" is the average distance between surface stones, boulders, or both, measured between edges.

(2) Significance.—The mean distance between rocks is a field clue for naming stony or bouldery map units. The closer the distance, the more equipment limitations there are for harvesting forestland or soil cultivation.

(3) Estimates.—Table 3-12 of the *Soil Survey Manual* shows the distance between stones and boulders if the diameter is 0.25 m, 0.6 m, or 1.2 m. This table should be used with caution because stones and boulders are rarely equally spaced or have the same diameter.

(4) Entries.—Enter the high, low, and representative values for the mean distance between rocks. The range of valid entries is from 0 to 50 meters, and hundredths (two decimal places) are allowed.

F. Surface Fragment Roundness

(1) Definition.—"Surface fragment roundness" is an expression of the sharpness of edges and corners of surface fragments.

(2) Classes.—The surface fragment roundness classes are described below:

Figure 618-A30

Roundness Class	Definition
Very angular	Strongly developed faces with very sharp, broken edges
Angular	Strongly developed faces with sharp edges (SSM)
Subangular	Detectable flat faces with slightly rounded corners
Subrounded	Detectable flat faces with well rounded corners (SSM)
Rounded	Flat faces absent or nearly absent with all corners rounded (SSM)
Well rounded	Flat faces absent with all corners rounded

(3) Entries.—Enter the appropriate surface fragment roundness class name for the record of surface fragments populated in the "Component Surface Fragments" table in the NASIS database.

G. Surface Fragment Hardness

(1) Definition.—"Surface fragment hardness" is equivalent to the rupture resistance cemented of a surface fragment of specified size that has been air-dried and then submerged in water.

(2) Measurements.—Procedures and classes of cementation are listed with the rupture resistance classes in the *Soil Survey Manual*. Classes are described for similar specimens about 25-30 mm on edge which are air-dried and then submerged in water for at least 1 hour. The specimen is compressed between extended thumb and forefinger, between both hands, or between the foot and a hard flat surface. If the specimen resists compression, a weight is dropped onto it from progressively greater heights until it ruptures. Failure is considered at the initial detection of deformation or rupture. Stress applied in the hand should be over a 1-second period. The tactile sense of the class limits may be learned by applying force to top-loading scales and sensing the pressure through the tips of the fingers or through the ball of the foot. Postal scales may be used for the resistance range that is testable with the fingers. A bathroom scale may be used for the higher rupture resistance range.

(3) Significance.—The hardness of a surface fragment is significant where the rupture resistance class is strongly cemented or greater. These classes can impede or restrict the movement of soil water vertically through the soil profile and have a direct impact on the quality and quantity of ground water and surface water.

(4) Classes.—The surface fragment hardness (rupture resistance) classes are the following:

  (ii) Extremely weakly cemented
  (iii) Very weakly cemented
  (iv) Weakly cemented
  (v) Moderately cemented
  (vi) Strongly cemented
  (vii) Very strongly cemented
  (viii) Indurated

(5) Entries.—Enter the appropriate class name for each record of surface fragments populated in the "Component Surface Fragments" table in the NASIS database. Choose the term without the word "cemented" (e.g., choose the "moderately" class to represent the moderately cemented class).

H. Surface Fragment Shape

(1) Definition.—"Surface fragment shape" is a description of the overall shape of the surface fragment.

(2) Classes.—The surface fragment shape classes are "flat" and "nonflat."

(3) Entries.—Enter the appropriate surface fragment shape class name for each record of surface fragments populated in the "Component Surface Fragments" table in the NASIS database.

618.67 T Factor

A. Definition.—The "T factor" is the soil loss tolerance (in tons per acre). It is defined as the maximum amount of erosion at which the quality of a soil as a medium for plant growth can be maintained. This quality of the soil to be maintained is threefold in focus. It includes maintaining the surface soil as a seedbed for plants, the atmosphere-soil interface to allow the entry of air and water into the soil and still protect the underlying soil from wind and water erosion, and the total soil volume as a reservoir for water and plant nutrients, which is preserved by minimizing soil loss. Erosion losses are estimated by USLE and RUSLE2.

A. Classes.—The classes of T factors are: 1, 2, 3, 4, and 5.

B. Significance.—Soil loss tolerances commonly serve as objectives for conservation planning on farms. These objectives assist in the identification of cropping sequences and management systems that can maximize production and also sustain long-term productivity. T factors represent the goal for maximum annual soil loss.

C. Guidelines.—Conservation objectives for soil loss tolerance include maintaining a suitable seedbed and nutrient supply in the surface soil, maintaining an adequate depth and quality of the rooting zone, and minimizing unfavorable changes in water status throughout the soil. A single T factor is assigned to each map unit component.

D. Estimates.—The T factor is assigned to soils without respect to land use or cover. T factors are assigned to compare soils and do not imply differences to vegetation response directly. Many of the factors used to assign a T factor are also important to vegetation response, but the T factor is not assigned to imply vegetation sensitivity to all vegetation. The general guideline given in part 618, subpart B, section 618.93, is used to assign T factors but more specific criteria are used to select limiting soil properties.

E. Entries.—The estimated soil loss tolerance should be calculated from the soil properties and qualities posted in the database for each map unit component based generally on the guideline given in part 618, subpart B, section 618.93. Acceptable values are: 1, 2, 3, 4, and 5.

618.68 Taxonomic Family Temperature Class

A. Definition

(1) The soil temperature classes are part of the family categorical level as defined in Soil Taxonomy. They differ from "soil temperature regimes" (Data Element: taxonomic temp regime) in that the cryic temperature regime is divided between the frigid and isofrigid classes based on differences in mean winter and mean summer soil temperatures. Soil temperature classes are based on mean annual and mean seasonal soil temperatures using the Celsius (centigrade) scale and taken either at a depth of 50 cm from the soil surface or at a lithic or paralithic contact, whichever is shallower.

(2) For soil families in Gelisols, Gelic suborders, and Gelic great groups, the soil temperature classes, defined in terms of the mean annual soil temperature, are as follows:

(i) Hypergelic: -10 °C or lower

    (ii) Pergelic: -4 to -10 °C
    (iii) Subgelic: +1 to -4 °C
(3) For soil families that have a difference of 6 °C or more between mean summer (June, July, and August in the Northern Hemisphere) temperature and mean winter (December, January, and February in the Northern Hemisphere) temperature, the soil temperature classes, defined in terms of the mean annual soil temperature, are as follows:
    (i) Frigid: Lower than 8 °C
    (ii) Mesic: 8 to 15 °C
    (iii) Thermic: 15 to 22 °C
    (iv) Hyperthermic: 22 °C or higher
(4) For soil families that have a difference of less than 6 °C between the mean summer and mean winter soil temperatures, the soil temperature classes, defined in terms of the mean annual soil temperature, are as follows:
    (i) Isofrigid: Lower than 8 °C
    (ii) Isomesic: 8 to 15 °C
    (iii) Isothermic: 15 to 22 °C
    (iv) Isohyperthermic: 22 °C or higher

B. Significance.—All soils have a taxonomic soil temperature class. Soil temperature classes are used as family differentiae in all the orders defined in *Soil Taxonomy*. The names are used as part of the family name unless the criteria for a higher taxon carry the same limitation. The frigid or isofrigid class is implied in all cryic suborders and great groups, but the class is not used as part of the family name because it would be redundant.

C. Estimates.—Estimates of soil temperature classes are made with models that use climatic data including mean annual and mean seasonal air temperatures, precipitation, and evapotranspiration. Some models include snow cover, topographic, and vegetative inputs.

D. Measurement.—The Celsius (centigrade) scale is the standard. It is assumed that the temperature is that of a nonirrigated soil. The soil temperature classes are based on long-term averages of mean annual and mean seasonal soil temperatures taken either at a depth of 50 cm from the soil surface or at a lithic or paralithic contact, whichever is shallower.

E. Entries.—Enter the appropriate soil temperature class from the following list:

(1) Frigid
(2) Hypergelic
(3) Hyperthermic
(4) Isofrigid
(5) Isohyperthermic
(6) Isomesic
(7) Isothermic
(8) Mesic
(9) Pergelic
(10) Subgelic
(11) Thermic
(12) Not used

618.69 Taxonomic Moisture Class

A. Definition.—Soil moisture classes refer to the soil moisture regimes defined in *Soil Taxonomy*. Soil moisture regimes are defined by the presence or absence either of ground water or of water held at a tension of less than 1500 kPa, in the soil or in specific horizons, by periods of the year.

B. Significance.—All soils have a soil moisture regime. Soil moisture regimes are used as differentiae in all the orders defined in Soil Taxonomy. Data on the moisture regime are used for making interpretations for cropland agriculture, correlating soils to ecological sites, and determining suitability for wildlife habitat. The moisture regime of some soils is not apparent in the classification given in Soil Taxonomy. Ustolls and Xerolls, for example, can have an aridic moisture regime. Some soils have more than one moisture regime. An example is a soil that meets the requirements of the aquic moisture regime in the wet season and also meets the requirements of the ustic regime.

C. Estimates.—Estimates of soil moisture regimes are made with models that use climatic data, including mean annual and mean seasonal air temperatures, precipitation, and evapotranspiration. Some models include topographic and vegetative inputs. The soil moisture control section, also defined in *Soil Taxonomy*, is used to facilitate the estimation of soil moisture regimes. For more guidance, see Soil Survey Technical Note 9, available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_053566.

D. Measurement.—The soil moisture regimes are based on annual and seasonal soil moisture measurements taken in the soil moisture control section. The soil should not be irrigated, fallowed, or influenced by other moisture-altering practices.

E. Entries.—Enter the appropriate soil moisture regimes from the following list:

(1) Aquic
(2) Aridic (torric)
(3) Peraquic
(4) Perudic
(5) Udic
(6) Ustic
(7) Xeric

618.70 Taxonomic Moisture Subclass (Subclasses of Soil Moisture Regimes)

A. Definition.—"Subclasses of soil moisture regimes" are defined at the subgroup categorical level in Soil Taxonomy. The criteria differ among the great groups. For example, aquic, aridic, and udic are subclasses of the soil moisture regime in Haplustalfs. A subclass is entered for all soils in a great group that meet the subclass criteria, even if the subclass is not part of the taxonomic classification. For example, aquic, aridic, udic, or typic should be used as a subclass of the soil moisture regime in Lithic Haplustalfs if the criteria are met.

B. Significance.—Subclasses of soil moisture regimes are used at the subgroup categorical level in all orders in Soil Taxonomy except Histosols. They typically indicate an intergrade between two moisture regimes that affect the use and management of the soil. The subclasses of soil moisture regimes are used for making interpretations for cropland agriculture, correlating soils to ecological sites, and determining suitability for wildlife habitat.

C. Estimates.—Estimates of subclasses of soil moisture regimes are made with models that use climatic data, including mean annual and mean seasonal air temperatures, precipitation, and evapotranspiration. Some models include topographic and vegetative inputs. The soil moisture control section, also defined in Soil Taxonomy, is used to facilitate estimation of some subclasses of soil moisture regimes. For more guidance, see Soil Survey Technical Note 9, available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_053566.

D. Measurement.—The subclasses of soil moisture regimes are based on annual and seasonal soil moisture measurements taken in the soil moisture control section. The soil should not be irrigated, fallowed, or influenced by other moisture-altering practices.

E. Entries.—Enter the appropriate subclass of soil moisture regimes from the following list:

(1) Aeric
(2) Anthraquic
(3) Aquic
(4) Aridic (torric)
(5) Oxyaquic
(6) Typic
(7) Udic
(8) Ustic
(9) Xeric

618.71 Taxonomic Temperature Regime (Soil Temperature Regimes)

A. Definition.—“Soil temperature regimes” refer to the temperature regimes as defined in *Soil* Taxonomy.

B. Significance.—Soil temperature regimes are used as differentiae above the family categorical level in all orders in Soil Taxonomy. (Soil temperature classes, defined above, are used as family differentiae.) Soil temperature regimes greatly affect the use and management of soils, particularly the selection of adapted plants. Temperature regimes are used for making interpretations for cropland agriculture, correlating soils to ecological sites, and determining suitability for wildlife habitat.

C. Estimates.—Estimates of soil temperature regimes are made with models that use climatic data, including mean annual and mean seasonal air temperatures, precipitation, and evapotranspiration. Some models include topographic and vegetative inputs.

D. Measurement.—The soil temperature regime is based on mean annual and seasonal soil temperatures using the Celsius (centigrade) scale and taken either at a depth of 50 cm from the soil surface or at a lithic or paralithic contact, whichever is shallower.

E. Entries.—Enter the appropriate soil temperature regimes from the following list:

(1) Gelic

(2) Cryic
(3) Frigid
(4) Mesic
(5) Thermic
(6) Hyperthermic
(7) Isofrigid
(8) Isomesic
(9) Isothermic
(10) Isohyperthermic

618.72 Texture Class, Texture Modifier, and Terms Used in Lieu of Texture

A. Definition.—"Texture class" refers to the soil texture classification used by the U.S. Department of Agriculture as defined in the *Soil Survey Manual*. Soil texture is the relative proportion, by weight, of the particle separate classes finer than 2 mm in equivalent diameter. The material finer than 2 mm is the fine-earth fraction. Material 2 mm or larger is rock or pararock fragments. An interactive online soil texture calculator is available at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167. Enter the percent sand and clay, and the calculator will do the rest.

B. Significance.—Soil texture influences engineering works and plant growth and indicates how soils formed. Soil texture has a strong influence on soil mechanics and the behavior of soil when it is used as construction or foundation material. It influences such engineering properties as bearing strength, compressibility, saturated hydraulic conductivity, shrink-swell potential, and compaction. Engineers are also particularly interested in rock and pararock fragments. Soil texture influences plant growth by its affect on aeration, the water intake rate, the available water capacity, the cation-exchange capacity, saturated hydraulic conductivity, erodibility, and workability. Changes in texture as related to depth are indicators of how soils formed. When texture is plotted with depth, smooth curves indicate translocation and accumulation. Irregular changes in particle-size distribution, especially in the sand fraction, may indicate lithologic discontinuities, specifically differences in parent material. Soil texture is used for soil classification in criteria for certain taxa such as the Psamments suborder, "Psamm" great groups, and Arenic, Grossarenic, and Psammentic subgroups. Soil texture is also used in the family category of Soil Taxonomy for differentiae such as particle-size class.

C. Measurement.—USDA texture can be measured in the laboratory by determining the proportion of the various size particles in a soil sample. The analytical procedure is called particle-size analysis or mechanical analysis. Stone, gravel, and other material 2 mm or larger are sieved out of the sample and thus are not considered in the analysis of the sample. Their amounts are measured separately. Of the remaining material smaller than 2 mm, the amount of the various sizes of sand is determined by sieving. The amount of silt and clay is determined by a differential rate of settling in water. Either the pipette or hydrometer method is used for the silt and clay analysis. Organic matter and dissolved mineral matter are removed in the pipette procedure but not in the hydrometer procedure. The two procedures are generally very similar, but a few samples, especially those with high organic matter or high soluble salts, exhibit wide discrepancies. The detailed procedures are outlined in Soil Survey Investigations Report No. 42, S*oil Survey Laboratory Methods Manual*, Version 4.0, November 2004, USDA, NRCS.

D. Estimates

(1) The determination of soil texture for the less-than-2-mm material is made in the field mainly by feeling the soil with the fingers. The soil must be well moistened and rubbed vigorously between the fingers for a proper determination of texture class by feel. This method requires skill and experience but good accuracy can be obtained if the field soil scientist frequently checks his or her estimates against laboratory results. Many NRCS offices collect reference samples for this purpose. The content of particles ≥2 mm cannot be evaluated by feel. The content of the fragments is determined by estimating the proportion of the soil volume that they occupy. Fragments in the soil are discussed in section 618.32.

(2) Each soil scientist must develop the ability to determine soil texture by feel for each genetic soil group according to the standards established by particle-size analysis. Soil scientists must remember that soil horizons that are in the same texture class but are in different subgroups or families may have a different feel. For example, natric horizons generally feel higher in clay than "non-natric" horizons. Laboratory analysis generally shows that the clay in natric horizons is less than the amount estimated from the field method. The scientist needs to adjust judgment and not the size distribution standards.

E. Entries.—Texture is displayed by the use of six data elements in the NASIS database: texture class, texture modifier, texture modifier and class, stratified texture flag, representative value indicator, and terms used in lieu of texture. Only use multiple textures if they interpret the same for the horizon. Only textures that represent complete horizons should be entered. In NASIS the representative value indicator is identified (i.e., representative? = yes) for the single row that contains the texture term considered typical for each interpretive horizon of the component. This choice should match the representative values of the various soil particle-size separates posted elsewhere in the database.

F. Texture Class

(1) Definition

(i) "Texture class" is an expression, based on the USDA system of particle sizes, for the relative portions of the various size groups of individual mineral soil grains less than 2 mm equivalent diameter in a mass of soil.

(ii) Each texture class has defined limits for each particle separate class of mineral particles less than 2 mm in effective diameter. The basic texture classes, in the approximate order of increasing proportions of fine particles, are: sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further subdivided into coarse, fine, or very fine. The basic USDA texture classes are given graphically in part 618, subpart B, section 618.87, as a percentage of sand, silt, and clay. The chart at the bottom of the figure shows the relationship between the particle size and texture classes among the AASHTO, USDA, and Unified soil classification systems.

(2) Entries.—Enter the texture class for each horizon using the list in part 618, subpart B, section 618.94.

G. Terms Used in Lieu of Texture

(1) Definition.—"Terms used in lieu of texture" are substitute terms applied to materials that do not fit into a texture class because of high organic matter content, high fragment

content, high gypsum content, cementation, or another reason. Examples include artifacts, bedrock, gravel, muck, and shells. Part 618, subpart B, section 618.94, provides a list of these terms and their codes. Some of these terms may be modified with terms from the list of texture modifiers, such as mossy (code MS) when used to modify the term peat (e.g., "mossy peat").

(2) Application

(i) The terms used in lieu of texture "highly decomposed plant material," "moderately decomposed plant material," and "slightly decomposed plant material" (codes HPM, MPM, and SPM) should only be used to describe near-surface horizons composed of plant material in various stages of decomposition that are saturated with water for less than 30 cumulative days in normal years and are not artificially drained. These terms are used to describe folistic epipedons (i.e., in mineral soils only) or organic horizons of any thickness (i.e., in organic or mineral soils) provided they meet the saturation requirements. The terms "muck," "mucky peat," and "peat" (codes MUCK, MPT, and PEAT) are used to describe histic epipedons (i.e., in mineral soils only) and organic horizons of any thickness (i.e., in organic or mineral soils) that are saturated with water for 30 or more cumulative days in normal years or are artificially drained.

(ii) For soil materials with 40 percent or more, by weight, gypsum in the fine-earth fraction, gypsum dominates the physical and chemical properties of the soil and particle-size classes are not meaningful. Two terms in lieu of texture are used. "Coarse gypsum material" (code CGM) is used for these materials where 50 percent or more of the fine-earth fraction is comprised of particles ranging from ≥0.1 to <2.0 mm in diameter. "Fine gypsum material" (code FGM) is applied to materials where less than 50 percent of the fine-earth fraction is comprised of particles ranging from ≥0.1 to <2.0 mm in diameter.

(iii) The term "material" (code MAT) is generic and requires the use of a texture modifier. It is intended for cemented diagnostic horizons, such as duripans, petrocalcic horizons, and petrogypsic horizons (coded CEM-MAT), by using the texture modifier "cemented" with the term in lieu of texture "material." The concatenated texture term for such horizons in pedon descriptions is "cemented material." In the past, texture modifier terms, such as "coprogenous," "gypsiferous," and "marly," were used to describe material, but such use has been discontinued and is no longer permitted. Examples of current usage are shown below and combine the texture modifier with an appropriate texture class (e.g., marly silt loam).

(3) Entries.—Enter the term used in lieu of texture for each horizon, if applicable, from the list in part 618, subpart B, section 618.94.

H. Texture Modifier

(1) Definition.—"Texture modifier" is a term used to denote the presence of a condition or object other than sand, silt, or clay.

(2) Application.—Texture modifier terms may apply to both texture and terms used in lieu of texture. Some may apply to both, others only apply to one or the other. Combinations of some texture modifiers are allowed. A list of allowable texture modifier terms and their codes is given in part 618, subpart B, section 618.94. Some rules of application are given below.

(i) If the content of fragments equals 15 percent or more, by volume, texture modifiers are used. An example is gravelly loam or parachannery loam. The adjectives "very" and "extremely" are used when the content of fragments equals 35 to less than 60 percent and 60 to less than 90 percent, by volume, respectively.

(ii) Texture modifiers, such as paragravelly and paracobbly, are used to identify the presence of pararock fragments. The size, shape, and amounts of pararock fragments required for these terms are the same as for rock fragments.

(iii) "Mucky" and "peaty" are used to modify near-surface horizons of mineral soils that are saturated with water for 30 or more cumulative days in normal years or are artificially drained. An example is mucky loam. Excluding live roots, the horizon has organic carbon content (by weight) of one of the following:

- If the mineral fraction contains no clay, 5 to < 12 percent
- If the mineral fraction contains 60 percent or more clay, 12 to < 18 percent
- If the mineral fraction contains less than 60 percent clay, [5 + (clay percentage multiplied by 0.12)] to < [12 + (clay percentage multiplied by 0.10)]

(iv) "Highly organic" is used to modify near-surface horizons of mineral soils that are saturated with water for less than 30 cumulative days in normal years and are not artificially drained. Excluding live roots, the horizon has an organic carbon content (by weight) of one of the following:

- If the mineral fraction contains no clay, 5 to < 20 percent
- If the mineral fraction contains 60 percent or more clay, 12 to < 20 percent
- If the mineral fraction contains less than 60 percent clay, [5 + (clay percentage multiplied by 0.12)] to < 20 percent

(v) Shell fragments can be recognized in subaqueous or subaerial soils. In this context, "shell" is a hard, protective outer layer created by invertebrate organisms in marine and freshwater environments and is composed primarily of calcium carbonate materials of Holocene age. Examples include oyster shells, hard and soft shell clams, scallops, snails (including terrestrial), mussel, and hard coral. Shell fragments greater than or equal to 2 mm in size are included in measurement. Rock fragment classes are to be used in addition to the shell fragment classes where appropriate, similar to the artifactual classes of anthropogenic soils.

(vi) Compound texture modifiers may be used. For example, a term may be used to indicate the presence of fragments and another used to indicate some nonfragment condition. The term used to indicate rock fragments should be listed first. Examples are very gravelly mucky silt loam and paragravelly ashy loam; very flaggy-artifactual loam; or gravelly-shelly silt loam.

(vii) In some cases, mineral soil may contain a combination of both artifacts and fragments in the soil such as rock fragments and pararock fragments. In all cases, the artifacts, rock fragments, and pararock fragments are each described separately. The assignment of texture modifiers for such horizons is handled differently depending on the nature of the artifacts. Artifacts in soils which are discrete (i.e., ≥ 2 mm), cohesive, and persistent (e.g., concrete) function in a manner which is similar to rock fragments. Artifacts which are either noncohesive or nonpersistent (e.g., cardboard) behave differently than other discrete artifacts and also rock fragments. When describing the texture of soil horizons with artifacts or a combination of artifacts and fragments, the following rules of application are followed:

- Describe the individual kinds and amounts (percent by volume) of artifacts and any fragments, if present. Record all pertinent attributes for artifacts (see section 618.5), paying particular attention to data on artifact cohesion and persistence.

- If the combined volume of artifacts, which are both cohesive *and* persistent, plus any rock fragments present is less than 15 percent, use the table below:

Figure 618-A31

Less than 15 percent	No artifact texture modifier is used.
15 to < 35 percent	The adjectival term "artifactual" is used as a modifier of the texture class, such as "artifactual loam."
35 to < 60 percent	The adjectival term "very artifactual" is used as a modifier of the texture class, such as "very artifactual loam."
60 to < 90 percent	The adjectival term "extremely artifactual" is used as a modifier of the texture class, such as "extremely artifactual loam."
90 percent or more	No texture modifier terms are used. If there is too little fine earth to determine the texture class (less than about 10 percent, by volume) the term used in lieu of texture, "artifacts," is populated.

- If both artifacts and rock fragments are present and the combined volume of rock fragments and artifacts, which are both cohesive and persistent, is 15 percent or more, assign dual rock fragment-artifact texture modifiers. Dual rock fragment-artifact texture modifiers are based on the combined volume of both. The modifiers are concatenated terms joined with a hyphen. For example, use "gravelly-artifactual loam" as the texture modifier for a horizon with a fine-earth texture class of loam that contains 10 percent quartzite gravel, 3 percent brick (a cohesive and persistent artifact), 2 percent glass (a cohesive and persistent artifact), and 25 percent plasterboard (a noncohesive artifact). See part 618, subpart B, section 618.94, for the list of 18 dual rock fragment-artifact texture modifiers.
- If artifacts, pararock fragments, and rock fragments are present, but the combined volume of artifacts, which are both cohesive and persistent, and any rock fragments present is less than 15 percent, compound texture modifiers are used. The compound texture modifiers connote only the artifacts and the pararock fragments. The modifier for artifacts is assigned (using the table shown above) preceding the texture modifier for pararock fragments. Some examples are "artifactual paracobbly coarse sandy loam" for a horizon that contains 20 percent rubber (e.g., shredded tires) and 20 percent granite paracobbles and "very artifactual parachannery clay" for a horizon with 40 percent carpet pieces and 20 percent siltstone parachanners. In NASIS, the compound texture modifier is built using an artifact and pararock fragment modifier selected from the choice list.

(vii) If a horizon includes both rock fragments and pararock fragments, use the following rules for selecting texture modifiers:

- Describe the individual kinds and amounts of rock fragments and pararock fragments.
- Do not use a fragment texture modifier when the combined volume of rock fragments and pararock fragments is less than 15 percent.
- When the combined volume of rock fragments and pararock fragments is 15

percent or more and the volume of rock fragments is less than 15 percent, assign pararock fragment modifiers based on the combined volume of fragments. For example, use "paragravelly" as a texture modifier for soils with 10 percent rock and 10 percent pararock gravel-sized fragments.
- When the volume of rock fragments is 15 percent or more, use the appropriate texture modifier for rock fragments (see part 618, subpart B, section 618.90), regardless of the volume of pararock fragments. (Do not add the volume of rock and pararock fragments to determine the texture modifier.)

(viii) The definitions of the following four compositional texture modifiers guide their usage. Examples are "hydrous clay," "medial silt loam," "ashy loam," and "gypsiferous fine sandy loam."
- Hydrous.—Material that has andic soil properties and an undried 15 bar (1500 kPa) water content of 100 percent or more of the dry weight.
- Medial.—Material that has andic soil properties and has a 15 bar (1500 kPa) water content of less than 100 percent on undried samples and of 12 percent or more on air-dried samples.
- Ashy.—Material that has andic soil properties and is neither hydrous nor medial or material that does not have andic soil properties and the fine-earth fraction contains 30 percent or more particles ≥0.02 to <2.0 mm in diameter, of which 5 percent or more is composed of volcanic glass and the [(aluminum plus 1/2 iron percent by ammonium oxalate) times 60] plus the volcanic glass percent is equal to or more than 30.
- Gypsiferous.—Material that contains 15 to < 40 percent, by weight, gypsum.

(ix) Woody, grassy, mossy, and herbaceous texture modifiers are only used to modify muck, peat, or mucky peat terms (used for histic epipedons and organic horizons of any thickness that are saturated with water for 30 or more cumulative days in normal years, or are artificially drained, including those in Histels and Histosols, except for Folists). The definitions of the following four compositional texture modifiers guide their usage:
- Woody.—Any material that contains 15 percent or more wood fragments ≥2 cm in size or organic soil materials, other than SPM, MPM, or HPM, that contain 15 percent or more fibers that can be identified as wood origin and contain more wood fibers than any other kind of fiber.
- Grassy.—Organic soil material that contains more than 15 percent fibers that can be identified as grass, sedges, cattails, and other grasslike plants and contains more grassy fibers than any other kind of fiber.
- Mossy.—Organic soil material that contains more than 15 percent fibers that can be identified as moss and contains more moss fibers than any other kind of fiber.
- Herbaceous.—Organic soil material that contains more than 15 percent fibers that can be identified as herbaceous plants other than moss and grass or grasslike plants and more of these fibers than any other kind of fiber.

(x) In rare instances, some soil materials can be described by using a texture modifier, even though they do not fit the requirements of texture. An example is "gypsiferous material."

(xi) Limnic materials have modifiers to texture to connote the origin of the material. The three kinds of limnic materials are coprogenous earth, diatomaceous earth, and marl. These materials were deposited in water by precipitation or through the action of aquatic organisms or derived from plants and organisms. Refer to the *Keys to Soil Taxonomy* for the complete definitions and taxonomic criteria of limnic materials. The following three compositional texture modifiers are used with limnic materials to indicate presence and origin without respect to any set quantity of pellets, grains, or particles. Examples are "coprogenous silty clay loam," "diatomaceous very fine sandy loam," and "marly silt loam."

- Coprogenous.—Soil material that is a limnic layer containing many very small (0.1 to 0.001 mm) fecal pellets.
- Diatomaceous.—Soil material that is a limnic layer composed of diatoms.
- Marly.—Soil material that is a limnic layer that is light colored and reacts with HCl to evolve CO_2.

(xii) "Permanently frozen" is a texture modifier term applied to a soil layer in which the temperature is perennially at or below 0 degrees C, whether its consistence is very hard or loose.

(3) Entries.—Enter the applicable texture modifiers from the list in part 618, subpart B, section 618.94. Multiple texture modifiers are used in some horizons based on the application rules for texture modifier presented above. They must be assigned sequence numbers in the "Horizon Texture Modifier" table in the NASIS database for the proper calculated result.

(I) Texture Modifier and Class

(1) Definition.—"Texture modifier and class" is a concatenation of texture modifier and texture class or texture modifier and a term used in lieu of texture. This data element indicates the full texture term of the horizon. If texture modifiers are used, they are attached to the texture class by a hyphen, for example, GR-SL. If a layer is stratified, enter SR as a texture modifier and the end members of the textural range and connect them by hyphens, for example, SR-C L and SR-GR S GR-C.

(2) Entries.—Enter the appropriate texture modifier and class for each horizon. These entries are calculated in the "Horizon Texture Group" table in the NASIS database.

(J) Stratified Texture Flag

(1) Application.—A "stratified texture flag" is used to identify stratified textures in the "Horizon Texture Group" table in the NASIS database.

(2) Entries.—A Boolean flag is set to "yes" by checking the box for the stratified texture flag. This indicates that the textures that comprise a particular record are stratified. The default entry is "no" and is displayed by keeping the box for stratified texture flag unchecked.

(K) Representative Indicator Flag

(1) Application.—A "representative indicator flag" is used to identify one representative texture (comprised of texture modifier and class) in the "Horizon Texture Group" table in the NASIS database.

(2) Entries.—A Boolean flag is set to "yes" by checking the box for the representative indicator flag. This indicates that the texture that comprises a record in the particular horizon texture group is representative. It also indicates that the selected texture validates the soil properties populated for the layer. The selected texture record must be in agreement with the representative values for important soil properties, such as clay content, sand content, rock fragment content, and organic matter content. The flag must be set even when only one texture record is populated for a particular horizon (such as in

surface layers or bedrock layers). The default entry is “no” and is displayed by keeping the box for representative indicator flag unchecked. Only one texture record may be selected as representative for a given horizon or layer.

618.73 Von Post Humification Scale

A. Definition.— The Von Post Humification Scale is a field method that indicates the scale of peat decomposition and characteristics. The scale ranges from least decomposed (H1) to most decomposed (H10) plant materials.

B. Significance.—The von Post scale is used in modeling to predict bulk density, hydraulic conductivity, and n value in organic soils. The scale can also be used to check the agreement between fibric (H1-H3), hemic (H4-H6), and sapric (H7-H10) materials. The von Post scale is the most reliable field method available for estimating humification. Field estimates very closely match measurements obtained with costly laboratory measurements.

C. Estimates.—The humification scale is estimated by squeezing a handful of wet soil until as much soil as possible has extruded through the fingers. Color and viscosity of the extruded portion and material remaining in the hand are evaluated using the scale below.

(1) H1.—Completely undecomposed peat; only clear water can be squeezed from peat.
(2) H2.—Almost undecomposed; mud-free peat; water squeezed from peat is almost clear and colorless.
(3) H3.—Very little decomposition; very slightly muddy peat; water squeezed from peat is muddy; no peat passes through fingers when squeezed; residue retains structure of peat.
(4) H4.—Poorly decomposed; somewhat muddy peat; water squeezed from peat is muddy; residue is muddy but it shows structure of peat.
(5) H5.—Somewhat decomposed; muddy; growth structure discernible but indistinct; when squeezed some peat passes through fingers but most muddy water passes through fingers; compressed residue is muddy.
(6) H6.—Somewhat decomposed; muddy; growth structure indistinct; less than one-third of peat passes through fingers when squeezed; residue very muddy.
(7) H7.—Well decomposed; very muddy; growth structure indistinct; about one-half of peat passes through fingers when squeezed; exuded liquid has a pudding-like consistence.
(8) H8.—Well decomposed; growth structure very indistinct; about two-thirds of peat passes through fingers when squeezed; residue consists mainly of roots and resistant fibers.
(9) H9.—Almost completely decomposed; peat is mud-like; almost no growth structure can be seen; almost all of peat passes through the fingers when squeezed.
(10) H10.—Completely decomposed; no discernible growth structure; entire peat mass passes through fingers when squeeze.

D. Entries.—Enter von Post at field moist condition for each organic horizon. Pedons may be aggregated to identify the low, high, and representative values for each horizon where the von Post scale is applicable.

618.74 Water, One-Tenth Bar

A. Definition.—“Water, one-tenth bar” is the amount of soil water retained at a tension of 1/10 bar (10 kPa), expressed as a percentage of the whole soil on a volumetric basis.

B. Significance.—Water retained at one-tenth bar is significant in the determination of soil water-retention difference, which is used as the initial estimation of available water capacity for some soils.

C. Measurement.—Measurement in the laboratory is done on natural clods using a pressure desorption method. Measurement for nonswelling soils, loamy sand or coarser soils, and some sandy loams is also done using a pressure desorption method but sieved (< 2 mm) air-dry samples are used. Gravimetric water contents are reported in laboratory measurements as a percentage of the fine-earth (<2 mm) fraction. Conversion to a volumetric basis is made using bulk density and rock fragment content.

D. Entries.—Enter the low, high, and representative values for the horizon. The range of valid entries is from 0 to 100 percent, and tenths (one decimal place) are allowed. A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.105.

618.75 Water, One-Third Bar

A. Definition.—“Water, one-third bar” is the amount of soil water retained at a tension of 1/3 bar (33 kPa), expressed as a percentage of the whole soil on a volumetric basis.

B. Significance.—Water retained at one-third bar is significant in the determination of soil water-retention difference, which is used as the initial estimation of available water capacity for some soils.

C. Measurement.—Measurement in the laboratory is done on natural clods using a pressure desorption method. Measurement for nonswelling soils, loamy sand or coarser soils, and some sandy loams is also done using a pressure desorption method but sieved (< 2 mm) air-dry samples are used. Gravimetric water contents are reported in laboratory measurements as a percentage of the fine-earth (< 2 mm) fraction. Conversion to a volumetric basis is made using bulk density and rock fragment content.

D. Entries.—Enter the low, high, and representative values for the horizon. The range of valid entries is from 0 to 100 percent, and tenths (one decimal place) are allowed. A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.105.

618.76 Water, 15 Bar

A. Definition.—“Water, 15 bar” is the amount of soil water retained at a tension of 15 bars (1500 kPa), expressed as a percentage of the whole soil on a volumetric basis.

B. Significance.—Water retained at 15 bar is significant in the determination of soil water-retention difference, which is used as the initial estimation of available water capacity for some soils. Water retained at 15 bar is an estimation of the wilting point.

C. Measurement.—Measurement in the laboratory is done on sieved (< 2 mm) air-dry samples using a pressure desorption method. Gravimetric water contents are reported in laboratory measurements as a percentage of the fine-earth (< 2 mm) fraction. Conversion to a volumetric basis is made using bulk density and rock fragment content.

D. Entries.—Enter the low, high, and representative values for the horizon. The range of valid entries is from 0 to 100 percent, and tenths (one decimal place) are allowed. A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.105.

618.77 Water, Satiated

A. Definition.—“Water, satiated” is the estimated volumetric soil water content at or near zero bar tension, expressed as a percentage of the whole soil.

B. Significance.—"Water, satiated” represents the total possible water content of the soil, including the amount in excess of field capacity, and is used to estimate the amount of water available for leaching and translocation. Satiated water content approximates the water content at saturated conditions. It is used in such resource assessment tools as Soil Hydrology, Water Budgets, Leaching, and Nutrient/Pesticide Loading models.

C. Estimates.—The values are derived by the following formula:

Satiated water % = total porosity % - entrapped air %

Where total porosity % = 100(1-bulk density moist/particle density).

Assume approximately 3% entrapped air.

D. Entries.—Enter the high, low, and representative values for the horizon. The range of valid entries is from 0 to 100 percent, and only whole numbers (integers) are allowed. A NASIS calculation is available and can be viewed in part 618, subpart B, section 618.105.

618.78 Water Temperature

A. Definition.—“Water temperature” is the mean annual water temperature (MAWT) at or near the water/soil contact in a subaqueous soil setting.

B. Significance.—Temperature is important to many biological and physical processes that occur in marine and freshwater aquatic environments. The properties of the water column above subaqueous soils are important to interpretations such as aquaculture, shellfish restoration, and seagrass survival.

C. Estimates.—Water temperature can be estimated from measured water temperatures of the vicinity. Seasonal air temperature and water current fluctutations affect water temperatures.

Estimates of water temperature should take these factors into account when water temperatures are extrapolated from one soil map unit component to another. Temperatures can be summations of the daily values collected and populated for point data in the NASIS data element "Water Temp – Lower" (sas_water_temp_lower). Such temperatures are measured in the lower 10 cm of the water column immediately above the surface of subaqueous soils.

D. Measurement.—Water temperature can be measured by many types of thermometers, including mercury, bimetallic, thermisters, and thermocouples. Many types of instruments can be configured for remote, unattended, and submerged operation.

E. Entries.—Enter the high, low, and representative values for the range of mean annual water temperature for the component as the average of the mean monthly water temperatures in the "Component" table in NASIS. The range of valid entries is from -10 to 50 degrees Celsius, and tenths (one decimal place) are allowed.

618.79 Wind Erodibility Group and Index

A. Definition.—A wind erodibility group (WEG) is a grouping of soils that have similar properties affecting their resistance to soil blowing in cultivated areas. The groups indicate the susceptibility to blowing. The wind erodibility index (I), used in the wind erosion equation, is assigned using the wind erodibility groups.

B. Significance.—There is a close correlation between soil blowing and the size and durability of surface clodiness, fragments, organic matter, and the calcareous reaction. The soil properties that are most important with respect to soil blowing are listed below. Soil moisture and the presence of frozen soil also influence soil blowing.

(1) Soil texture class
(2) Organic matter content
(3) Carbonates in the fine-earth fraction as determined by effervescence class
(4) Rock and pararock fragment content
(5) Mineralogy

C. Estimates.—Soils are placed into wind erodibility groups on the basis of the properties of the soil surface layer. Part 618, subpart B, section 618.95, lists the wind erodibility index values assigned to the wind erodibility groups. The wind erodibility index values are assigned because the dry soil aggregates are very use-dependent on crop management factors.

D. Entries.—Enter the wind erodibility group and wind erodibility index values for surface layers only. The valid entries for wind erodibility group data are: 1, 2, 3, 4, 4L, 5, 6, 7, and 8. The lowest valid entry for wind erodibility index data is 0, and the highest is 310. The index values should correspond exactly to their wind erodibility group.

---

* As first defined by the 1951 "Soil Survey Manual" (p. 214), the upper diameter for gravel is 3 inches, the ASTM U.S. standard test sieve size—a value that coincides with the upper limit used in engineering computations (Soil Survey Manual, 1991 edition, p. 142). In conversion, 3 inches equals 76.2 mm, which rounds to 76 mm. However, 75 mm (which is the standard of the International

Standards Organization (ISO)) and 3 inches have both been reported as the upper limit for gravel because commercially available sieves exist for those size fractions, but not for the 76 mm fraction. Consequently, "< 75 mm" has sometimes been reported as the upper limit of gravel. The prime example occurs on the NRCS soil characterization data sheets (Method 3A2 in the "Soil Survey Laboratory Methods Manual," Soil Survey Investigations Report No. 42, 2014 edition). At the bulk soil sample scale, 75 mm and 76 mm are functionally equivalent and the difference does not pose a problem. However, the reader needs to be aware of this discrepancy and recognize that because (1) samples have been measured using a 75-mm sieve and (2) more data has been entered in NASIS as 75 mm, the Standards Staff at the National Soil Survey Center decided that 75 mm, and not <76 mm, is to be used as the upper size limit for gravel.

Part 618 – Soil Properties and Qualities

Subpart B – Exhibits

618.80 Guides for Estimating Risk of Corrosion Potential for Uncoated Steel

Property	**Limits**		
	Low	**Moderate**	**High**
Internal free water occurrence class (or drainage class) and general texture group 1/ 2/	•Very deep internal free water occurrence (or excessively drained to well drained) coarse to medium textured soils; *or* •Deep internal free water occurrence (or moderately well drained) coarse textured soils; *or* •Moderately deep internal free water occurrence (or somewhat poorly drained) coarse textured soils	•Very deep internal free water occurrence (or well drained) moderately fine textured soils; *or* •Deep internal free water occurrence (or moderately well drained) moderately coarse and medium textured soils; *or* •Moderately deep internal free water occurrence (or somewhat poorly drained) moderately coarse textured soils; *or* •Very shallow internal free water occurrence (or very poorly drained) soils with a stable high water table	•Very deep internal free water occurrence (or well drained) fine textured or stratified soils; *or* •Deep internal free water occurrence (or moderately well drained) moderately fine and fine textured or stratified soils; *or* •Moderately deep internal free water occurrence (or somewhat poorly drained) medium to fine textured or stratified soils; *or* •Shallow or very shallow internal free water occurrence (or poorly or very poorly drained) soils with a fluctuating water table
Total acidity (cmol(+)/kg^{-1}) 3/ 4/	<10	10-25	≥25
Conductivity of saturated extract (dS/m^{-1}) 3/ 5/	<1	1-4 4-10 for saturated soils 6/	>4 >10 for saturated soils 6/
Resistivity at saturation (ohm/cm) 1/ 7/	≥5,000	2,000-5,000	<2,000

1/ Based on data in the publication "Underground Corrosion," table 99, p.167, Circular 579, U.S. Department of Commerce, National Bureau of Standards.

2/ The depth classes for internal free water occurrence are defined in table 3-5 of the Soil Survey Manual (1993). The classes relate to the wet water state in soils (i.e., free water present). The general texture groups are defined in chapter 3 of the Soil Survey Manual.

3/ Based on data in Moore and Hallmark (1987), “Soil Properties Influencing Corrosion of Steel in Texas Soils”, Soil Sci. Soc. Am. J. 51:1250-1256.

4/ Total acidity is roughly equal to extractable acidity. Extractable acidity is determined by method 4B2a1a1, as outlined in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004.

5/ Electrical conductivity is measured using method 4F2, as outlined in Soil Survey Investigations Report No. 42, *Soil Survey Laboratory Methods Manual*, Version 4.0, November 2004. The relationship between resistivity of a saturated soil paste and electrical conductivity of the saturation extract is influenced by variations in the saturation percentage, salinity, and conductivity of the soil minerals. These two measurements generally correspond closely enough to place a soil in one risk of corrosion potential class.

6/ Soils that remain saturated for extended periods are excluded from the high risk of corrosion potential class unless EC values are more than 10 dS m^{-1} (Moore and Hallmark, 1987). In the NASIS steel corrosion calculation, saturation for extended periods is defined as having very shallow internal free water occurrence for 12 months.

7/ Resistivity at saturation is roughly equivalent to resistivity of fine and medium textured soils measured at saturation (Method 4F2b2 as outlined in Soil Survey Investigations Report No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004). Resistivity at saturation for coarse textured soils is generally lower than that obtained at field capacity and may cause the soil to be placed in a higher risk of corrosion potential class.

618.81 Guide for Estimating Risk of Corrosion Potential for Concrete

Property	**Limits 1/**		
	Low	**Moderate**	**High**
Texture and reaction	Sandy and organic soils with pH>6.5 *or* Loamy and clayey soils with pH>6.0	Sandy and organic soils with pH 5.5 to 6.5 *or* Loamy and clayey soils with pH 5.0 to 6.0	Sandy and organic soils with pH<5.5 *or* Loamy and clayey soils with pH<5.0
Na and/or Mg sulfate (ppm)	Less than 1000	1000 to 7000	More than 7000
NaCl (ppm)	Less than 2000	2000 to 10000	More than 10000

1/ Based on data in National Handbook of Conservation Practices, Standard 606, Subsurface Drain, 1980.

618.82 Crop Names and Units of Measure

Refer to the NASIS-related metadata at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/tools/?cid=nrcs142p2_053548 . Then follow the link to the "NASIS Version 7.x" index web page. On the NASIS Version index web page, see the file named "Domains.pdf" for the most current list of crop names and crop yield units.

618.83 Classification of Soils and Soil-Aggregate Mixtures for the AASHTO System

General Classification	**Granular Materials (35% or less passing No. 200)**							**Silt-Clay Materials (More than 35% passing No. 200)**			
Group classification	**A-1**		**A-3**	**A-2**				**A-4**	**A-5**	**A-6**	**A-7**
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve analysis, % passing											
No. 10	50 max	-	-	-	-	-	-	-	-	-	-
No. 40	30 max	50 max	51 min	-	-	-	-	-	-	-	-
No. 200	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing No. 40											
Liquid limit	-		-	40 max	41 min	40 max	41 min	40 max	41 min	40 max	* 41 min
Plasticity index	6 max		NP	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Usual types of significant constituent materials	Stone Fragments, Gravel and Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General rating as subgrade	Excellent to Good					Fair to Poor					

* Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30.

618.84 Potential Frost Action

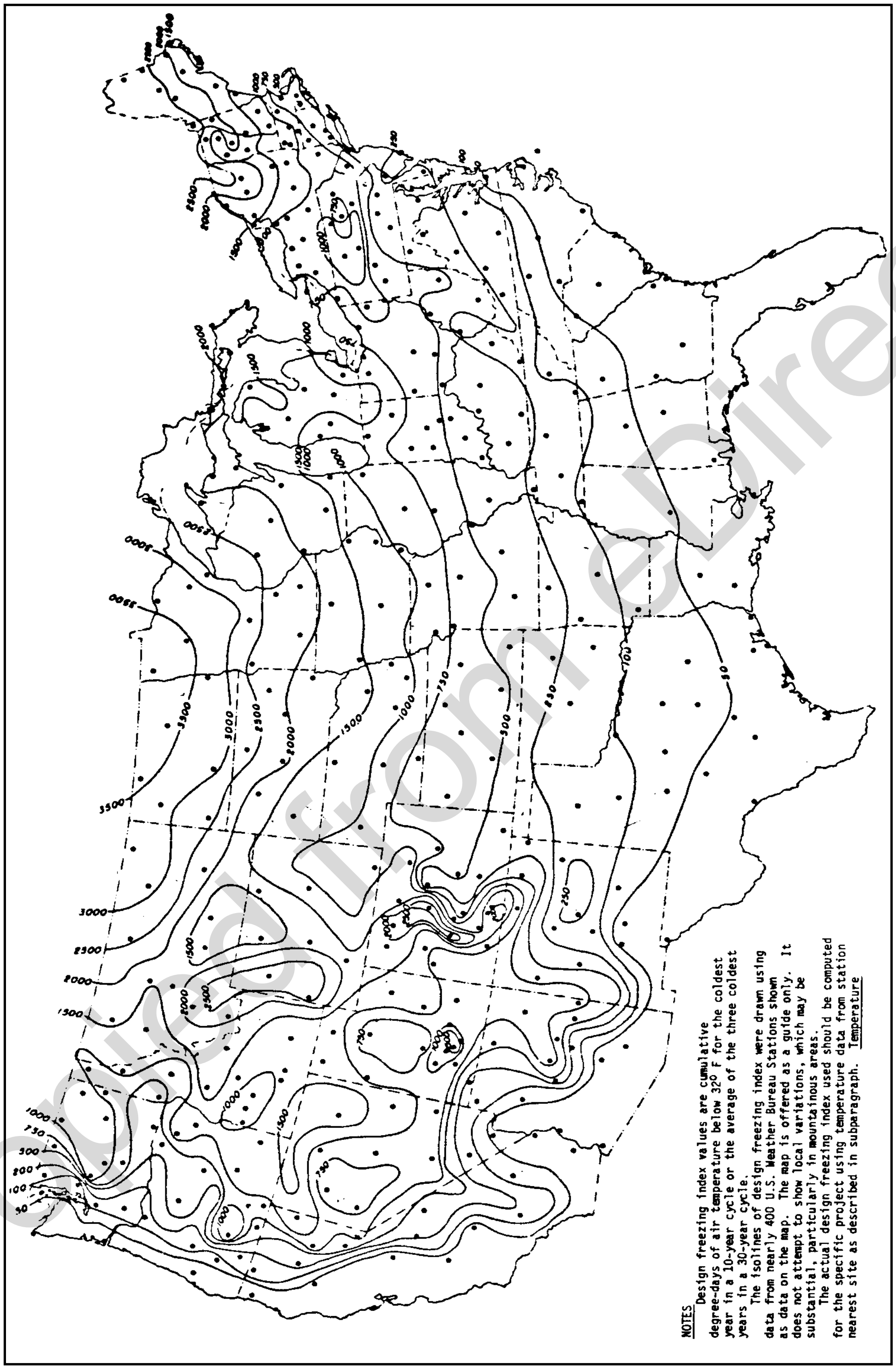
Soil moisture regime	**Frost action classes** 1/, 2/		
	Low	**Moderate**	**High** 3/
Aquic, Peraquic	Cindery, Fragmental, Pumiceous	Sandy, Sandy-skeletal	Coarse-loamy, Fine-loamy, Coarse-silty, Fine-silty, Loamy, Loamy-skeletal, Clayey, Clayey-skeletal, Fine, Very-fine, Organic soil material, Ashy, Ashy-pumiceous, Ashy-skeletal, Medial, Medial-pumiceous, Medial-skeletal, Hydrous-pumiceous, Hydrous-skeletal, Hydrous
Udic, Perudic, Xeric, Ustic (when irrigated), Aridic and torric (when irrigated)	Fragmental, Cindery, Sandy, Sandy-skeletal, Pumiceous	Coarse-loamy, Fine-loamy, Loamy-skeletal, Clayey, Clayey-skeletal, Fine, Very-fine, Ashy-pumiceous, Ashy-skeletal, Hydrous-skeletal, Medial-skeletal, Medial-pumiceous	Coarse-silty, Fine-silty, Ashy, Medial, Hydrous-pumiceous, Hydrous
Ustic, Aridic and torric	Fragmental, Sandy, Sandy-skeletal, Clayey, Clayey-skeletal, Fine, Very-fine, Cindery, Ashy, Ashy-pumiceous, Ashy-skeletal, Medial, Medial-skeletal, Pumiceous	Coarse-loamy, Fine-loamy, Coarse-silty, Fine-silty, Loamy, Loamy-skeletal, Medial-pumiceous, Hydrous-pumiceous, Hydrous-skeletal, Hydrous	

1/ Taxonomic family particle-size classes apply to the whole soil to the depth of frost penetration, which is not necessarily the same as the taxonomic family particle-size control section.

2/ Isomesic and warmer soil temperature regimes should have no frost action problems (“none”).

3/ Organic soil materials with a mesic or colder soil temperature regime and a udic soil moisture regime (e.g., Folists) have a “high” frost action class.

618.85 Distribution of Design Freezing Index Values in the Continental United States



NOTES

Design freezing index values are cumulative degree-days of air temperature below 32° F for the coldest year in a 10-year cycle or the average of the three coldest years in a 30-year cycle.

The isolines of design freezing index were drawn using data from nearly 400 U.S. Weather Bureau Stations shown as data on the map. The map is offered as a guide only. It does not attempt to show local variations, which may be substantial, particularly in mountainous areas.

The actual design freezing index used should be computed for the specific project using temperature data from station nearest site as described in subparagraph. Temperature

618.86 Estimating LL and PI from Percent and Type of Clay

The following two formulas provide estimates of liquid limit and plasticity index. These calculations are included in the NASIS database and provide default values to LL and PI.

$$\text{LL} = 11.60 + [1.49 \times \text{15 bar water \%}] + [1.35 \times \text{org. carbon \%}] + [0.6 \times \text{LEP}] + [0.26 \times \text{noncarbonate clay \%}]^{*}$$

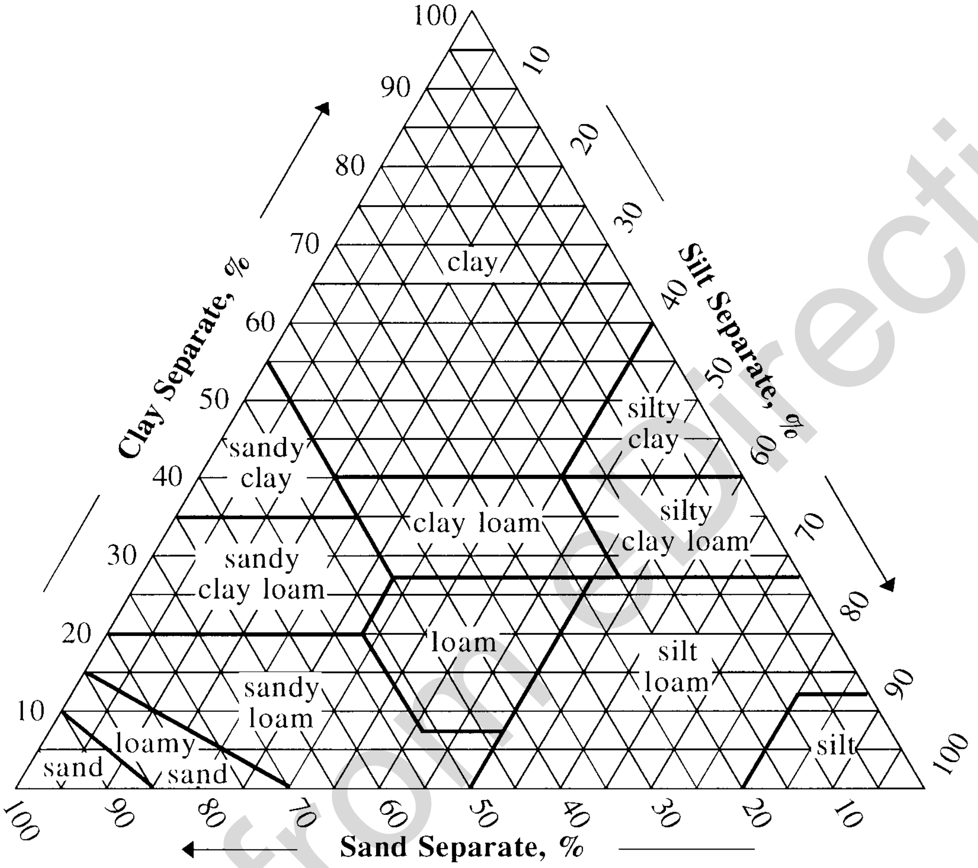
where LL is liquid limit and LEP is linear extensibility percent

$$\text{PI} = -1.86 + [0.69 \times \text{15 bar water \%}] - [1.19 \times \text{organic carbon \%}] + [0.13 \times \text{LEP}] + [0.47 \times \text{noncarbonate clay \%}]^{*}$$

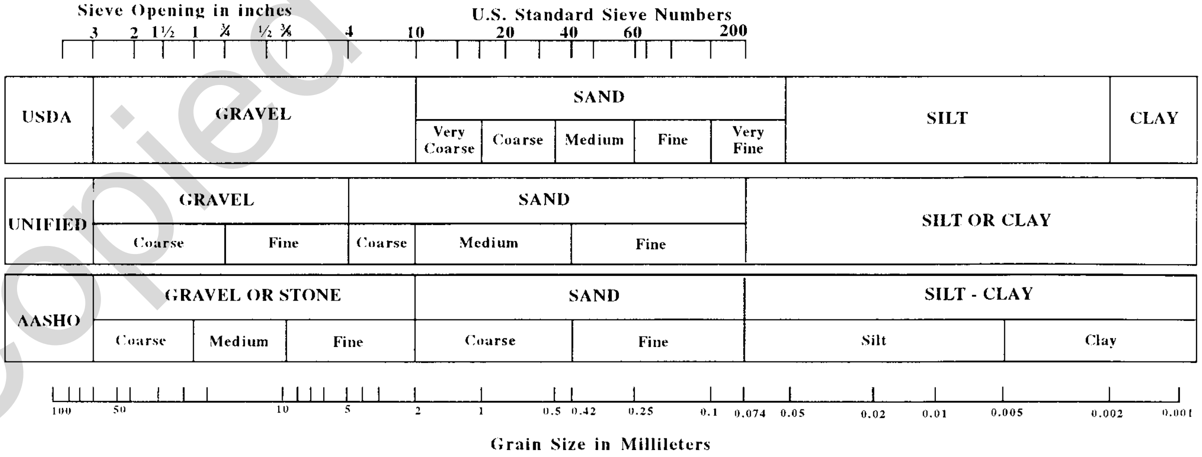
where PI is plasticity index and LEP is linear extensibility percent

* When the calculated $\text{PI} < 0.5$, the PI is set to zero (nonplastic). When the calculated $\text{LL} < 15$ or $\text{PI} < 0.5$, the LL is set to zero.

618.87 Texture Triangle and Particle-Size Limits of AASHTO, USDA, and Unified Classification Systems



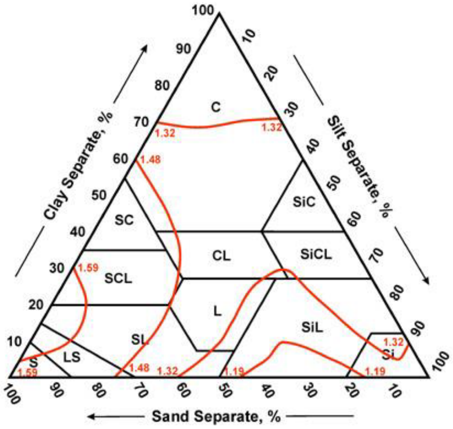
COMPARISON OF PARTICLE SIZE SCALES



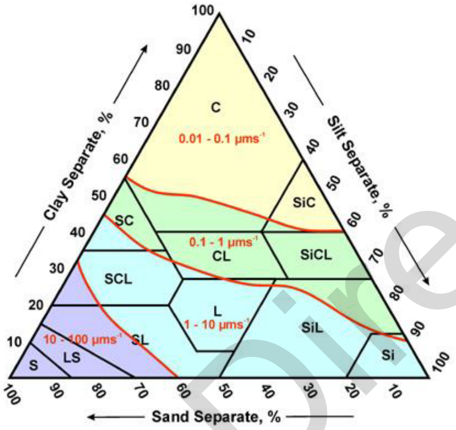
618.88 Guide for Estimating K_{sat} from Soil Properties

Estimate saturated hydraulic conductivity (K_{sat}) from soil texture by first selecting the bulk density class of medium, low, or high. Then use the corresponding texture triangle to select the range of saturated hydraulic conductivity in µms^{-1}. Overrides follow the texture triangles.

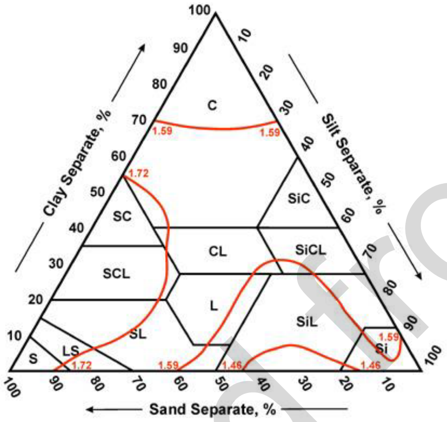
Medium Density



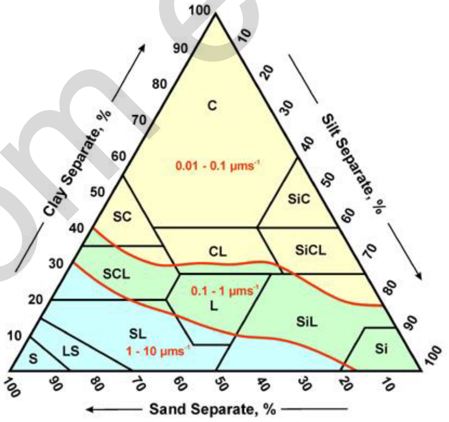
Ksat for Medium Bulk Density



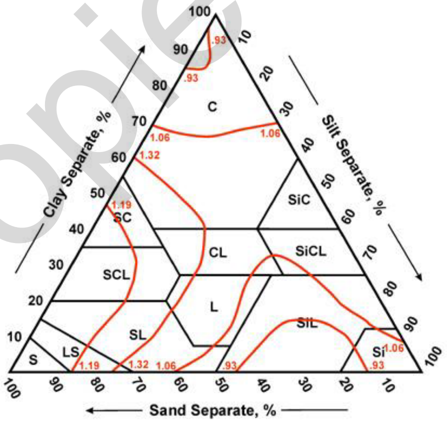
High Density



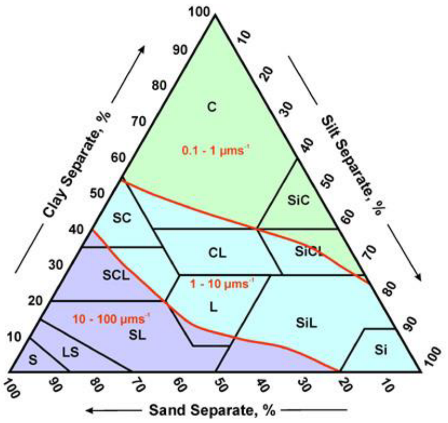
Ksat for High Bulk Density



Low Density



Ksat for Low Bulk Density



If overriding conditions (listed below) exist, use this table to estimate K_{sat} instead of the texture triangles. A single property statement is sufficient for an override from the texture guides.

Overriding Condition	**Saturated Hydraulic Conductivity (μm s^{-1})**
All fragmental, cindery, or pumiceous.	≥ 100
Many medium or coarser vertical pores that extend through the layer.	≥ 100
Medial-pumiceous, medial-skeletal, ashy-pumiceous, ashy-skeletal, or hydrous-pumiceous material that is very friable, friable, soft, or loose.	10 – 100
When material is moderately moist or wetter, structure is moderate or strong granular, strong blocky, or prismatic smaller than very coarse; no stress surfaces or slickensides.	10 – 100
Common medium or coarser vertical pores extend through the layer.	10 – 100
Strong very coarse blocky or prismatic structure and no stress surfaces or slickensides.	1 – 10
≥ 35 percent clay that is soft, slightly hard, very friable or friable; no stress surfaces or slickensides and the clay activity is in the range of the Subactive class (i.e., CEC7/noncarbonate clay = < 0.24) after subtracting the quantity [2 × (% OC × 1.7)].	1 – 10
Few stress surfaces, few slickensides, or both.	0.1 – 1
Massive and very firm or extremely firm or weakly cemented.	0.1 – 1
Continuously moderately cemented.	0.1 – 1
Common or many stress surfaces or common or many slickensides.	0.01 - 0.1
Continuously indurated or very strongly cemented.	< 0.01

618.89 Guide to Estimating Water Movement Through Bedrock for Layers Designated as R and Cr

This table is to be used as a guide and may be adjusted to reflect local, regional, or State bedrock permeability data[1, 2]. Fracturing may increase hydraulic conductivity of consolidated rock by a factor of 10^4 to 10^6, which is dependent on the degree and interconnection of fracturing. This table assumes that materials are level bedded. Tilted beds of some materials may have rapid rates of water movement for water that goes directly to an aquifer.

Material	Water Movement µm s^{-1}
Sandstone	
unfractured	<10
fractured	10-100
weathered	10-100
Limestone	
unfractured	<1
fractured	<10
weathered	<10
Limestone, Karst	>100
Shales and Mudstones	
consolidated	<1
weathered	<10
Igneous and Metamorphic Rocks	
unfractured	<1
fractured	1-100
weathered	<1

[1] Freeze, R., and J. Cherry. 1979. *Groundwater*.

[2] Legget, R., and P. Karrow. 1983. *Handbook of Geology in Civil Engineering*.

618.90 Rock Fragment Modifier of Texture

Instructions for Table 1, Guide for determining rock fragment modifier of texture: First choose the row with the appropriate total rock fragments. Then read the criteria in the columns under "Gravel, cobbles, stones, and boulders," starting from the left-most column and proceeding to the right. Stop in the first column in which a criterion is met.

Table 1.—Guide for Determining Rock Fragment Modifier of Texture.

(Click here for an MS Excel spreadsheet that calculates the texture modifiers for flat and nonflat rock fragments.).

Total Rock Fragments (Vol. %)	**Gravel (GR), cobbles (CB), stones (ST), and boulders (BY)** (Substitute channers for gravel and flagstones for cobbles, where applicable)[1]			
	IF GR ≥ 1.5 CB + 2 ST + 2.5BY	**IF CB ≥ 1.5 ST + 2 BY**	**IF ST ≥ 1.5 BY**	**IF ST < 1.5 BY**
≥ 15 < 35	Gravelly	Cobbly	Stony	Bouldery
≥ 35 < 60	Very Gravelly	Very Cobbly	Very Stony	Very Bouldery
≥ 60 < 90	Extremely Gravelly	Extremely Cobbly	Extremely Stony	Extremely Bouldery
≥ 90	Gravel	Cobbles	Stones	Boulders

Example: Determine the rock fragment modifier for a soil that contains 15 percent gravel (GR), 10 percent cobbles (CB), and 3 percent stones (ST).

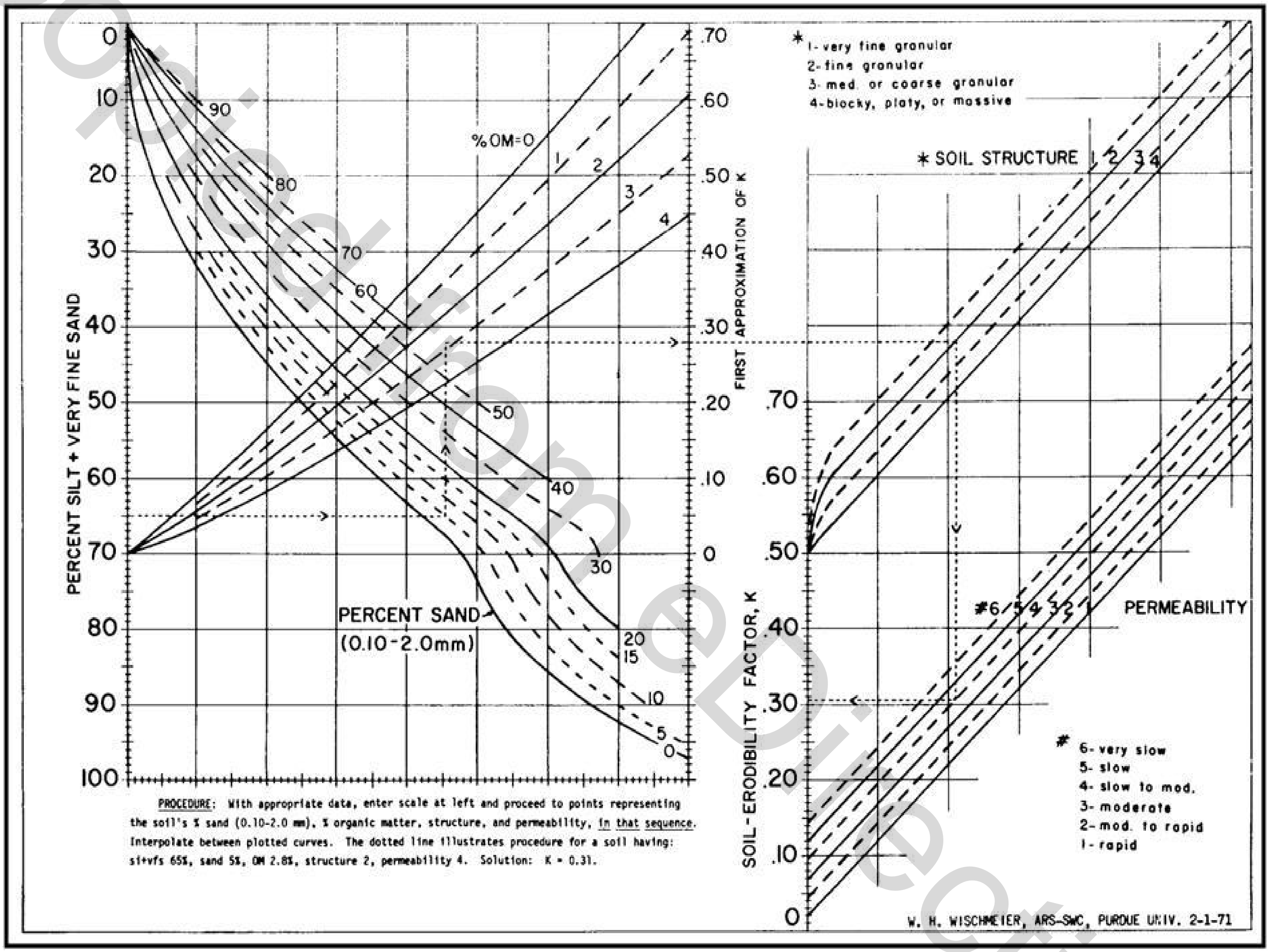
1. Since total rock fragments are 28 percent, choose the first row (≥ 15 and < 35).
2. Under "Gravel (GR), cobbles, . . .", test the criterion in the left-most column.
   Is 15%GR ≥ 1.5 (10% CB) + 2 (3% ST)? Answer: NO.
3. Proceed to the next column.
   Is 10%CB ≥ 1.5 (3% ST)? Answer: YES. STOP. The modifier is Cobbly.

[1] If both flat and nonflat rock fragments are present, the quantity in each size class is summed (e.g., gravel + channers, cobbles + flagstones). The sums are used to determine the appropriate quantity/size modifier. If the amounts of flat and nonflat rock fragments within any given size class are equal, the nonflat modifier takes precedence. For example, if there are 10 percent gravel and 10 percent channers, the modifier is gravelly.

Soils With Pararock Fragments Only.—The same basic weighting rules apply with pararock fragments as with flat and nonflat rock fragments. However, the above spreadsheet only outputs modifier terms for rock fragments. To assign the correct pararock fragment modifier to the outputted rock modifier term, simply precede the modifier with "para." For example, if the calculator outputs "very cobbly," the correct modifier is "very paracobbly."

Soils With Both Rock and Pararock Fragments.—Refer to instructions in section 618.67H(2)(vii) of this handbook.

618.91 Soil Erodibility Nomograph



PROCEDURE: With appropriate data, enter scale at left and proceed to points representing the soil's % sand (0.10-2.0 mm), % organic matter, structure, and permeability, in that sequence. Interpolate between plotted curves. The dotted line illustrates procedure for a soil having: si+vfs 65%, sand 5%, OM 2.8%, structure 2, permeability 4. Solution: K = 0.31.

618.92 Kw Value Associated With Various Fragment Contents

Fragment vol. %	**Mulch factor [1]**	**Kf value classes of less than 2 mm soil fraction**										
		.10	.15	.20	.24	.28	.32	.37	.43	.49	.55	.64
5	.90	.09	.14	.18	.22	.25	.29	.33	.39	.44	.50	.58
10	.77	.08	.12	.15	.18	.22	.25	.28	.33	.38	.42	.49
15	.68	.07	.10	.14	.16	.19	.22	.25	.29	.33	.37	.43
20	.61	.06	.09	.12	.15	.17	.20	.23	.26	.30	.37	.39
25	.54	.05	.08	.11	.13	.15	.17	.20	.23	.26	.30	.35
30	.48	.05	.07	.10	.12	.13	.15	.18	.21	.24	.26	.31
35	.43	.04	.06	.09	.10	.12	.14	.16	18	.21	.24	.28
40	.38	.04	.06	.08	.09	.11	.12	.14	.16	.19	.21	.24
45	.34	.03	.05	.07	.08	.10	.11	.13	.15	.17	.19	.22
50	.30	.03	.05	.06	.07	.08	.10	.11	.13	.15	.17	.19
55	.26	.03	.04	.05	.06	.07	.08	.09	.11	.13	.12	.14
60	.22	.02	.03	.04	.05	.06	.07	.08	.09	.11	.12	.14
65	.19	.02	.03	.04	.05	.05	.06	.07	.08	.09	.10	.12
70	.16	.02	.02	.03	.04	.04	.05	.06	.07	.08	.09	.10
75	.13	.01	.02	.03	.04	.04	.04	.04	.06	.06	.07	.08
80	.10	.01	.02	.02	.02	.03	.03	.04	.04	.05	.06	.06
85	.08	.01	.02	.02	.02	.02	.03	.03	.03	.04	.04	.05
90	.06	.01	.01	.01	.01	.02	.02	.02	.03	.03	.03	.04
95	.04	.01	.01	.01	.01	.01	.01	.02	.02	.02	.02	.03
100	.03	.01	.01	.01	.01	.01	.01	.01	.01	.02	.02	.02

[1] Mulch factor is the ratio of the soil loss from soils with the specified fragment volumes to that from soils with no fragments. The table was constructed from the zero canopy curve, figure 6, page 19 in Agriculture Handbook 537 (USDA Science and Education Administration, 1978).

618.93 General Guidelines for Assigning Soil Loss Tolerance "T"

Soil loss tolerance "T" is assigned according to properties of root and plant growth limiting subsurface soil layers. The designation of a limiting layer implies that the material above the layer has more favorable plant growth properties. As limiting or less favorable soil layers become closer to the soil surface, the relative ability of a soil to maintain its productivity through natural and managed processes decreases.

Caution should be used in comparing T factors across soils for soil quality or productivity. For examples, soils with a T factor of 5 may not be the most productive and soils with the same T factor rating may not be equally productive. For example, a soil that has a T factor of 5 and is sandy throughout is not as naturally fertile nor can it hold as much available water as a soil that has a T factor of 5 that is loamy throughout.

The criteria for assigning T factor are estimated from both of the following:

1. The severity of physical or chemical properties of subsurface layers

2. The economic feasibility of utilizing management practices to overcome limiting layers or conditions

The following general guide was used with specific soil properties and conditions to write criteria statements for programming T factors as a calculation in NASIS.

Depth to limiting layer (cm)	Soil loss tolerance in tons per acre		
	Group 1	Group 2	Group 3
0 - 25	1	1*	3
25 - 50	1	2	3
50 - 100	2	3	4
100 - 150	3	4	4
>150	5	5	5

* Some soils are assigned a soil loss tolerance of 2.

Group 1.—The limitations are significant or there are permanent layers of root limitation (nonrenewable).

Group 2.—The limitations for roots are moderate, or there is a less than permanent loss to productivity (renewable).

Group 3.—The limitations can be overcome through natural or managed processes, and the productivity level of the noneroded soil can be achieved (very renewable).

All restrictions in the NASIS "Component Restrictions Table" are considered root-limiting, either physically or chemically.

T factors are assigned based on the criteria presented below. If there is more than one limiting soil characteristic, then the soil is rated based on the most limiting soil characteristic based on the "T" criteria in the table.

"T" Criteria

12/31/2009

"T" Criteria [1/]			
Soil Characteristic	**Definition**	**Depth Limit (cm)**	**T Factor** [2/]
1. Organic	A. For Histosols, depth to the first mineral horizon with < 20% organic matter; soil is not in a lithic, limnic, hydric, or fluvaquentic subgroup and not in Sulfohemists or Sulfihemists great groups.	≤150 >150	1 2
	OR		
	B. For soils that are Histosols in a lithic, limnic, hydric, or fluvaquentic subgroup or are in Sulfohemists or Sulfihemists great groups.		1
	OR		
	C. Except in Alaska; mineral soils that are histic intergrades (i.e., histic subgroup). If the histic epipedon has been destroyed, then ignore this rating and rate T based on other limiting features of the mineral soil.		1
2. Bedrock	A. Except in Alaska; depth to densic bedrock as identified in the NASIS "Component Restrictions Table." (renewable)	<25 25-50 50-100 100-150 >150	1 2 3 4 5

	In Alaska (nonrenewable)	<50	1
		50-100	2
		100-150	3
		>150	5
	OR		
	B. Except in Alaska; depth to paralithic bedrock as identified in the NASIS "Component Restrictions Table." (renewable)	<25	1
		25-50	2
		50-100	3
		100-150	4
		>150	5
	In Alaska (nonrenewable)	<50	1
		50-100	2
		100-150	3
		>150	5
	OR		
	C. Depth to lithic bedrock as identified in the NASIS "Component Restrictions Table." (nonrenewable)	<50	1
		50-100	2
		100-150	3
		>150	5
3. Permafrost	Depth to permafrost as identified in the NASIS "Component Restrictions Table." (nonrenewable)	<50	1
		50-100	2
		100-150	3
		>150	5
4. Cemented layers/pans	A. Depth to duripan or petroferric, petrocalcic, petrogypsic, placic, ortstein, or cemented layer (or contiguous layers) that is ≤ 7.6 cm (3 inches) thick; hardness (i.e., rupture resistance) is extremely weakly, very weakly, weakly, or moderately as identified in the NASIS "Component Restrictions Table." (very renewable)	<50	3
		50-150	4
		>150	5

OR

B. Except in Alaska; depth to a duripan or petroferric, petrocalcic, petrogypsic, placic, ortstein, or cemented layer (or contiguous layers) that is ≤ 7.6 cm (3 inches) thick; hardness (i.e., rupture resistance) is strongly or very strongly as identified in the NASIS “Component Restrictions Table.” (renewable)	<25	1
	25-50	2
	50-100	3
	100-150	4
	>150	5
Alaska (nonrenewable)	<50	1
	50-100	2
	100-150	3
	>150	5

OR

C. Depth to a duripan or petroferric, petrocalcic, petrogypsic, placic, ortstein, or cemented layer that is ≤ 7.6 cm (3 inches) thick; hardness (i.e., rupture resistance) is indurated as identified in the NASIS “Component Restrictions Table.” (nonrenewable)	<50	1
	50-100	2
	100-150	3
	>150	5

OR

D. Except in Alaska; depth to a duripan or petrocalcic, petrogypsic, petroferric, placic, ortstein, or cemented layer (or contiguous layers) that is > 7.6 cm (3 inches) thick (or if thickness is not specified); hardness (i.e., rupture resistance) is extremely, very weakly, weakly, or moderately as identified in the NASIS “Component Restrictions Table.” (renewable)	<25	1
	25-50	2
	50-100	3
	100-150	4
	>150	5
In Alaska (nonrenewable)	<50	1
	50-100	2
	100-150	3
	>150	5

OR

	E. Depth to a duripan or petrocalcic, petrogypsic, petroferric, placic, ortstein, or cemented layer (or contiguous layers) that is > 7.6 cm (3 inches) thick (or if thickness is not specified); strongly or greater hardness (i.e., rupture resistance) as identified in the NASIS "Component Restrictions Table." (nonrenewable)	<50 50-100 100-150 >150	1 2 3 5
5. Fragmental	Depth to fragmental layer (i.e., consists of "in lieu of" textures of artifacts, boulders, cobbles, channers, flagstones, gravel, or stones). (nonrenewable)	<50 50-100 100-150 >150	1 2 3 5
6. Rock fragments	A. Except in Alaska; if the weighted average of rock fragments in the 0-25 cm depth is < 35% (by volume), then rate T based on depth to the first subsurface layer with ≥ 60% rock fragments that has its lower boundary extending to 150 cm or more. (renewable)	<50 50-100 100-150 >150	2 3 4 5
	In Alaska only; if the weighted average of rock fragments in the 0-12 cm depth is < 35% (by volume), then rate T based on depth to the first subsurface layer with ≥ 60% rock fragments that has its lower boundary extending to 150 cm or more. (nonrenewable)	<50 50-100 100-150 >150	1 2 3 5
	OR		
	B. Except in Alaska; if the weighted average of rock fragments in the 0-25 cm depth is < 35% (by volume), then rate T based on depth to the first subsurface layer with ≥ 60% rock fragments that has its lower boundary within 150 cm. (very renewable)	<50 50-150 >150	3 4 5
	In Alaska only; if the weighted average of rock fragments in the 0-12 cm depth is < 35% (by volume), then rate T based on depth to the first subsurface layer with ≥ 60% rock fragments that has its lower boundary within 150 cm. (nonrenewable)	<50 50-100 100-150 >150	1 2 3 5

	OR		
	C. Except in Alaska; if the weighted average of rock fragments in the 0-25 cm depth is ≤ 15% (by volume), then rate T based on depth to the first subsurface layer with ≥ 35% rock fragments that has its lower boundary extending to 150 cm or more. (very renewable)	<50 50-150 >150	3 4 5
	In Alaska only; if the weighted average of rock fragments in the 0-12 cm depth is ≤ 15% (by volume), then rate T based on depth to the first subsurface layer with ≥ 35% rock fragments that has its lower boundary extending to 150 cm or more. (nonrenewable)	<50 50-100 100-150 >150	1 2 3 5
7. Plinthite	Depth to plinthite as identified in the NASIS "Component Restrictions Table." (nonrenewable)	<50 50-100 100-150 >150	1 2 3 5
8. Fragipan and fragic soil properties	A. Depth to fragipan, as identified in the NASIS "Component Restrictions Table," that has ≥ 35% rock fragments. (renewable)	<50 50-100 100-150 >150	2 3 4 5
	OR		
	B. Depth to fragipan, as identified in the NASIS "Component Restrictions Table," that has < 35% rock fragments. (very renewable)	<50 50-150 >150	3 4 5
	OR		
	C. Soils that are in a fragic subgroup or have an "x" suffix symbol (fragipan character) in any horizon designation; rate T based on depth to the layer that has the greatest bulk density change (from a lower to higher bulk density) and has a $K_{sat} \le 1.41$ µm/s (0.5 cm/h). (very renewable)	<50 50-150 >150	3 4 5

9. Natric	A. Depth to natric horizon, as identified in the NASIS “Component Restrictions Table.” (renewable)	<50	2
		50-100	3
		100-150	4
		>150	5
	OR		
	B. For soils that have horizons that do not meet natric horizon criteria but have a subsoil with ≥ 35% clay, K_{sat} ≤ 1.41 µm/s (0.5 cm/h), and SAR ≥ 13 and have adjacent upper layers with a K_{sat} > 1.41 µm/s (0.5 cm/h) that extend to the surface (and the soils are not glossic). (renewable)	<50	2
		50-100	3
		100-150	4
		>150	5
10. Dense layers	Except in Alaska; depth to densic material, as identified in the NASIS “Component Restrictions Table.” (renewable)	<50	2
		50-100	3
		100-150	4
		>150	5
	In Alaska (nonrenewable)	<50	1
		50-100	2
		100-150	3
		>150	5
11. Abrupt increase in clay	A. Depth to layer with an abrupt textural change as identified in the NASIS “Component Restrictions Table.” (very renewable)	<50	3
		50-150	4
		>150	5
	OR		
	B. Depth to substratum that has ≥ 35% clay, has a K_{sat} < 1.41 µm/s (0.5 cm/h), and an adjacent upper layer with a K_{sat} > 4.23 µm/s (1.5 cm/h); or a subsoil that has a K_{sat} < 0.42 µm/s (0.15 cm/h) and an adjacent upper surface layer with a K_{sat} > 1.41 µm/s (0.5 cm/h); the clay increase between the adjacent layers must be ≥ 20%, and the surface or upper layers are greater than or equal to 25 cm thick. (very renewable)	<50	3
		50-150	4
		>150	5

12. Strongly contrasting textural stratification	Depth to layers that have strongly contrasting textural stratification, as identified in the NASIS “Component Restrictions Table.” (very renewable)	<50	3
		50-150	4
		>150	5
13. Sandy substratum	A. Except in Alaska; depth to sandy substratum (COS, S, FS, LS, LCOS, or LFS) with a $K_{sat} > 42.3$ µm/s (15.2 cm/h) that extends to 150 cm or more, and the adjacent upper layers have a $K_{sat} < 42.3$ µm/s (15.2 cm/h) and have < (0.667*% clay + 50) percent fine or coarser sand separates in the fine-earth fraction that extends to the surface[3/]; the surface or upper layers are greater than or equal to 25 cm in thickness. (renewable)	<50	2
		50-100	3
		100-150	4
		>150	5
	In Alaska only; depth to sandy substratum (COS, S, FS, LS, LCOS, or LFS) with a $K_{sat} > 42.3$ µm/s (15.2 cm/h) that extends to 150 cm or more, and the adjacent upper layers have a $K_{sat} < 42.3$ µm/s (15.2 cm/h) and have < (0.667*% clay + 50) percent fine or coarser sand separates in the fine-earth fraction that extends to the surface[3/]; the surface or upper layers are greater than or equal to 12 cm in thickness. (renewable)	<50	2
		50-100	3
		100-150	4
		>150	5
	OR		
	B. Except in Alaska; depth to substratum with strongly contrasting sandy textural stratification or stratified with sandy textures of COS, S, LS, FS, LCOS, or LFS and $K_{sat} > 42.3$ µm/s (15.2 cm/h) that extends to 150 cm or below, and the adjacent upper layers have a $K_{sat} < 42.3$ µm/s (15.2 cm/h) and have < (0.667*% clay + 50) percent fine or coarser sand separates in the fine-earth fraction that extends to the surface[3/]; the surface or upper layers are greater than or equal to 25 cm in thickness. (renewable)	<50	2
		50-100	3
		100-150	4
		>150	5

	In Alaska only; depth to substratum with strongly contrasting sandy textural stratification or stratified with sandy textures of COS, S, LS, FS, LCOS, or LFS and $K_{sat} > 42.3$ µm/s (15.2 cm/h) that extends to 150 cm or below, and the adjacent upper layers have a $K_{sat} < 42.3$ µm/s (15.2 cm/h) and have < (0.667*% clay + 50) percent fine or coarser sand separates in the fine-earth fraction that extends to the surface [3/]; the surface or upper layers are greater than or equal to 12 cm in thickness. (renewable)	<50 50-100 100-150 >150	2 3 4 5
14. High gypsum	A. Soils that have a surface layer with ≤ 15% gypsum (by weight) and have subsurface layers with ≥ 25% gypsum; rate T based on depth to the first subsurface layer with ≥ 25% gypsum. (renewable)	<50 50-100 100-150 >150	2 3 4 5
	OR		
	B. Soils that have a surface layer with > 15 and ≤ 60% gypsum (by weight) and have subsurface layers that exceed the surface layer in gypsum content by 20% or more; rate T based on depth to the first subsurface layer that exceeds the surface by 20% or more gypsum. (renewable)	<50 50-100 100-150 >150	2 3 4 5
15. High salts	Depth to salic horizon, as identified in the NASIS "Component Restrictions Table." (very renewable)	<50 50-150 >150	3 4 5
16. High sulfur	Depth to sulfuric horizon, as identified in the NASIS "Component Restrictions Table." (very renewable)	<50 50-150 >150	3 4 5
17. High carbonates	A. Soils that have a surface layer with ≤ 15% calcium carbonate ($CaCO_3$) equivalent and have subsurface layers with ≥ 40% $CaCO_3$ equivalent; rate T based on depth to the first subsurface layer with ≥ 40% $CaCO_3$ equivalent. (renewable)	<50 50-100 100-150 >150	2 3 4 5

	OR		
	B. Soils that have a surface layer with > 15 and ≤ 60% calcium carbonate ($CaCO_3$) equivalent and have subsurface layers that exceeds the surface layer in $CaCO_3$ equivalent by 25% or more; rate T based on depth to the first subsurface layer that exceeds the surface layer by 25% or more $CaCO_3$ equivalent. (renewable)	<50 50-100 100-150 >150	2 3 4 5
18. Human-manufactured materials	Depth to human-manufactured materials (‘M’ layers), as identified in the NASIS “Component Restrictions Table.” (nonrenewable)	<50 50-100 100-150 >150	1 2 3 5
19. High aluminum	A. Depth to ≥ 60% Al saturation of the ECEC and soil pH (1:1 water) is ≤ 5.5. (very renewable)	<50 50-150 >150	3 4 5
	OR		
	B. In Pacific Islands only; for Oxisols or soils in Oxic subgroups or for Ultisols with an isohyperthermic soil temperature regime; depth to ≥ 45% Al saturation of the ECEC and soil pH (1:1 water) is ≤ 5.5. (nonrenewable)	<50 50-100 100-150 >150	1 2 3 5

1/ Subaqueous soils (i.e., soils classified in Wassents or Wassists suborders) are excluded from assignment of T factors.

2/ Severely eroded soils, as designated by a the local phase or erosion class of 3 or 4, are adjusted one class of T factor lower.

3/ Determines the line between the 30% clay and 70% sand point and the 0% clay and 50% sand point on the texture triangle (see part 618, subpart B, section 618.87). If the total of the vcos, cos, ms, and fs sand separates and total clay (of the adjacent layers above the sandy substratum) plot above this line on the texture triangle, then the uppers layers are considered different from the sandy substratum textures. Thus, the sandy substratum is recognized and the T factor is lowered.

618.94 Texture Class, Texture Modifier, and Terms Used in Lieu of Texture

Texture Class		Texture Modifier 1/		Terms Used in Lieu of Texture	
Class	**Code**	**Modifier**	**Code**	**Term**	**Code**
Clay	C	Artifactual	ART	Artifacts	ART
Clay loam	CL	Very artifactual	ARTV	Bedrock	BR
Coarse sand	COS	Extremely artifactual	ARTX	Boulders	BY
Coarse sandy loam	COSL	Ashy	ASHY	Cobbles	CB
Fine sand	FS	Bouldery	BY	Coarse gypsum material	CGM
Fine sandy loam	FSL	Bouldery-artifactual	BYART	Channers	CN
Loam	L	Very bouldery	BYV	Fine gypsum material	FGM
Loamy coarse sand	LCOS	Very bouldery-artifactual	BYVART	Flagstones	FL
Loamy fine sand	LFS	Extremely bouldery	BYX	Gravel	GR
Loamy sand	LS	Extremely bouldery-artifactual	BYXART	Highly decomposed plant material	HPM
Loamy very fine sand	LVFS	Cobbly	CB	Material	MAT
Sand	S	Cobbly-artifactual	CBART	Moderately decomposed plant material	MPM
Sandy clay	SC	Very cobbly	CBV	Mucky peat	MPT
Sandy clay loam	SCL	Very cobbly-artifactual	CBVART	Muck	MUCK
Silt	SI	Extremely cobbly	CBX	Paraboulders	PBY
Silty clay	SIC	Extremely cobbly-artifactual	CBXART	Paracobbles	PCB
Silty clay loam	SICL	Cemented	CEM	Parachanners	PCN
Silt loam	SIL	Channery	CN	Peat	PEAT
Sandy loam	SL	Channery-artifactual	CNART	Paraflagstones	PFL
Very fine sand	VFS	Very channery	CNV	Paragravel	PG
Very fine sandy loam	VFSL	Very channery-artifactual	CNVART	Parastones	PST
		Extremely channery	CNX	Shells	SHL
		Extremely channery-artifactual	CNXART	Slightly decomposed plant material	SPM
		Coprogenous	COP	Stones	ST
		Diatomaceous	DIA	Water	W
		Flaggy	FL		
		Flaggy-artifactual	FLART		
		Very flaggy	FLV		
		Very flaggy-artifactual	FLVART		
		Extremely flaggy	FLX		
		Extremely flaggy-artifactual	FLXART		
		Gravelly	GR		
		Gravelly-artifactual	GRART		
		Coarse gravelly	GRC		
		Fine gravelly	GRF		
		Medium gravelly	GRM		
		Very gravelly	GRV		
		Very gravelly-artifactual	GRVART		
		Extremely gravelly	GRX		

		Extremely gravelly-artifactual	GRXART		
		Grassy	GS		
		Gypsiferous	GYP		
		Herbaceous	HB		
		Highly organic	HO		
		Hydrous	HYDR		
		Medial	MEDL		
		Mucky	MK		
		Marly	MR		
		Mossy	MS		
		Parabouldery	PBY		
		Very parabouldery	PBYV		
		Extremely parabouldery	PBYX		
		Paracobbly	PCB		
		Very paracobbly	PCBV		
		Extremely paracobbly	PCBX		
		Parachannery	PCN		
		Very parachannery	PCNV		
		Extremely parachannery	PCNX		
		Permanently frozen	PF		
		Paraflaggy	PFL		
		Very paraflaggy	PFLV		
		Extremely paraflaggy	PFLX		
		Paragravelly	PGR		
		Very paragravelly	PGRV		
		Extremely paragravelly	PGRX		
		Parastony	PST		
		Very parastony	PSTV		
		Extremely parastony	PSTX		
		Peaty	PT		
		Shelly	SHF		
		Very shelly	SHFV		
		Extremely shelly	SHFX		
		Shelly-artifactual	SHFART		
		Very shelly-artifactual	SHFVART		
		Extremely shelly-artifactual	SHFEART		
		Stony	ST		
		Stony-artifactual	START		
		Very stony	STV		
		Very stony-artifactual	STVART		
		Extremely stony	STX		
		Extremely stony-artifactual	STXART		
		Woody	WD		

1/ "Texture modifiers" may apply to both "texture class" and "terms used in lieu of texture." Some apply to both, others only apply to one or the other. See part 618, subpart A, section 618.71, for more information.

618.95 Wind Erodibility Groups (WEG) and Index

WEG [1,3,4,5,7]	**Properties of Soil Surface Layer**	**Dry Soil Aggregates More Than 0.84 mm (wt.%)**	**Wind Erodibility Index (I) (tons/ac/yr)**
1	Very fine sand, fine sand, sand, or coarse sand[2]	1 2 3 5 7	310 250 220 180 160
2	Loamy very fine sand, loamy fine sand, loamy sand, and loamy coarse sand; very fine sandy loam and silt loam with 5 or less percent clay; and sapric soil materials (as defined in Soil Taxonomy), except Folists.	10	134
3	Very fine sandy loam (but does not meet WEG criterion 2), fine sandy loam, sandy loam, and coarse sandy loam; noncalcareous silt loam that has greater than or equal to 20 to less than 50 percent very fine sand and greater than or equal to 5 to less than 12 percent clay.	25	86
4	Clay, silty clay, noncalcareous clay loam that has more than 35 percent clay and noncalcareous silty clay loam that has more than 35 percent clay; all of these do not have sesquic, parasesquic, ferritic, ferruginous, or kaolinitic mineralogy (high iron oxide content).	25	86
4L	Calcareous[6] loam, calcareous silt loam, calcareous silt, calcareous sandy clay, calcareous sandy clay loam, calcareous clay loam, and calcareous silty clay loam.	25	86
5	Noncalcareous loam that has less than 20 percent clay, noncalcareous silt loam with greater than or equal to 5 to less than 20 percent clay (but does not meet WEG criterion 3), noncalcareous sandy clay loam, noncalcareous sandy clay, and hemic soil materials (as defined in Soil Taxonomy).	40	56
6	Noncalcareous loam and silt loam that have greater than or equal to 20 percent clay; noncalcareous clay loam and noncalcareous silty clay loam that have less than or equal to 35 percent clay; silt loam that has parasesquic, ferritic, or kaolinitic mineralogy (high iron oxide content).	45	48
7	Noncalcareous silt; noncalcareous silty clay, noncalcareous silty clay loam, and noncalcareous clay that have sesquic, parasesquic, ferritic, ferruginous, or kaolinitic mineralogy (high content of iron oxide) and are Oxisols or Ultisols; and fibric soil materials (as defined in Soil Taxonomy).	50	38
8	Soils not susceptible to wind erosion due to rock and pararock fragments at the surface and/or wetness; and Folists.	--	0

The following footnotes are applied in the order listed:

1 For all WEGs except 1 and 2 (sands and loamy sand textures), if percent rock and pararock fragments (>2mm) by volume is 15-35, reduce "I" value by one group with more favorable rating. If percent rock and pararock fragments by volume is 35-60, reduce "I" value by two favorable groups except for sands and loamy sand textures which are reduced by one group with more favorable rating. If percent rock and pararock fragments is greater than 60, use "I" value of 0 for all textures except sands and loamy sand textures which are reduced by three groups with more favorable ratings. An example of more favorable "I" rating is next lower number: "I" factor of 160 to "I" factor of 134 or "I" factor of 86 to "I" factor of 56. The index values should correspond exactly to their wind erodibility group (e.g., "I" factor of 56 = WEG 5).

2 The "I" values for WEG 1 vary from 160 for coarse sands to 310 for very fine sands. Use an "I" of 220 as an average figure.

3 All material that meets criterion 3 in the required characteristics for andic soil properties as defined in the Keys to Soil Taxonomy, 11th edition. Such material is placed in WEG 2 regardless of the texture class of the fine-earth fraction.

4 All material that meets criterion 2, but not criterion 3, in the required characteristics for andic soil properties as defined in the Keys to Soil Taxonomy, 11th edition. Such material is placed in WEG 6, regardless of the texture class of the fine-earth fraction. The only exception to this is for Cryic Spodosols which have a medial substitute class and a MAAT < 4 degrees C.; these soils are placed in WEG 2.

5 For surface layers or horizons that do not meet the required characteristics for andic soil properties but do meet Vitrandic, Vitritorrandic, Vitrixerandic, and Ustivitrandic subgroup criteria (thickness criterion excluded) move one wind erodibility group (WEG) with a less favorable rating.

6 Calcareous is a strongly or violently effervescent reaction (class) of the fine-earth fraction to cold dilute (1N) HCL; a paper "Computing the Wind Erodible Fraction of Soils" by D. W. Fryear et.al (1994) in the Journal of Soil and Water Conservation 49 (2) 183-188 raises a yet unresolved question regarding the effect of carbonates on wind erosion.

7 For mineral soils with thin "O" horizons, the WEG is based on the first mineral horizon.

618.96 Key Landforms and Their Susceptibility to Slippage

Topography	**Landform or Geological Materials**	**Slippage Potential** [A]
I. Level Terrain		
A. Not elevated	Flood plain, till plain, lakebed	3
B. Elevated		
1. Uniform tones	Terrace, lakebed,	2
2. Surface irregularities, sharp cliffs	basaltic plateau	1
3. Interbedded, porous over impervious layers	lakebed, coastal plain	1
II. Hilly Terrain		
A. Surface drainage not well integrated		
1. Disconnected drainage	Limestone	3
2. Deranged drainage, overlapping hills, associated with lakes and swamps (glaciated areas only)	Moraine	2
B. Surface drainage well integrated		
1. Parallel ridges		
a. Parallel drainage, dark tones	Basaltic hills	1
b. Trellis drainage, ridge-and-valley topography, banded hills	Downslope tilted sedimentary rock	1
c. Pinnate drainage, vertical-sided gullies	Loess	2
2. Branching ridges, hilltops at common elevation		
a. Pinnate drainage, vertical-sided gullies	Loess	2
b. Dendritic drainage		
(1) Banding on slopes	Flat-lying sed. rocks	2
(2) No banding on slopes		
(a) Moderately to highly dissected ridges, uniform slopes	Clay shale	1
(b) Low ridges associated with coastal features	Dissected coastal plains	1
(c) Winding ridges connection, conical hills, sparse vegetation	Serpentinite	1
3. Random ridges or hills		
a. Dendritic drainage		
(1) Low, rounded hills, meandering streams	Clay shale	1
(2) Winding ridges, connecting conical hills, sparse vegetation	Serpentinite	1
(3) Massive, uniform, rounded to A-shaped hills	Granite	2
(4) Bumpy topography (glaciated areas only)	Moraines	2
III. Level to Hilly Terrain		
A. Steep slopes	Talus, colluvium	1
B. Moderate to flat slopes	Fan, delta	3
C. Hummocky slopes with scarp at head	Old slide	1

A. Ratings for slippage potential:
1 = susceptible to slippage (unstable); 2 = susceptible to slippage under certain conditions (moderately unstable); 3 = not susceptible to slippage except in vulnerable locations (slightly unstable to stable)

618.97 Example Worksheets for Soil Moisture State by Month and Depth

SOIL MOISTURE STATE BY MONTH AND DEPTH

Aridic Thermic

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ppt (mm)	10	10	8	4	6	2	8	10	6	4	8	8
0 SOIL DEPTH 200 cm	M D	M D	M D	M D	D	D	D	D	D	D	D	M D

Xeric Mesic

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ppt (mm)	180	140	110	60	40	30	10	20	40	80	170	200
0 SOIL DEPTH 200 cm	M W	M W	M W	M	M	D M	D M	D M	M D M	M	M	W

Ustic Mesic

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ppt (mm)	10	15	50	60	80	100	70	70	70	40	25	15
0 SOIL DEPTH 200 cm	M D M	M D M	M D M	M	M	M	D M	D M	D M	M D M	M D M	M D M

Udic Mesic

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ppt (mm)	50	60	80	80	100	100	110	90	70	50	80	70
0 SOIL DEPTH 200 cm	M — W	M — W	M — W	M — W	M — W	M	M	D — M	D — M	M	M — W	M — W

SOIL MOISTURE STATE BY MONTH AND DEPTH

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ppt (mm)												
0 SOIL DEPTH 200 cm												

SOIL MOISTURE STATE BY MONTH AND DEPTH

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ppt (mm)												
0 SOIL DEPTH 200 cm												

SOIL MOISTURE STATE BY MONTH AND DEPTH

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ppt (mm)												
0 SOIL DEPTH 200 cm												

618.98 NASIS Calculation for Estimating AASHTO Group Index

Definition.—Computes the AASHTO Group Index for a horizon

Inputs.—This calculation requires the following data to be populated:

number 200 sieve
liquid limit
plasticity index

Calculation.

```
DEFINE skip_ll       ANY (aashto_class == "a-2-6" or aashto_class == "a-2-7").
DEFINE aashind       .01*(sieveno200_r-15)*(pi_r-10).

ASSIGN aashind      IF skip_ll OR (sieveno200_r<35 and pi_r>=10) THEN aashind ELSE (sieveno200_r
- 35)*(.2 + .005*(ll_r - 40)) + aashind.

ASSIGN aashind      IF pi_r==0 OR (aashind<0 AND NOT ISNULL(aashind)) THEN 0 ELSE aashind.
```

618.99 NASIS Calculation for Estimating Cation-Exchange Capacity

Definition.—If the rv pH (in water) is greater than or equal to 5.5, then CEC is calculated; if the rv pH is less than 5.5, then ECEC is calculated for a horizon.

Caution: Estimates of CEC or ECEC for soil layers with andic soil properties may be unreliable. Read the documentation to this calculation to see if it will work for your soils.

Inputs.—This calculation requires the following data to be populated:

organic matter (high, low, and rv)
pH in water (high, low, and rv)
pH in CaCl (for organic layers) (high, low, and rv)
total clay (high, low, and rv)
carbonate clay (high, low, and rv)
total silt (high, low, and rv)
$CaCO_3$ (high, low, and rv) used only for soils containing gypsum
gypsum (high, low, and rv) used only for soils containing gypsum
taxonomic family mineralogy
taxonomic order
taxonomic CEC-activity class

1) The calculation is based on Soil Taxonomy (Soil Survey Staff, 1999). The CEC or ECEC is calculated based on the family mineralogy/CEC-activity class first. If an equation does not exist for a mineralogy/CEC-activity class, then the CEC/ECEC is based on the soil order.
2) If the family mineralogy class, CEC-activity class (if appropriate), and soil order are not populated, a null is returned.
3) If there is more than one family mineralogy class populated in the “Component-Taxonomic-Family-Mineralogy Table,” the first one is used.
4) If the pH in water is not populated, then pH in CaCl is used. If the pH (CaCl) is greater than or equal to 5.1, then CEC is calculated; otherwise ECEC is calculated for a horizon.
5) If any required data element (OM, pH, clay, silt) for an equation is not populated (null entry), a null is returned, except for carbonate clay.
6) If carbonate clay is null, zero carbonate clay is assumed.
7) Noncarbonate clay is calculated by subtracting percent carbonate clay from total clay (noncarbonated clay = total_clay - carbonate_clay).
8) Percent organic matter is converted to percent organic C by dividing by 1.72 (OC = OM/1.72).
9) If only low and high values are populated for a data element, an rv is calculated by taking the average of the low and high values.
10) In the calculation of CEC for isotic and amorphic mineralogies and Andisols and for isotic mineralogy for ECEC, gravimetric 15-bar water is used. An internal calculation calculates the 15-bar water using the following formula:
    15-bar water = [total_clay (1 - organic_matter / 100) 0.4 + organic_matter]
11) In the calculation of ECEC, if the mineralogy class is not parasesquic, smectitic, or isotic and is not mixed or siliceous with a CEC activity class and the soil order is Andisols, Gelisols, Aridisols, or Vertisols, then no ECEC is calculated (null is returned).

Calculation.

```
Estimate # -------- gypsum soils ----------------------------------------------------------

DEFINE cecr IF ISNULL(ph1) THEN 1/0
```

```
ELSE IF ph1 =="yes" and gyp2mm > 4 and gyp2mm <= 40 THEN EXP(0.851*ln_clayr - 0.02*caco3_r -
0.009*gyp2mm + 0.174) * (1-(gyp2mm/100))
ELSE IF ph1 =="yes" and gyp2mm > 40 THEN 10.035 - 0.093*gyp2mm

# -------- phwat >= 5.5 or phcacl2 >=5.1 and phwat<=7.0 and OC > 8 -----------------
ELSE IF ph1 =="yes"and ocr>14.5 and ph2 =="no"and
 (lieutex1 == "muck" OR lieutex1 == "hpm")
THEN ((2.12 * (ocr)) + (9.992 * (phcacl2r)) - 10.684)
ELSE IF ph1 =="yes"and ocr>14.5 and ph2 =="no"and
(lieutex1 == "mpt" OR lieutex1 == "mpm")
THEN ((2.03 * (ocr)) + (3.396 * (phcacl2r)) - 2.939)
ELSE IF ph1 =="yes"and ocr>14.5 and ph2 =="no"and
  (lieutex1 == "peat" or lieutex1 == "spm")
THEN ((1.314 * (ocr)) + 27.047)
ELSE IF ph1 =="yes"and ocr>8 and ph2 =="no"and ocr <= 14.5
THEN ((1.823 * (ocr)) + (0.398 * (nclayr)) + 15.54)

# ------------ phwat >=5.5 or phcacl2r >= 5.1 and OC >8 and phwat >7.0 ---------------
ELSE IF ph1 =="yes"and ocr>8 and ph2 =="yes"and ocr <= 14.5
THEN EXP(1.316 * (ln_ocr) + 1.063 * (ln_nclayr) - 3.211)
ELSE IF ph1 =="yes"and ocr>8 and ph2 =="yes"and ocr >14.5
THEN (4.314 * (ocr) - 26.492)

# ------------ phwat >= 5.5 or phcacl2 >= 5.1 and OC <= 8, use Mineralogy  -------------
ELSE IF (ph1 =="yes"and ocr <= 8 and taxminalogy1 == "ferruginous")
THEN (2.48 * (ocr) + 0.128 * (siltr) + 3.208)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxminalogy1 == "amorphic")
THEN EXP((0.182*(ln_ocr)) + (0.817*(ln_w15barr)) + (0.736*(ln_phwatr)) - 0.608)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxminalogy1 == "glassy")
THEN EXP((0.102*(ln_ocr)) + (1.219*(ln_w15barr)) - 0.005)
ELSE IF (ph1 =="yes"and ocr <= 8 and (taxminalogy1 == "carbonatic" or taxminalogy1 =="calcareous"))
THEN EXP((0.253*(ln_ocr)) + (0.828*(ln_nclayr)) + 0.321)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxminalogy1 == "magnesic")
THEN (2.38*(ocr) + 0.555*(nclayr) - 0.219*(siltr) + 10.428)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxminalogy1 == "parasesquic")
THEN EXP((0.13*(ln_ocr)) + (0.65*(ln_nclayr)) + (0.340*(ln_phwatr)) - 0.406)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxminalogy1 == "kaolinitic")
THEN EXP((0.206*(ln_ocr)) + (0.618*(ln_nclayr)) + (0.303*(ln_siltr)) + (0.491*(ln_phwatr)) - 1.786)
ELSE IF (ph1 =="yes"and ocr <= 8 and (taxminalogy1 == "smectitic" OR taxminalogy1 ==
"montmorillonitic"))
THEN EXP((0.033*(ln_ocr)) + (0.861*(ln_nclayr)) + 0.246)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxminalogy1 == "illitic")
THEN EXP((0.102*(ln_ocr)) + (0.596*(ln_nclayr)) - (1.108*(ln_phwatr)) + 2.892)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxminalogy1 == "vermiculitic")
THEN (0.365*(nclayr) - 9.724*(phwatr) + 90.293)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxminalogy1 == "isotic")
THEN EXP((0.163*(ln_ocr)) + (0.683*(ln_w15barr)) + (0.812*(ln_phwatr)) - 0.299)
ELSE

# ----------------- use CEC Activity Class ----------------------
IF (ph1 =="yes"and ocr <=8 and taxceactcl1 == "superactive")
THEN EXP((0.039*(ln_ocr)) + (0.901*(ln_nclayr)) + 0.131)
```

```
ELSE IF (ph1 =="yes"and ocr <= 8 and taxceactcl1 == "active")
THEN EXP((0.015*(ln_ocr)) + (0.987*(ln_nclayr)) - 0.576)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxceactcl1 == "semiactive")
THEN EXP((0.02*(ln_ocr)) + (0.974*(ln_nclayr)) - 0.927)
ELSE IF (ph1 =="yes" and ocr <= 8 and taxceactcl1 == "subactive")
THEN EXP((0.009*(ln_ocr)) + (1.02*(ln_nclayr)) - 1.675)
ELSE

# -------------------use Taxonomic Order -------------------------
IF (ph1 =="yes"and ocr <= 0.3 and taxorder1 == "alfisols")
THEN EXP((0.911*(ln_nclayr)) - 0.308)
ELSE IF (ph1 =="yes"and ocr > 0.3 and ocr <= 8 and taxorder1 == "alfisols")
THEN EXP((0.158*(ln_ocr)) + (0.805*(ln_nclayr)) + 0.216)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxorder1 == "andisols")
THEN EXP((0.088*(ln_ocr)) + (0.885*(ln_w15barr)) + (0.867*(ln_phwatr)) - 0.985)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxorder1 == "aridisols")
THEN EXP((0.042*(ln_ocr)) + (0.828*(ln_nclayr)) + 0.236)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxorder1 == "entisols")
THEN EXP((0.078*(ln_ocr)) + (0.873*(ln_nclayr)) + 0.084)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxorder1 == "inceptisols")
THEN EXP((0.134*(ln_ocr)) + (0.794*(ln_nclayr)) + 0.239)
ELSE IF (ph1 =="yes"and ocr <= 0.3 and taxorder1 == "mollisols")
THEN EXP((0.932*(ln_nclayr)) - 0.174)
ELSE IF (ph1 =="yes"and ocr > 0.3 and ocr <= 8 and taxorder1 == "mollisols")
THEN EXP((0.113*(ln_ocr)) + (0.786*(ln_nclayr)) + 0.475)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxorder1 == "oxisols")
THEN (2.738*(ocr) + 0.103*(nclayr) + 0.123*(siltr) - 2.531)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxorder1 == "spodosols")
THEN EXP((0.045*(ln_ocr)) + (0.798*(ln_nclayr)) + 0.029)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxorder1 == "ultisols")
THEN EXP((0.184*(ln_ocr)) + (0.57*(ln_nclayr)) + (0.365*(ln_siltr)) - 0.906)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxorder1 == "vertisols")
THEN EXP((0.059*(ln_ocr)) + (0.86*(ln_nclayr)) + 0.312)
ELSE IF (ph1 =="yes"and ocr <= 8 and taxorder1 == "histosols")
THEN EXP((0.319*(ln_ocr)) + (0.497*(ln_nclayr)) + 1.075) ELSE 1/0.
```

618.100 NASIS Calculation for Estimating Effective Cation-Exchange Capacity

Inputs.—See the documentation in part 618, subpart B, section 618.99, on the NASIS calculation for estimating cation-exchange capacity.

Calculation.

```
#---------Calculates ECEC when pH(water) < 5.5-------------------------------------------
DEFINE ececr
IF ISNULL(ph1) THEN 1/0
ELSE IF ph1 == "no" AND ocr > 8 AND taxminalogy1 == "andisols"
THEN EXP(0.938*ln_ocr - 0.029*phcacl2r - 0.054)
ELSE IF ph1 == "no" AND ocr > 8
THEN EXP(0.699*ln_ocr + 0.556*phcacl2r - 1.497)
ELSE IF ph1 =="no"AND ocr <= 8 AND desgnmaster1 == "E"
THEN EXP((0.371*ln_ocr) + (0.728*ln_nclayr) + (0.392*ln_siltr) + (0.728*ln_phwatr) - 2.145)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxminalogy1 == "parasesquic"
THEN EXP(0.109*ln_ocr + 0.904*ln_clayr - 0.927*ln_phwatr - 0.083)
ELSE IF ph1 =="no"AND ocr <= 8 AND (taxminalogy1 == "smectitic" OR taxminalogy1 ==
"montmorillonitic")
THEN EXP(0.965*ln_clayr + 0.939*ln_phwatr - 1.974)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxminalogy1 == "isotic"
THEN EXP(0.124*ln_ocr + 0.535*ln_w15barr + 0.405*ln_siltr - 0.455)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxceactcl1 == "superactive"
THEN EXP(0.035*ln_ocr + 0.913*ln_clayr - 0.341)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxceactcl1 == "active"
THEN EXP(1.15*ln_clayr - 0.115*ln_ocr - 1.725)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxceactcl1 == "semiactive"
THEN EXP(1.049*ln_clayr - 0.058*ln_ocr - 1.864)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxceactcl1 == "subactive"
THEN EXP(0.757*ln_clayr - 1.01*ln_phwatr + 0.214*ln_siltr - 0.465)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxorder1 == "alfisols"
THEN EXP(0.019*ln_ocr + 0.834*ln_clayr + 0.325*ln_phwatr + 0.288*ln_siltr - 1.937)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxorder1 == "entisols"
THEN EXP(0.387*ln_ocr + 0.818*ln_clayr - 0.343)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxorder1 == "inceptisols"
THEN EXP(0.283*ln_ocr + 0.541*ln_clayr + 1.913*ln_phwatr - 2.869)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxorder1 == "mollisols"
THEN EXP(0.122*ln_ocr + 0.721*ln_clayr + 0.6*ln_phwatr - 0.635)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxorder1 == "oxisols"
THEN EXP(0.21*ln_ocr + 0.685*ln_clayr - 2.381*ln_phwatr + 0.355*ln_siltr + 1.169)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxorder1 == "spodosols"
THEN EXP(0.309*ln_ocr + 0.526*ln_clayr + 0.25*ln_siltr - 0.535)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxorder1 == "ultisols"
THEN EXP(0.555*ln_clayr + 0.481*ln_siltr - 1.204*ln_phwatr + 0.016)
ELSE IF ph1 =="no"AND ocr <= 8 AND taxorder1 == "histosols"
THEN 0.443*clayr + 2.377*ocr - 2.906
ELSE 1/0.
```

618.101 NASIS Calculation for Estimating Extractable Acidity

Definition.—Computes the extractable acidity for a horizon.

Inputs.—This calculation requires the following data to be populated:

- organic matter (high, low, and rv)
- pH in water (high, low, and rv)
- pH in $CaCl_2$ (high, low, and rv) only used for organic layers
- total clay (high, low, and rv) only used for medial textures
- CEC or ECEC (high, low, and rv)
- texture (used for identifying hydrous, medial, ashy, and organic soil layers)
- taxonomic order

Limitations.

1) The calculation is based on regression equations developed from measured data in the characterization database. There are regression equations for O horizons of Histosols, O horizons of other soil orders, hydrous textures, medial textures, ashy textures, and mineral layers for each soil order.
2) There are a set of regression equations that use CEC and another set that use ECEC as a predictor variable. IF the pH is < 5.5, then the set of equations that use ECEC is used. IF ECEC in not populated then a null is returned (regardless if CEC is populated or not).
3) If any required data element (OM, pH, CEC, or ECEC) for an equation is not populated (null entry), a null is returned.
4) Organic C is used in the equations. Percent organic matter is converted to percent organic C by dividing by 1.72 (OC = OM/1.72).

Calculation.

```
DEFINE    ocr    om_r/1.72.
DEFINE    ocl    om_l/1.72.
DEFINE och     om_h/1.72.

#-----Calculate RV extractable acidity---------------

DEFINE acidr  IF NOT ISNULL(cec7_r) AND (ph1to1h2o_r >= 5.5 OR ph01mcacl2_r >= 5.5) THEN
IF (hzname matches "*O*" OR texture matches "*MPT*" OR texture matches "*MUCK*" OR texture
matches "*PEAT*" OR texture matches "*HPM*" OR texture matches "*MPM*" OR texture matches
"*SPM*") AND ph1to1h2o_r > 6.1 THEN 0.19*cec7_r - 11.411*ph1to1h2o_r + 78.341 ELSE IF taxord
== "histosols"  AND NOT ISNULL(taxord) AND (hzname matches "*O*" OR texture matches "*MPT*"
OR texture matches "*MUCK*" OR texture matches "*PEAT*") THEN 0.289*cec7_r + 0.358*ocr -
26.390*ph01mcacl2_r + 149.662 ELSE IF (hzname matches "*O*" AND NOT ISNULL(hzname)) OR
((texture matches "*HPM*" OR texture matches "*MPM*" OR texture matches "*SPM*" OR texture
matches "*MPT*" OR texture matches "*MUCK*" OR texture matches "*PEAT*") AND NOT
ISNULL(texture)) THEN 0.470*cec7_r + 0.298*ocr - 19.702*ph01mcacl2_r + 100.585 ELSE IF texture
matches "*HYDR*" AND NOT ISNULL(texture) THEN -0.312*cec7_r + 3.726*ocr -
20.442*ph1to1h2o_r + 159.093 ELSE IF texture matches "*MEDL*" AND NOT ISNULL(texture)
THEN 0.564*cec7_r - 0.326*claytotal_r - 8.825*ph1to1h2o_r + 75.799 ELSE IF texture matches
"*ASHY*" AND NOT ISNULL(texture) THEN 0.134*cec7_r + 2.669*ocr - 1.972*ph1to1h2o_r +
14.051 ELSE IF taxord == "histosols" THEN 0.673*cec7_r - 7.659*ph1to1h2o_r + 44.466 ELSE IF
taxord == "gelisols" THEN 0.36*cec7_r - 4.301*ph1to1h2o_r + 31.87 ELSE IF taxord == "entisols"
THEN 0.148*cec7_r + 1.679*ocr - 1.791*ph1to1h2o_r + 12.254 ELSE IF taxord == "mollisols" THEN
```

```
0.112*cec7_r + 0.595*ocr - 2.745*ph1to1h2o_r + 19.964 ELSE IF taxord == "alfisols"  THEN
0.205*cec7_r + 1.113*ocr - 2.928*ph1to1h2o_r + 19.545 ELSE IF taxord == "aridisols"  THEN
0.047*cec7_r + 0.535*ocr - 0.973*ph1to1h2o_r + 7.735 ELSE IF taxord == "ultisols"  THEN
0.850*cec7_r + 0.361*ocr - 2.125*ph1to1h2o_r + 11.741 ELSE IF taxord == "inceptisols"  THEN
0.496*cec7_r + 0.698*ocr - 5.010*ph1to1h2o_r + 31.299 ELSE IF taxord == "vertisols"  THEN
0.061*cec7_r + 0.775*ocr -3.557*ph1to1h2o_r + 26.936 ELSE IF taxord == "spodosols" THEN
1.226*cec7_r - 0.524*ocr - 3.429*ph1to1h2o_r + 20.975 ELSE IF taxord == "oxisols"  THEN
0.499*cec7_r + 1.679*ocr - 2.055*ph1to1h2o_r + 16.422 ELSE IF taxord == "andisols"  THEN
0.763*cec7_r - 4.328*ph1to1h2o_r + 28.591  ELSE 1/0 ELSE IF NOT ISNULL(ecec_r) THEN IF taxord
== "histosols"  AND NOT ISNULL(taxord) AND (hzname matches "*O*" OR texture matches "*MPT*"
OR texture matches "*MUCK*" OR texture matches "*PEAT*") THEN 0.471*ocr -
20.556*ph01mcacl2_r + 142.732 ELSE IF (hzname matches "*O*" AND NOT ISNULL(hzname)) OR
((texture matches "*HPM*" OR texture matches "*MPM*" OR texture matches "*SPM*" OR texture
matches "*MPT*" OR texture matches "*MUCK*" OR texture matches "*PEAT*") AND NOT
ISNULL(texture)) THEN 1.03*ocr - 19.587*ph01mcacl2_r + 110.208 ELSE IF taxord == "histosols"
THEN 2.717*ocr + 9.247 ELSE IF taxord == "gelisols"  THEN 0.965*ocr - 4.503*ph1to1h2o_r + 35.377
ELSE IF taxord == "entisols"  THEN 0.147*claytotal_r  + 2.7*ocr - 1.484*ph1to1h2o_r + 9.572 ELSE IF
taxord == "mollisols"  THEN 0.148*claytotal_r + 1.692*ocr - 2.411*ph1to1h2o_r + 15.606 ELSE IF
taxord == "alfisols"  THEN 0.188*claytotal_r  + 2.353*ocr - 4.612*ph1to1h2o_r + 25.601 ELSE IF taxord
== "aridisols"  THEN 0.033*claytotal_r  + 2.392*ocr + 2.391*ph1to1h2o_r - 9.935 ELSE IF taxord ==
"ultisols"  THEN 0.899*ecec_r + 0.111*claytotal_r  + 2.438*ocr - 1.254*ph1to1h2o_r + 6.046 ELSE IF
taxord == "inceptisols"  THEN 0.429*ecec_r + 0.078*claytotal_r  + 3.052*ocr - 2.053*ph1to1h2o_r +
15.165 ELSE IF taxord == "vertisols"  THEN 0.157*claytotal_r  + 2.437*ocr - 2.949*ph1to1h2o_r +
15.531 ELSE IF taxord == "spodosols"  THEN 1.581*ecec_r + 3.054*ocr + 6.68 ELSE IF taxord ==
"oxisols"  THEN 0.342*ecec_r + 0.078*claytotal_r  + 3.176*ocr + 3.932 ELSE IF taxord == "andisols"
THEN 0.879*ocr - 12.847*ph1to1h2o_r + 96.871 ELSE 1/0 ELSE 1/0.


ASSIGN acidr   IF acidr < 0 AND NOT ISNULL(acidr)  THEN 0 ELSE acidr.


#-----Calculate  low  extractable  acidity---------------

DEFINE acidl

IF NOT ISNULL(cec7_l)  AND (ph1to1h2o_r >= 5.5 OR ph01mcacl2_r  >= 5.5) THEN IF (hzname
matches "*O*" OR texture matches "*MPT*" OR texture matches "*MUCK*" OR texture matches
"*PEAT*" OR texture matches "*HPM*" OR texture matches "*MPM*" OR texture matches "*SPM*")
AND ph1to1h2o_r > 6.1 THEN 0.19*cec7_l - 11.411*ph1to1h2o_h + 78.341 ELSE IF taxord ==
"histosols"  AND NOT ISNULL(taxord)  AND (hzname matches "*O*" OR texture matches "*MPT*" OR
texture matches "*MUCK*" OR texture matches "*PEAT*") THEN 0.289*cec7_l + 0.358*ocl -
26.390*ph01mcacl2_h  + 149.662 ELSE IF (hzname matches "*O*" AND NOT ISNULL(hzname)) OR
((texture matches "*HPM*" OR texture matches "*MPM*" OR texture matches "*SPM*" OR texture
matches "*MPT*" OR texture matches "*MUCK*" OR texture matches "*PEAT*") AND NOT
ISNULL(texture))  THEN 0.470*cec7_l + 0.298*ocl - 19.702*ph01mcacl2_h  + 100.585 ELSE IF texture
matches "*HYDR*" AND NOT ISNULL(texture)  THEN -0.312*cec7_h + 3.726*ocl -
20.442*ph1to1h2o_h + 159.093 ELSE IF texture matches "*MEDL*"  AND NOT ISNULL(texture)
THEN 0.564*cec7_l - 0.326*claytotal_h  - 8.825*ph1to1h2o_h + 75.799 ELSE IF texture matches
"*ASHY*"  AND NOT ISNULL(texture)  THEN 0.134*cec7_l + 2.669*ocl - 1.972*ph1to1h2o_h +
14.051 ELSE IF taxord == "histosols"  THEN 0.673*cec7_l - 7.659*ph1to1h2o_h + 44.466 ELSE IF
taxord == "gelisols"  THEN 0.36*cec7_l - 4.301*ph1to1h2o_h + 31.87 ELSE IF taxord == "entisols"
THEN 0.148*cec7_l + 1.679*ocl - 1.791*ph1to1h2o_h  + 12.254 ELSE IF taxord == "mollisols"  THEN
```

0.112*cec7_l + 0.595*ocl - 2.745*ph1to1h2o_h + 19.964 ELSE IF taxord == "alfisols" THEN 0.205*cec7_l + 1.113*ocl - 2.928*ph1to1h2o_h + 19.545 ELSE IF taxord == "aridisols" THEN 0.047*cec7_l + 0.535*ocl - 0.973*ph1to1h2o_h + 7.735 ELSE IF taxord == "ultisols" THEN 0.850*cec7_l + 0.361*ocl - 2.125*ph1to1h2o_h + 11.741 ELSE IF taxord == "inceptisols" THEN 0.496*cec7_l + 0.698*ocl - 5.010*ph1to1h2o_h + 31.299 ELSE IF taxord == "vertisols" THEN 0.061*cec7_l + 0.775*ocl -3.557*ph1to1h2o_h + 26.936 ELSE IF taxord == "spodosols" THEN 1.226*cec7_l - 0.524*och - 3.429*ph1to1h2o_h + 20.975 ELSE IF taxord == "oxisols" THEN 0.499*cec7_l + 1.679*ocl - 2.055*ph1to1h2o_h + 16.422 ELSE IF taxord == "andisols" THEN 0.763*cec7_l - 4.328*ph1to1h2o_h + 28.591 ELSE 1/0 ELSE IF NOT ISNULL(ecec_l) THEN IF taxord == "histosols" AND NOT ISNULL(taxord) AND (hzname matches "*O*" OR texture matches "*MPT*" OR texture matches "*MUCK*" OR texture matches "*PEAT*") THEN 0.471*ocl - 20.556*ph01mcacl2_h + 142.732 ELSE IF (hzname matches "*O*" AND NOT ISNULL(hzname)) OR ((texture matches "*HPM*" OR texture matches "*MPM*" OR texture matches "*SPM*" OR texture matches "*MPT*" OR texture matches "*MUCK*" OR texture matches "*PEAT*") AND NOT ISNULL(texture)) THEN 1.03*ocl - 19.587*ph01mcacl2_h + 110.208 ELSE IF taxord == "histosols" THEN 2.717*ocl + 9.247 ELSE IF taxord == "gelisols" THEN 0.965*ocl - 4.503*ph1to1h2o_h + 35.377 ELSE IF taxord == "entisols" THEN 0.147*claytotal_l + 2.7*ocl - 1.484*ph1to1h2o_h + 9.572 ELSE IF taxord == "mollisols" THEN 0.148*claytotal_l + 1.692*ocl - 2.411*ph1to1h2o_h + 15.606 ELSE IF taxord == "alfisols" THEN 0.188*claytotal_l + 2.353*ocl - 4.612*ph1to1h2o_h + 25.601 ELSE IF taxord == "aridisols" THEN 0.033*claytotal_l + 2.392*ocl + 2.391*ph1to1h2o_l - 9.935 ELSE IF taxord == "ultisols" THEN 0.899*ecec_l + 0.111*claytotal_l + 2.438*ocl - 1.254*ph1to1h2o_h + 6.046 ELSE IF taxord == "inceptisols" THEN 0.429*ecec_l + 0.078*claytotal_l + 3.052*ocl - 2.053*ph1to1h2o_h + 15.165 ELSE IF taxord == "vertisols" THEN 0.157*claytotal_l + 2.437*ocl - 2.949*ph1to1h2o_h + 15.531 ELSE IF taxord == "spodosols" THEN 1.581*ecec_l + 3.054*ocl + 6.68 ELSE IF taxord == "oxisols" THEN 0.342*ecec_l + 0.078*claytotal_l + 3.176*ocl + 3.932 ELSE IF taxord == "andisols" THEN 0.879*ocl - 12.847*ph1to1h2o_h + 96.871 ELSE 1/0 ELSE 1/0.

ASSIGN acidl IF acidl < 0 AND NOT ISNULL(acidl) THEN 0 ELSE acidl.

#-----Calculate high extractable acidity---------------

DEFINE acidh IF NOT ISNULL(cec7_h) AND (ph1to1h2o_r >= 5.5 OR ph01mcacl2_r >= 5.5) THEN IF (hzname matches "*O*" OR texture matches "*MPT*" OR texture matches "*MUCK*" OR texture matches "*PEAT*" OR texture matches "*HPM*" OR texture matches "*MPM*" OR texture matches "*SPM*") AND ph1to1h2o_r > 6.1 THEN 0.19*cec7_h - 11.411*ph1to1h2o_l + 78.341 ELSE IF taxord == "histosols" AND NOT ISNULL(taxord) AND (hzname matches "*O*" OR texture matches "*MPT*" OR texture matches "*MUCK*" OR texture matches "*PEAT*") THEN 0.289*cec7_h + 0.358*och - 26.390*ph01mcacl2_l + 149.662 ELSE IF (hzname matches "*O*" AND NOT ISNULL(hzname)) OR ((texture matches "*HPM*" OR texture matches "*MPM*" OR texture matches "*SPM*" OR texture matches "*MPT*" OR texture matches "*MUCK*" OR texture matches "*PEAT*") AND NOT ISNULL(texture)) THEN 0.470*cec7_h + 0.298*och - 19.702*ph01mcacl2_l + 100.585 ELSE IF texture matches "*HYDR*" AND NOT ISNULL(texture) THEN -0.312*cec7_l + 3.726*och - 20.442*ph1to1h2o_l + 159.093 ELSE IF texture matches "*MEDL*" AND NOT ISNULL(texture) THEN 0.564*cec7_h - 0.326*claytotal_l - 8.825*ph1to1h2o_l + 75.799 ELSE IF texture matches "*ASHY*" AND NOT ISNULL(texture) THEN 0.134*cec7_h + 2.669*och - 1.972*ph1to1h2o_l + 14.051 ELSE IF taxord == "histosols" THEN 0.673*cec7_h - 7.659*ph1to1h2o_l + 44.466 ELSE IF taxord == "gelisols" THEN 0.36*cec7_h - 4.301*ph1to1h2o_l + 31.87 ELSE IF taxord == "entisols" THEN 0.148*cec7_h + 1.679*och - 1.791*ph1to1h2o_l + 12.254 ELSE IF taxord == "mollisols" THEN 0.112*cec7_h + 0.595*och - 2.745*ph1to1h2o_l + 19.964 ELSE IF taxord == "alfisols" THEN 0.205*cec7_h + 1.113*och - 2.928*ph1to1h2o_l + 19.545 ELSE IF taxord == "aridisols" THEN 0.047*cec7_h + 0.535*och - 0.973*ph1to1h2o_l + 7.735 ELSE IF taxord == "ultisols" THEN

```
0.850*cec7_h + 0.361*och - 2.125*ph1to1h2o_l + 11.741 ELSE IF taxord == "inceptisols" THEN
0.496*cec7_h + 0.698*och - 5.010*ph1to1h2o_l + 31.299 ELSE IF taxord == "vertisols" THEN
0.061*cec7_h + 0.775*och -3.557*ph1to1h2o_l + 26.936 ELSE IF taxord == "spodosols" THEN
1.226*cec7_h - 0.524*ocl - 3.429*ph1to1h2o_l + 20.975 ELSE IF taxord == "oxisols" THEN
0.499*cec7_h + 1.679*och - 2.055*ph1to1h2o_l + 16.422 ELSE IF taxord == "andisols" THEN
0.763*cec7_h - 4.328*ph1to1h2o_l + 28.591 ELSE 1/0 ELSE IF NOT ISNULL(ecec_h) THEN IF
taxord == "histosols" AND NOT ISNULL(taxord) AND (hzname matches "*O*" OR texture matches
"*MPT*" OR texture matches "*MUCK*" OR texture matches "*PEAT*") THEN 0.471*och -
20.556*ph01mcacl2_l + 142.732 ELSE IF (hzname matches "*O*" AND NOT ISNULL(hzname)) OR
((texture matches "*HPM*" OR texture matches "*MPM*" OR texture matches "*SPM*" OR texture
matches "*MPT*" OR texture matches "*MUCK*" OR texture matches "*PEAT*") AND NOT
ISNULL(texture)) THEN 1.03*och - 19.587*ph01mcacl2_l + 110.208 ELSE IF taxord == "histosols"
THEN 2.717*och + 9.247 ELSE IF taxord == "gelisols" THEN 0.965*och - 4.503*ph1to1h2o_l + 35.377
ELSE IF taxord == "entisols" THEN 0.147*claytotal_h + 2.7*och - 1.484*ph1to1h2o_l + 9.572 ELSE IF
taxord == "mollisols" THEN 0.148*claytotal_h + 1.692*och - 2.411*ph1to1h2o_l + 15.606 ELSE IF
taxord == "alfisols" THEN 0.188*claytotal_h + 2.353*och - 4.612*ph1to1h2o_l + 25.601 ELSE IF taxord
== "aridisols" THEN 0.033*claytotal_h + 2.392*och + 2.391*ph1to1h2o_h - 9.935 ELSE IF taxord ==
"ultisols" THEN 0.899*ecec_h + 0.111*claytotal_h + 2.438*och - 1.254*ph1to1h2o_l + 6.046 ELSE IF
taxord == "inceptisols" THEN 0.429*ecec_h + 0.078*claytotal_h + 3.052*och - 2.053*ph1to1h2o_l +
15.165 ELSE IF taxord == "vertisols" THEN 0.157*claytotal_h + 2.437*och - 2.949*ph1to1h2o_l +
15.531 ELSE IF taxord == "spodosols" THEN 1.581*ecec_h + 3.054*och + 6.68 ELSE IF taxord ==
"oxisols" THEN 0.342*ecec_h + 0.078*claytotal_h + 3.176*och + 3.932 ELSE IF taxord == "andisols"
THEN 0.879*och - 12.847*ph1to1h2o_l + 96.871 ELSE 1/0 ELSE 1/0.


ASSIGN acidh IF acidh < 0 AND NOT ISNULL(acidh) THEN 0 ELSE acidh.


# Calcareous soils have little or no acidity. A pH value of 8.2 approximates the pH of calcareous soils.
# A check to make sure that zero extractable acidity is included in the acidity range when pH is >= 8.3
ASSIGN acidr     IF ph1to1h2o_l >= 8.3 THEN 0 ELSE acidr.
ASSIGN acidl     IF acidr == 0 THEN 0 ELSE acidl.
ASSIGN acidl     IF ph1to1h2o_r >= 8.3 THEN 0 ELSE acidl.
```

618.102 NASIS Calculation for Estimating Liquid Limit and Plasticity Index

Definition.—This calculation computes the Atterberg Limits (liquid limit and plasticity index). The low, rv, and high are calculated.

The calculation works on all records (horizons) in your selected set that you have permission to edit, except as described in (7) below. For some horizons, such as bedrock or cemented layers, it may not be appropriate to calculate Atterberg limits. You may wish to tailor your selected set accordingly.

There is a companion report available to preview results of this calculation. The calculation script is imbedded in the report script. The report is designed to display your current stored LL and PI values alongside the calculated values. Viewing the results in this fashion might be useful in determining whether or not you wish to run the calculation on your selected set. The name of the Pangaea report is "UTIL - Comparison of LL and PI, stored vs calculated."

Caution: These calculations for liquid limit and plasticity index may produce poor estimates for Andisols and Spodosols.

Inputs.—This calculation requires that the following data must be populated:

organic matter percent (l,rv,h)
linear extensibility percent (l,rv,h)
clay total separate (l,rv,h)
clay sized carbonate (l,rv,h)

Guidelines For Implementing Equations for LL and PI In NASIS

1) Values for LL and PI (low, high, and rv) are computed.
2) The calculations are based on the noncarbonate clay fraction.
3) If clay sized carbonate is null, then noncarbonate clay = total clay.
4) The water 15bar (volumetric) values from the database are not used. Instead water 15-bar value is estimated on a gravimetric basis using total clay and organic matter values.
5) If low and/or high values for LEP, clay sized carbonate, or OM are null, set to zero and proceed with estimate (reduced accuracy is < 1.5%).
6) If rv values for these input variables are null, compute as the average of low and high values (L + H/2) and proceed with the calculation.
7) If OM > 25% or total clay is null, then LL and PI are not calculated.
8) The PI is estimated first, then LL.
9) If PI equals 0, LL rv and low values are set to 0 and the LL high value is set to 14.
10) If LL is < 15, then LL rv and low values are set to 0 and LL high value is set to 14.
11) Computed values for LL and PI are converted to nearest whole number.

Calculation.

```
# Use zero if inputs are null (l).
DEFINE oml          IF ISNULL(om_l) THEN 0 ELSE om_l.
DEFINE lepl         IF ISNULL(lep_l) THEN 0 ELSE lep_l.
DEFINE claytotall         IF ISNULL(claytotal_l) THEN 0 ELSE claytotal_l.
DEFINE claysizedcarbl     IF ISNULL(claysizedcarb_l) THEN 0 ELSE claysizedcarb_l.
DEFINE ncclayl          claytotall - claysizedcarbl.
```

```
# Calculate the 15 bar water content (low) on a gravimetric basis.
# Assume ratio of 1500KPa to Clay percent is 0.4
DEFINE F INITIAL 0.4.
DEFINE wfifteenbarl (claytotall * (1 - oml/100) * F + oml).

# Calculate the low assuming all inputs are in range.
DEFINE pi_l     -1.86 + 0.69*wfifteenbarl - 0.69*oml + 0.13*lepl + 0.47*ncclayl.
DEFINE ll_l     11.6 + 1.49*wfifteenbarl + 0.78*oml + 0.6*lepl + 0.26*ncclayl.


# Use zero if inputs are null (h).
DEFINE omh          IF ISNULL(om_h) THEN 0 ELSE om_h.
DEFINE leph         IF ISNULL(lep_h) THEN 0 ELSE lep_h.
DEFINE claytotalh     IF ISNULL(claytotal_h) THEN 0 ELSE claytotal_h.
DEFINE claysizedcarbh     IF ISNULL(claysizedcarb_h) THEN 0 ELSE claysizedcarb_h.
DEFINE ncclayh          claytotalh - claysizedcarbh.

# Calculate the 15 bar water content (high) on a gravimetric basis.
# Assume ratio of 1500KPa to Clay percent is 0.4
# DEFINE F INITIAL 0.4 was done above.
DEFINE wfifteenbarh (claytotalh * (1 - omh/100) * F + omh).

# Calculate the high assuming all inputs are in range.
DEFINE pi_h     -1.86 + 0.69*wfifteenbarh - 0.69*omh + 0.13*leph + 0.47*ncclayh.
DEFINE ll_h     11.6 + 1.49*wfifteenbarh + 0.78*omh + 0.6*leph + 0.26*ncclayh.


# Use (low + high)/2 if inputs are null (rv).
DEFINE om     IF ISNULL(om_r) THEN (oml + omh)/2 ELSE om_r.
DEFINE lep     IF ISNULL(lep_r) THEN (lepl + leph)/2 ELSE lep_r.
DEFINE claytotal     IF ISNULL(claytotal_r) THEN (claytotall + claytotalh)/2 ELSE claytotal_r.
DEFINE claysizedcarb     IF ISNULL(claysizedcarb_r) THEN (claysizedcarbl + claysizedcarbh)/2 ELSE
claysizedcarb_r.
DEFINE ncclay          claytotal - claysizedcarb.

# Calculate the 15 bar water content (rv) on a gravimetric basis.
# Assume ratio of 1500KPa to Clay percent is 0.4
# DEFINE F INITIAL 0.4 was done above.
DEFINE wfifteenbar (claytotal * (1 - om/100) * F + om).

# Calculate the rv assuming all inputs are in range.
DEFINE pi_r     -1.86 + 0.69*wfifteenbar - 0.69*om + 0.13*lep + 0.47*ncclay.
DEFINE ll_r     11.6 + 1.49*wfifteenbar + 0.78*om + 0.6*lep + 0.26*ncclay.


# Check for inputs out of range and set results to null.

ASSIGN pi_r     IF ISNULL(claytotal_r) OR om > 25 OR ncclay < 0 THEN 1/0 ELSE pi_r.
ASSIGN ll_r     IF ISNULL(claytotal_r) OR om > 25 OR ncclay < 0 THEN 1/0 ELSE ll_r.
```

```
ASSIGN pi_l    IF ISNULL(claytotal_l) OR oml > 25 OR ncclayl < 0 THEN 1/0 ELSE pi_l.
ASSIGN ll_l    IF ISNULL(claytotal_l) OR oml > 25 OR ncclayl < 0 THEN 1/0 ELSE ll_l.
ASSIGN pi_h    IF ISNULL(claytotal_h) OR omh > 25 OR ncclayh < 0 THEN 1/0 ELSE pi_h.
ASSIGN ll_h    IF ISNULL(claytotal_h) OR omh > 25 OR ncclayh < 0 THEN 1/0 ELSE ll_h.

# If calculated PI is negative, set both PI and LL to zero.

ASSIGN pi_r    IF NOT ISNULL(pi_r) AND pi_r < 0 THEN 0 ELSE pi_r.
ASSIGN ll_r    IF ISNULL(pi_r) THEN 1/0 ELSE IF pi_r < 0.5 OR (NOT ISNULL(ll_r) AND ll_r < 15) THEN 0 ELSE ll_r.
ASSIGN pi_l    IF NOT ISNULL(pi_l) AND pi_l < 0 THEN 0 ELSE pi_l.
ASSIGN ll_l    IF ISNULL(pi_l) THEN 1/0 ELSE IF pi_l < 0.5 OR (NOT ISNULL(ll_l) AND ll_l < 15) THEN 0 ELSE ll_l.
ASSIGN pi_h    IF NOT ISNULL(pi_h) AND pi_h < 0 THEN 0 ELSE pi_h.
ASSIGN ll_h    IF ISNULL(pi_h) THEN 1/0 ELSE IF pi_h < 0.5 OR (NOT ISNULL(ll_h) AND ll_h < 15) THEN 14 ELSE ll_h.

#Set results to interger values.

ASSIGN pi_r    ROUND(pi_r).
ASSIGN ll_r    ROUND(ll_r).
ASSIGN pi_l    ROUND(pi_l).
ASSIGN ll_l    ROUND(ll_l).
ASSIGN pi_h    ROUND(pi_h).
ASSIGN ll_h    ROUND(ll_h).
```

618.103 NASIS Calculation for Estimating Particle Size

Definition.—This calculation computes representative values for the sand fractions, total sand, and total silt. The following rules apply:

1) The results will be blank if needed data are not entered. Total clay and texture are always required, and particle size class is required for textures CL, L, SCL, SICL, and SIL.
2) When a horizon has multiple textures, the one marked rv is used or the first texture is used if there is no rv. No results are calculated for stratified textures at this time.
3) If total sand (rv) has been entered, the sand fractions will be adjusted so their sum equals the specified total. If you want to calculate a new sand total, you must erase the old one before running the calculation.

Inputs.—This calculation requires that the following data must be populated:

texture
clay total separate (l,rv,h)
taxonomic particle-size class

Calculation.

```
ASSIGN texcl IF ISNULL(texcl) OR stratextsflag==1
        THEN "null" ELSE CODENAME(texcl).

DEFINE sandclass
    IF (texcl=="sl" or texcl=="cosl" or texcl=="fsl" or texcl=="vfsl") THEN
      IF ISNULL(sandtotal_r) THEN 1 ELSE
      IF sandtotal_r > 60 THEN 1 ELSE
      IF sandtotal_r >= 53 THEN 2 ELSE 3
    ELSE IF (texcl=="cl" or texcl=="l" or texcl=="scl" or texcl=="sicl" or
      texcl=="sil") THEN family_sandclass
    ELSE 0.

DEFINE paramid_by_tex LOOKUP(1, texcl==texture and
            (sandcode==0 or sandcode==sandclass),
            paramid).
DEFINE claypct_by_tex LOOKUP(1, texcl==texture and
            (sandcode==0 or sandcode==sandclass),
            claypct).
DEFINE claydiff_by_tex ABS(claypct_by_tex - claytotal_r).
DEFINE closest_clay ARRAYMIN(claydiff_by_tex).
DEFINE select_row ARRAYMIN(LOOKUP(closest_clay, claydiff_by_tex,
            paramid_by_tex)).

# Get the equation number and coefficients from the selected parameter row.

DEFINE eqn lookup(select_row, paramid, equation).
DEFINE p1 lookup(select_row, paramid, param1).
DEFINE p2 lookup(select_row, paramid, param2).
DEFINE p3 lookup(select_row, paramid, param3).
DEFINE p4 lookup(select_row, paramid, param4).
DEFINE p5 lookup(select_row, paramid, param5).

# Compute all the distributions. We compute all 5 equations first then
# pick the right result, because this language doesn't have conditional
```

```
# execution.
# Start by computing some things that are used more than once.

DEFINE diamclay LOOKUP("clay", psclass, psdiam). # Upper clay diameter.
DEFINE cr2    POW(2, 1/3).            # Cube root of 2.
DEFINE crdiam POW(psdiam, 1/3).         # Cube root of psclass diameter.
DEFINE crdiamclay POW(diamclay, 1/3). # Cube root of clay diam.
DEFINE sqr2    SQRT(2).            # Square root of 2.
DEFINE sqrdiam SQRT(psdiam).           # Square root of psclass diameter.

DEFINE eq1tmp POW(1 + p4*POW(cr2-crdiam, p3), p2).
DEFINE eq2tmp EXP(p3 * POW(cr2-crdiam, p2)).
DEFINE eq3tmp EXP(1/POW(p4*cr2,p3) - 1/POW(p4*crdiam,p3)).
DEFINE eq4tmp p3*(POW(crdiam,2) - POW(cr2,2)) + p4*(psdiam-2) +
        p5*(POW(crdiam,4) - POW(cr2,4)).
DEFINE eq5tmp p3*(1/psdiam - 1/2) + p4*(sqrdiam - sqr2).

# Next adjust the parameters to make the clay come out the same as the input.

DEFINE tmp   LOOKUP("clay", psclass, eq1tmp).
DEFINE eq1p1 (tmp * claytotal_r - 100) / (tmp - 1).

ASSIGN tmp LOOKUP("clay", psclass, eq2tmp).
DEFINE eq2p1 (tmp * claytotal_r - 100) / (tmp - 1).

ASSIGN tmp LOOKUP("clay", psclass, eq3tmp).
DEFINE eq3p2 (claytotal_r - 100 * tmp) / (1 - tmp).

ASSIGN tmp   LOOKUP("clay", psclass, eq4tmp).
DEFINE eq4p2 (claytotal_r - 100 - tmp) / (crdiamclay - cr2).

ASSIGN tmp LOOKUP("clay", psclass, eq5tmp).
DEFINE eq5p2 (claytotal_r - 100 - tmp) / (diamclay - 2).

# Compute the five equations for all particle size classes.

DEFINE eq1 eq1p1 + (100-eq1p1) / eq1tmp.
DEFINE eq2 eq2p1 + (100-eq2p1) / eq2tmp.
DEFINE eq3 eq3p2 + (100-eq3p2) * eq3tmp.
DEFINE eq4 100 + eq4p2*(crdiam - cr2) + eq4tmp.
DEFINE eq5 100 + eq5p2*(psdiam - 2) + eq5tmp.

# Select the right equation. The variable psd will have 7 vaules, one
# for each particle size class. The value for each class is picked out
# of the array with a LOOKUP.

DEFINE psd IF eqn==1 THEN eq1 ELSE
      IF eqn==2 THEN eq2 ELSE
      IF eqn==3 THEN eq3 ELSE
      IF eqn==4 THEN eq4 ELSE
      IF eqn==5 THEN eq5 ELSE
      eq5/0.          # sets psd to 7 nulls when texcl is null
```

```
# Pick out the cumulative percents then compute the individual fractions.

DEFINE clay LOOKUP("clay", psclass, psd).
DEFINE silt LOOKUP("silt", psclass, psd).
DEFINE vfs LOOKUP("vfs", psclass, psd).
DEFINE fs   LOOKUP("fs", psclass, psd).
DEFINE ms LOOKUP("ms", psclass, psd).
DEFINE cs LOOKUP("cos", psclass, psd).
DEFINE vcs  LOOKUP("vcos", psclass, psd).

ASSIGN vcs  vcs - cs.
ASSIGN cs   cs - ms.
ASSIGN ms   ms - fs.
ASSIGN fs   fs - vfs.
ASSIGN vfs  vfs - silt.
ASSIGN silt silt - clay.

DEFINE sand vfs + fs + ms + cs + vcs.

# Find an adjustment factor for the sand fractions.
# If total sand was given, adjust each sand fraction by the ratio needed to
# make the sum equal to the given total.
# If total sand was not given, verify that the sand and silt are within the
# texture class limits and if not adjust them by the appropriate ratio.

DEFINE sand_diff IF ISNULL (sandtotal_r) THEN
          IF (texcl=="cos" or texcl=="s" or texcl=="fs" or texcl=="vfs")
            and ((clay + silt) > (15 - .5*clay))
          THEN (clay + silt) - (15 - .5*clay) ELSE
          IF (texcl=="lcos" or texcl=="ls" or texcl=="lfs" or texcl=="lvfs")
            and (clay + silt) > (30 - clay)
          THEN (clay + silt) - (30 - clay)    ELSE
          IF texcl=="sil" and silt < 50
          THEN silt - 50              ELSE
          IF texcl=="sicl" and sand > 20
          THEN 20 - sand              ELSE
          IF texcl=="sc" and sand < 45
          THEN 45 - sand              ELSE
          IF texcl=="sic" and silt < 40
          THEN silt - 40              ELSE 0
        ELSE
          sandtotal_r - sand.
DEFINE adj (sand + sand_diff) / sand.

# Adjust the sands and silt by the adjustment factor.
# Round to one decimal place before computing total sand to avoid roundoff error.

ASSIGN vfs ROUND(vfs * adj, 1).
ASSIGN fs   ROUND(fs  * adj, 1).
ASSIGN ms   ROUND(ms  * adj, 1).
ASSIGN cs   ROUND(cs  * adj, 1).
```

```
ASSIGN vcs ROUND(vcs * adj, 1).
ASSIGN sand  vfs + fs + ms + cs + vcs.

# The rounding may result in a sum that does not equal the target sandtotal,
# so another adjustment has to be made.
# This time, apply it to the first non-zero fraction.

ASSIGN adj   IF NOT ISNULL(sandtotal_r)  THEN sandtotal_r - sand ELSE 0.

ASSIGN vcs IF vfs==0 AND fs==0 AND ms==0 AND cs==0 THEN vcs + adj ELSE vcs.
ASSIGN cs    IF vfs==0 AND fs==0 AND ms==0 AND cs>0 THEN cs + adj ELSE cs.
ASSIGN ms    IF vfs==0 AND fs==0 AND ms>0 THEN ms + adj ELSE ms.
ASSIGN fs    IF vfs==0 AND fs>0 THEN fs + adj ELSE fs.
ASSIGN vfs IF vfs > 0 THEN vfs + adj ELSE vfs.
ASSIGN sand  vfs + fs + ms + cs + vcs.

ASSIGN silt  100 - sand - clay.

# When vcos is < 0.
ASSIGN cs    IF vcs < 0 AND vfs+fs+ms+cs > sand THEN cs - ((vfs+fs+ms+cs) - sand) ELSE cs.
ASSIGN vcs   IF vcs < 0 THEN 0 ELSE vcs.

# Store the results as RV values for the horizon.

SET sandtotal_r from sand,
    sandvc_r from vcs,
    sandco_r from cs,
    sandmed_r from ms,
    sandfine_r from fs,
    sandvf_r from vfs,
    silttotal_r  from silt.
```

618.104 NASIS Calculation for Estimating Rock Fragments and Percent Passing Sieves

Definition.—This calculation computes the percent soil material (< 3 inch basis) passing the #4 (4.7 mm), #10 (2.0 mm), #40 (0.42 mm), and #200 sieves (0.074 mm) and the percent rock fragments 3 to 10 inches and > 10 inches (whole soil basis).

1. Percent passing sieves are on a < 3-inch basis and rock fragments are a whole-soil basis.
2. The calculation of percent passing sieves and rock fragments excludes pararock fragments, wood, and noncemented fragments. Pararock fragments are defined by fragment hardness of extremely weakly, very weakly, weakly, or moderately cemented.
3. If fragment hardness is not populated, “indurated” is assumed.
4. If fragment kind is not populated, a fragment density of 2.65 g cm-3 is assumed.
5. Fragment density is assigned based on the fragment kind (table 2). If an average density for each fragment kind is not available, a default density of 2.65 g cm-3 is used.
6. If only low and high values are populated for fragment volume, fragment size, total sand, total silt, total clay, or sand separates, then rv’s are generated from the high and low values (takes the average).
7. The low and high values must be populated for fragment size, otherwise the calculation will produce incorrect or no results.
8. Low and high values for percent passing #40 and #200 sieves are based on the average low and high values for the particle-size separates.
9. If low and high values are not populated for total sand, total silt, or total clay or for the sand separates, then low and high values for the #40 and #200 sieves are generated from the low and high values of total clay. If high and low values for total clay are also null, then nulls are returned.
10. Low and high values for percent passing #4 and #10 sieves and the rock fragments are based on the low and high fragment volumes (in “Horizon Table,” if populated). If low and high fragment volumes (in “Horizon Table”) are not populated, then total low and high fragment volumes in the “Horizon Fragment Table” are used. If low and high fragment volumes in the “Horizon Fragment Table” are null, then nulls are returned.
11. **Caution:** If percent passing sieves are populated and only clay is populated (l, rv, h) in the particle-size separates, the calculation will wipe out the calculated values and put in null values. If there is not enough data to run the calculation, nulls are returned.
12. For stratified textures, if data is populated, the calculation proceeds as normal. If the particle-size separates are not populated, then the #40 and #200 sieves are not calculated (nulls are returned).
13. If the organic matter content > 35%, then percent passing sieves is not calculated and only rock fragments (3 to 10 in and >10 in) are calculated.
14. **Caution:** If 1/3-bar bulk density rv is not populated, null values for all sieves and rock fragments are returned.
15. The calculation rounds all sieve values to the nearest whole number.

Limitations

1) The pararock fragments are not included in the calculation because they can be crushed to < 2 mm. It is assumed that the pararock fragments, when crushed, will reflect the existing particle-size distribution. If there are pararock fragments that when crushed produce a different particle-size distribution, the calculation will over- or under-estimate the percent passing the #40 and #200 sieves.
2) When actually measuring percent passing sieves, the organic matter is not removed. The calculation of percent passing sieves calculates using organic matter free particle-size fractions. The calculation does not take into account the distribution of organic matter particles.

3) The fragment densities applied here are average values from the literature and may not represent the true density of fragments in your area. Fragment densities can be highly variable from location to location for a fragment kind.
4) If the total fragment volumes in the “Component Horizon Table” are not populated, then the low and high calculated values are based on the “Horizon Fragment Table” volumes and texture ranges in the NASIS database; these values may not reflect the actual percent passing sieves and rock fragment ranges. It is assumed that the total of the lows and the total of the highs in the “Horizon Fragment Table” equal the total high and low fragment volumes.
5) If the low and high calculated values are based on the total fragment volumes in the “Component Horizon Table” because actual fragment kind distributions (e.g., rock vs. pararock) that make up the fragment volume totals are not known, percent passing sieves and rock fragment may not reflect actual ranges. It computes representative values for the sand fractions, total sand and total silt. The following rules apply:
    a. The results will be blank if needed data are not entered. Total clay and texture are always required, and particle size class is required for textures CL, L, SCL, SICL, and SIL.
    b. When a horizon has multiple textures the one marked rv is used; the first texture is used if there is no rv. No results are calculated for stratified textures at this time.
    c. If total sand (rv) has been entered, the sand fractions will be adjusted so their sum equals the specified total. If you want to calculate a new sand total you must erase the old one before running the calculation.

Inputs.—This calculation requires the following data to be populated:

fragment volume total (high, low) in “Horizon Table”
fragment volume (high, low, and rv) in “Horizon Fragment Table”
fragment kind in “Horizon Fragment Table”
fragment size (high, low, and rv) in “Horizon Fragment Table”
fragment hardness in “Horizon Fragment Table”
total sand (high, low, and rv)
total clay (high, low, and rv)
total silt (high, low, and rv)
very fine sand (high, low, and rv)
fine sand (high, low, and rv)
medium sand (high, low, and rv)
coarse sand (high, low, and rv)
very coarse sand (high, low, and rv)
one-third bar bulk density (rv)
organic matter (rv)

Calculation

```
DEFINE curvenum_l 0.56559. #run curve fitting routine
DEFINE curvenum_h 0.56559. #run curve fitting routine
DEFINE curvenum_r    0.56559. #run curve fitting routine

DEFINE densityrock
IF fragkind2 == "`a`a lava" THEN 2.00
ELSE IF fragkind2 == "amphibolite" THEN 2.99
ELSE IF fragkind2 == "andesite" THEN 2.65
ELSE IF fragkind2 == "anorthosite" THEN 2.73
ELSE IF fragkind2 == "basalt" THEN 2.69
ELSE IF fragkind2 == "calcrete (caliche)" THEN 1.44
ELSE IF fragkind2 == "chalk" THEN 2.35
ELSE IF fragkind2 == "charcoal" THEN 0.45
```

```
ELSE IF fragkind2 == "chert" THEN 2.76
ELSE IF fragkind2 == "cinders" THEN 1.45
ELSE IF fragkind2 == "coal" THEN 1.6
ELSE IF fragkind2 == "dacite" THEN 1.67
ELSE IF fragkind2 == "diabase" THEN 2.92
ELSE IF fragkind2 == "diorite" THEN 2.83
ELSE IF fragkind2 == "dolomite (dolostone)" THEN 2.79
ELSE IF fragkind2 == "gabbro" THEN 2.99
ELSE IF fragkind2 == "gibbsite concretions" THEN 2.35
ELSE IF fragkind2 == "gneiss" THEN 2.79
ELSE IF fragkind2 == "granite" THEN 2.66
ELSE IF fragkind2 == "granodiorite" THEN 2.72
ELSE IF fragkind2 == "granulite" THEN 2.91
ELSE IF fragkind2 == "graywacke" THEN 2.69
ELSE IF fragkind2 == "gypsum, rock" THEN 2.55
ELSE IF fragkind2 == "ironstone concretions" THEN 2.93
ELSE IF fragkind2 == "limestone, unspecified" THEN 2.61
ELSE IF fragkind2 == "marble" THEN 2.74
ELSE IF fragkind2 == "monzonite" THEN 2.8
ELSE IF fragkind2 == "obsidian" THEN 2.37
ELSE IF fragkind2 == "orthoquartzite" THEN 2.41
ELSE IF fragkind2 == "peridotite" THEN 3.22
ELSE IF fragkind2 == "petroferric fragments" THEN 2.93
ELSE IF fragkind2 == "phyllite" THEN 2.74
ELSE IF fragkind2 == "pumice" THEN 0.98
ELSE IF fragkind2 == "pyroxenite" THEN 3.28
ELSE IF fragkind2 == "quartz-diorite" THEN 2.79
ELSE IF fragkind2 == "quartzite" THEN 2.7
ELSE IF fragkind2 == "rhyolite" THEN 2.51
ELSE IF fragkind2 == "sandstone, calcareous" THEN 2.03
ELSE IF fragkind2 == "sandstone, unspecified" THEN 2.29
ELSE IF fragkind2 == "schist, mica" THEN 2.76
ELSE IF fragkind2 == "schist, unspecified" THEN 2.84
ELSE IF fragkind2 == "serpentinite" THEN 2.63
ELSE IF fragkind2 == "shale, calcareous" THEN 2.67
ELSE IF fragkind2 == "shale, clayey" THEN 2.78
ELSE IF fragkind2 == "shale, unspecified" THEN 2.6
ELSE IF fragkind2 == "slate" THEN 2.81
ELSE IF fragkind2 == "soapstone" THEN 2.7
ELSE IF fragkind2 == "syenite" THEN 2.74
ELSE IF fragkind2 == "tonalite" THEN 2.67
ELSE IF fragkind2 == "trachyte" THEN 2.57
ELSE IF fragkind2 == "tuff, unspecified" THEN 1.84
ELSE IF fragkind2 == "wood" THEN 0.6
ELSE 2.65.

#-------------------------------------------------------------------
# Start of percent passing sieves and rock fragments calculation for RV.
#-------------------------------------------------------------------

# Compute total volume percent of rock fragments, minus pararocks,
# on a whole soil basis.
```

```
DEFINE fragvols    IF (fraghard2=="strongly" or fraghard2=="very strongly" or

fraghard2=="indurated" or ISNULL(fraghard2)) AND fragkind2 != "wood"

THEN fragvlr ELSE 0.
DEFINE fragvolr    ARRAYSUM(fragvols).

# Compute percent volume of rock fragments that are < 75mm for each row
# in the rock fragment table.

DEFINE rockfrag_row_r     IF (75 >= fragsize_l and 75 <= fragsize_r)
THEN ((75-fragsize_l)/(fragsize_r-fragsize_l)/2*fragvlr)
ELSE IF (75 > fragsize_r and 75 <= fragsize_h)
THEN (((75-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5)*fragvlr
ELSE IF 75 > fragsize_h THEN fragvlr ELSE 0.

# Compute total volume percent of rock fragments that are < 75mm on a
# whole soil basis, minus pararocks.

DEFINE totalRFvol_s     IF (fraghard2=="strongly" or fraghard2=="very strongly" or
fraghard2=="indurated" or ISNULL(fraghard2))  AND fragkind2 != "wood"
THEN rockfrag_row_r ELSE 0.

DEFINE totalRFvol_r     ARRAYSUM(totalRFvol_s).

# Compute volume percent of rock fragments that are < 75mm on a < 75mm basis.

DEFINE vol75mm_r     totalRFvol_r/(1-(fragvolr-totalRFvol_r)/100).

# Compute volume percent of rock fragments that are < 75mm
# to a weight percent for each row in the rock fragment table.

DEFINE wtRF_row_r     IF totalRFvol_r == 0 THEN 0 ELSE
(rockfrag_row_r/totalRFvol_r*vol75mm_r)*densityrock/(((vol75mm_r/100)*densityrock)+((1-
vol75mm_r/100)*dbthirdbar_r)).

# Compute volume percent of rock fragments that are < 5mm to a weight percent for each row in the rock
fragment table.

DEFINE wtRF5mm_row_r     IF 5>=fragsize_h THEN wtRF_row_r
ELSE IF (5>=fragsize_l and 5<=fragsize_r)
THEN (5-fragsize_l)/(fragsize_r-fragsize_l)/2*wtRF_row_r
ELSE IF (5>fragsize_r and 5<=fragsize_h)
THEN (((5-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5)*wtRF_row_r
ELSE 0.


# Compute weight percent of rock fragments of the whole soil for each row.

DEFINE wtRFwhole_row_r     fragvlr*densityrock/(((fragvlr/100)*densityrock)+((1-
fragvlr/100)*dbthirdbar_r)).
```

```
# Compute weight percent of rock fragments > 75mm of the whole soil for each row.

DEFINE wtRFwhole75mm_row_s  IF (75>=fragsize_l and 75<=fragsize_r)
THEN ((1-((75-fragsize_l)/(fragsize_r-fragsize_l)/2))*wtRFwhole_row_r)
ELSE IF (75>fragsize_r  and 75<=fragsize_h)
THEN ((1-(((75-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5))*wtRFwhole_row_r)
ELSE IF 75>fragsize_h  THEN 0 ELSE wtRFwhole_row_r.

# Compute the percent weight of rock fragments > 75mm of whole soil, minus pararocks.

DEFINE wtRFwhole75mm_row_2  IF ISNULL(fragvlr) and ISNULL(fragvol_l) and
ISNULL(fragvol_h)
THEN 0 ELSE IF (fraghard2=="strongly" or fraghard2=="very strongly" or fraghard2=="indurated" or
ISNULL(fraghard2)) AND fragkind2 != "wood"
THEN wtRFwhole75mm_row_s  ELSE 0.

DEFINE wtRFwhole75mm_r      ARRAYSUM(wtRFwhole75mm_row_2).

# Compute weight percent of rock fragments >250mm of whole soil for each row.

DEFINE wtRFwhole250mm_row_s  IF (250>=fragsize_l  and 250<=fragsize_r)
THEN ((1-((250-fragsize_l)/(fragsize_r-fragsize_l)/2))*wtRFwhole_row_r)
ELSE IF (250>fragsize_r  and 250<=fragsize_h)
THEN ((1-(((250-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5))*wtRFwhole_row_r)
ELSE IF fragsize_l>=250  THEN wtRFwhole_row_r  ELSE 0.

# Compute the total weight percent of rock fragments >250mm of whole soil, minus pararocks.

DEFINE wtRFwhole250mm_row_2  IF ISNULL(fragvlr) and ISNULL(fragvol_l) and
ISNULL(fragvol_h)
THEN 0 ELSE IF (fraghard2=="strongly" or fraghard2=="very strongly" or fraghard2=="indurated" or
ISNULL(fraghard2)) AND fragkind2 != "wood"
THEN wtRFwhole250mm_row_s  ELSE 0.

DEFINE rockfrag_250r        ARRAYSUM(wtRFwhole250mm_row_2).

# Compute total weight percent of rock fragments 75 to 250mm, minus pararocks.

DEFINE rockfrag_75r      wtRFwhole75mm_r  - rockfrag_250r.

# Compute percent passing #10 sieve, minus pararocks.

DEFINE sieve_10s      IF (fraghard2=="strongly" or fraghard2=="very strongly" or
fraghard2=="indurated" or ISNULL(fraghard2)) AND fragkind2 != "wood" THEN wtRF_row_r ELSE 0.

DEFINE sieve_10r      IF ISNULL(ARRAYSUM(fragvlr))
THEN 100 ELSE 100-ARRAYSUM(sieve_10s).

# Compute percent passing #4 sieve, minus pararocks.
```

```
DEFINE sieve_4s    IF (fraghard2=="strongly" or fraghard2=="very strongly" or fraghard2=="indurated"
or ISNULL(fraghard2)) AND fragkind2 != "wood"THEN wtRF5mm_row_r ELSE 0.

DEFINE sieve_4r    IF ISNULL(ARRAYSUM(fragvlr)) THEN 100 ELSE
ARRAYSUM(sieve_4s)+sieve_10r.

# Compute percent passing #40 sieve, minus pararocks.

DEFINE sieve_40r    IF ISNULL(ARRAYSUM(fragvlr)) THEN 100 - (vcos_r + cos_r + ms_r*0.2515)
ELSE sieve_10r/100*((0.7485*ms_r)+fs_r+vfs_r+siltr+clayr).

# Compute percent passing #200 sieve, minus pararocks.

DEFINE sieve_200r    IF ISNULL(ARRAYSUM(fragvlr))
THEN IF vfs_r < 15 THEN (vfs_r*0.56559 + siltr + clayr)
ELSE (vfs_r*curvenum_r + siltr + clayr)
ELSE IF vfs_r < 15 THEN (vfs_r*0.56559 + siltr + clayr)*sieve_10r/100
ELSE (vfs_r*curvenum_r + siltr + clayr)*sieve_10r/100.

ASSIGN sieve_10r    IF om_r > 35 OR ISNULL(clayr) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE
sieve_10r.

ASSIGN sieve_4r    IF om_r > 35 OR ISNULL(clayr) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE
sieve_4r.

ASSIGN sieve_40r IF om_r > 35 OR (stratextsflag == 1 AND (ISNULL(clayr) OR ISNULL(siltr) OR
ISNULL(vcos_r) OR ISNULL(cos_r) OR ISNULL(ms_r))) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE
sieve_40r.

ASSIGN sieve_200r    IF om_r > 35 OR (stratextsflag == 1 AND (ISNULL(clayr) OR ISNULL(siltr)
OR ISNULL(vfs_r))) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE sieve_200r.

ASSIGN rockfrag_250r    IF om_r > 35 AND ISNULL(fragvolr) THEN 0 ELSE IF (ISNULL(clayr)
AND stratextsflag != 1) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE rockfrag_250r.

ASSIGN rockfrag_75r    IF om_r > 35 AND ISNULL(fragvolr) THEN 0 ELSE IF (ISNULL(clayr)
AND stratextsflag != 1) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE rockfrag_75r.

#--------------------------------------------------------------------------
# Start of percent passing sieves and rock fragments calculation of low values.
#--------------------------------------------------------------------------

# Compute total volume percent of rock fragments, minus pararocks,
# on a whole soil basis.

DEFINE fragvolls IF (fraghard2=="strongly" or fraghard2=="very strongly" or fraghard2=="indurated"
or ISNULL(fraghard2)) AND fragkind2 != "wood" THEN fragvol_l ELSE 0.
DEFINE fragvoll    ARRAYSUM(fragvolls).

# Uses the low fragment volume total from the Horizon Table.
DEFINE sumlowfrags    ARRAYSUM(fragvol_l).
```

```
ASSIGN fragvoll     IF (fragvoll / sumlowfrags) < 1 AND fragvoll != 0 AND NOT
ISNULL(sumlowfrags) AND sumlowfrags > 0 THEN (fragvoll / sumlowfrags) * fragvoltot_l ELSE IF
ISNULL(fragvoltot_l) THEN fragvoll ELSE fragvoltot_l.

# Compute volume percent of rock fragments that are < 75mm for each row
# in the rock fragment table.

DEFINE rockfrag_row_l     IF (75 >= fragsize_l and 75 <= fragsize_r)
THEN ((75-fragsize_l)/(fragsize_r-fragsize_l)/2*fragvol_l)
ELSE IF (75 > fragsize_r and 75 <= fragsize_h)
THEN (((75-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5)*fragvol_l
ELSE IF 75 > fragsize_h THEN fragvol_l ELSE 0.

# Compute total volume percent of rock fragments that are < 75mm on a
# whole soil basis, minus pararocks.

DEFINE totalRFvol_ls     IF (fraghard2=="strongly" or fraghard2=="very strongly" or
fraghard2=="indurated" or ISNULL(fraghard2)) AND fragkind2 != "wood" THEN rockfrag_row_l
ELSE 0.

DEFINE totalRFvol_l     ARRAYSUM(totalRFvol_ls).

# Compute volume percent of rock fragments that are < 75mm on a < 75mm basis.

DEFINE vol75mm_l    totalRFvol_l/(1-(fragvoll-totalRFvol_l)/100).

# Compute volume percent of rock fragments that are < 75mm
# to a weight percent for each row in the rock fragment table.

DEFINE wtRF_row_l     IF totalRFvol_l == 0 THEN 0 ELSE (rockfrag_row_l/totalRFvol_l*vol75mm_l)
* densityrock/(((vol75mm_l/100)*densityrock)+((1-vol75mm_l/100)*dbthirdbar_r)).

# Compute volume percent of rock fragments that are < 5mm
# to a weight percent for each row in the rock fragment table.

DEFINE wtRF5mm_row_l     IF 5>=fragsize_h THEN wtRF_row_l
ELSE IF (5>=fragsize_l and 5<=fragsize_r)
THEN (5-fragsize_l)/(fragsize_r-fragsize_l)/2*wtRF_row_l
ELSE IF (5>fragsize_r and 5<=fragsize_h)
THEN (((5-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5)*wtRF_row_l
ELSE 0.

# Compute weight percent of rock fragments of whole soil for each row.

DEFINE wtRFwhole_row_l     fragvol_l*densityrock/(((fragvol_l/100)*densityrock)+((1-fragvol_l/100)
* dbthirdbar_r)).

# Compute weight percent of rock fragments > 75mm of whole soil, minus pararocks.

DEFINE wtRFwhole75mm_row_ls     IF (75>=fragsize_l and 75<=fragsize_r)
THEN ((1-((75-fragsize_l)/(fragsize_r-fragsize_l)/2))*wtRFwhole_row_l)
```

```
ELSE IF (75>fragsize_r  and 75<=fragsize_h)
THEN ((1-(((75-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5))*wtRFwhole_row_l)
ELSE IF 75>fragsize_h  THEN 0 ELSE wtRFwhole_row_l.

DEFINE wtRFwhole75mm_row_l  IF ISNULL(fragvlr)  and ISNULL(fragvol_l)  and ISNULL(fragvol_h)
THEN 0 ELSE IF (fraghard2=="strongly"  OR fraghard2=="very  strongly"  or fraghard2=="indurated"  or
ISNULL(fraghard2))  AND  fragkind2  != "wood"  THEN wtRFwhole75mm_row_ls  ELSE 0.

DEFINE wtRFwhole75mm_l       ARRAYSUM(wtRFwhole75mm_row_l).

# Compute weight percent of rock fragments > 250mm of whole soil, minus pararocks.

DEFINE wtRFwhole250mm_row_j  IF (250>=fragsize_l  and 250<=fragsize_r)  THEN ((1-((250-
fragsize_l)/(fragsize_r-fragsize_l)/2))*wtRFwhole_row_l)  ELSE IF (250>fragsize_r  and
250<=fragsize_h)      THEN  ((1-(((250-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5))*wtRFwhole_row_l)
ELSE IF fragsize_l>=250  THEN wtRFwhole_row_l  ELSE 0.

DEFINE wtRFwhole250mm_row_l  IF ISNULL(fragvlr)  and ISNULL(fragvol_l)  and
ISNULL(fragvol_h)
THEN 0 ELSE IF (fraghard2=="strongly"  or fraghard2=="very  strongly"  or fraghard2=="indurated"  or
ISNULL(fraghard2))  AND  fragkind2  != "wood"  THEN wtRFwhole250mm_row_j  ELSE 0.

DEFINE rockfrag_250l     ARRAYSUM(wtRFwhole250mm_row_l).

# Compute weight percent of rock fragments that are 75 to 250mm, minus pararocks.

DEFINE rockfrag_75l          wtRFwhole75mm_l  - rockfrag_250l.

#-------------------------------------------------------------------------------
# Start of percent passing sieves and rock fragments calculation  for high values.
#-------------------------------------------------------------------------------
# Compute total volume percent of rock fragments, minus pararocks,
# on a whole soil basis.

DEFINE fragvolhs  IF (fraghard2=="strongly"  or fraghard2=="very  strongly"  or fraghard2=="indurated"
or ISNULL(fraghard2))  AND fragkind2  != "wood"   THEN fragvol_h  ELSE  0.

DEFINE fragvolh     ARRAYSUM(fragvolhs).
ASSIGN  fragvolh      IF fragvolh  > 90 THEN 90 ELSE fragvolh.  #Assumes there is at least 10% soil (<
2mm) at the high  fragment condition.

# Uses the high  fragment  volume total  from the Horizon Table.
DEFINE sumhighfrags       ARRAYSUM(fragvol_h).
ASSIGN  fragvolh      IF (fragvolh  / sumhighfrags)  < 1 AND  fragvolh  < fragvoltot_h  AND  fragvolh != 0
AND NOT ISNULL(sumhighfrags)  AND  sumhighfrags  > 0 THEN (fragvolh  / sumhighfrags)  *
fragvoltot_h  ELSE IF ISNULL(fragvoltot_h)  THEN fragvolh   ELSE fragvoltot_h.

# Compute volume percent of rock fragments that are < 75mm for each row
# in the fragment table.

DEFINE rockfrag_row_h      IF (75 >= fragsize_l  and 75 <= fragsize_r)   THEN ((75-
fragsize_l)/(fragsize_r-fragsize_l)/2*fragvol_h)    ELSE IF (75 > fragsize_r  and 75 <= fragsize_h) THEN
```

```
(((75-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5)*fragvol_h ELSE IF 75 > fragsize_h THEN fragvol_h
ELSE 0.

# Compute total volume % of rock fragments that are < 75mm on a
# whole soil basis, minus pararocks.

DEFINE totalRFvol_hs    IF (fraghard2=="strongly" or fraghard2=="very strongly" or fraghard2 ==
"indurated" or ISNULL(fraghard2)) AND fragkind2 != "wood" THEN rockfrag_row_h ELSE 0.

DEFINE totalRFvol_h    ARRAYSUM(totalRFvol_hs).

# Compute volume percent of rock fragments that are < 75mm on a < 75mm basis.

DEFINE vol75mm_h    totalRFvol_h/(1-(fragvolh-totalRFvol_h)/100).

# Compute volume percent of rock fragments that are < 75mm
# to a weight percent for each row in the fragment table.

DEFINE wtRF_row_h    IF totalRFvol_h == 0 THEN 0 ELSE (rockfrag_row_h/totalRFvol_h
*vol75mm_h)*densityrock/ (((vol75mm_h/100)*densityrock)+((1-vol75mm_h/100)*dbthirdbar_r)).

# Compute volume percent of rock fragments that are < 5mm to a weight percent for each row in the
fragment table.

DEFINE wtRF5mm_row_h    IF 5>=fragsize_h THEN wtRF_row_h ELSE IF (5>=fragsize_l and
5<=fragsize_r) THEN (5-fragsize_l)/(fragsize_r-fragsize_l)/2*wtRF_row_h ELSE IF (5>fragsize_r and
5<=fragsize_h) THEN (((5-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5)*wtRF_row_h ELSE 0.

# Compute weight percent of rock fragments of whole soil for each row.

DEFINE wtRFwhole_row_h    fragvol_h*densityrock/(((fragvol_h/100)*densityrock)+ ((1-
fragvol_h/100)*dbthirdbar_r)).

# Compute weight percent of rock fragments > 75mm of whole soil, minus pararocks.

DEFINE wtRFwhole75mm_row_k  IF (75>=fragsize_l and 75<=fragsize_r)  THEN ((1-((75-
fragsize_l)/(fragsize_r-fragsize_l)/2))*wtRFwhole_row_h) ELSE IF (75>fragsize_r and 75<=fragsize_h)
THEN ((1-(((75-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5))*wtRFwhole_row_h)
ELSE IF 75>fragsize_h THEN 0 ELSE wtRFwhole_row_h.

DEFINE wtRFwhole75mm_row_h IF ISNULL(fragvlr) and ISNULL(fragvol_l) and
ISNULL(fragvol_h)
THEN 0 ELSE IF (fraghard2=="strongly" or fraghard2=="very strongly" or fraghard2=="indurated" or
ISNULL(fraghard2)) AND fragkind2 != "wood" THEN wtRFwhole75mm_row_k ELSE 0.

DEFINE wtRFwhole75mm_h    ARRAYSUM(wtRFwhole75mm_row_h).

# Compute weight percent of rock fragments > 250mm of the whole soil, minus pararocks.

DEFINE wtRFwhole250mm_row_k IF (250>=fragsize_l and 250<=fragsize_r) THEN ((1-((250-
fragsize_l)/(fragsize_r-fragsize_l)/2))*wtRFwhole_row_h) ELSE IF (250>fragsize_r and
```

```
250<=fragsize_h)      THEN  ((1-(((250-fragsize_r)/(fragsize_h-fragsize_r)/2)+0.5))*wtRFwhole_row_h)
ELSE IF fragsize_l>=250  THEN wtRFwhole_row_h  ELSE 0.

DEFINE wtRFwhole250mm_row_h  IF ISNULL(fragvlr)  and ISNULL(fragvol_l)  and
ISNULL(fragvol_h)
THEN 0 ELSE IF (fraghard2=="strongly"  or fraghard2=="very  strongly"  or fraghard2=="indurated"  or
ISNULL(fraghard2))  AND  fragkind2  != "wood"  THEN wtRFwhole250mm_row_k  ELSE  0.

DEFINE rockfrag_250h       ARRAYSUM(wtRFwhole250mm_row_h).


# Compute weight percent of rock fragments that are 75 to 250mm, minus pararocks.

DEFINE rockfrag_75h       wtRFwhole75mm_h-rockfrag_250h.

# Compute percent passing #10 sieve, minus pararocks.

DEFINE sieve_10hs       IF (fraghard2=="strongly"  or fraghard2=="very  strongly"  or
fraghard2=="indurated"  or ISNULL(fraghard2))  AND  fragkind2  != "wood"  THEN wtRF_row_l ELSE 0.

DEFINE sieve_10h       IF ISNULL(ARRAYSUM(fragvlr))  THEN 100 ELSE 100-
RRAYSUM(sieve_10hs).

# Compute percent passing #4 sieve (minus pararocks).

DEFINE sieve_4hs      IF (fraghard2=="strongly"  or fraghard2=="very  strongly"   or
fraghard2=="indurated"  or ISNULL(fraghard2))  AND  fragkind2  != "wood"  THEN wtRF5mm_row_l
ELSE 0.

DEFINE sieve_4h     IF ISNULL(ARRAYSUM(fragvlr))  THEN 100 ELSE
ARRAYSUM(sieve_4hs)+sieve_10h.

# Compute percent passing #40 sieve (minus pararocks).

DEFINE sieve_40h     IF ISNULL(ARRAYSUM(fragvlr))  AND (ISNULL(ms_h) OR ISNULL(fs_h) OR
ISNULL(vfs_h)  OR ISNULL(silth))  THEN (((0.7485*ms_r)+fs_r+vfs_r+siltr+clayr)+(clayh-clayr))
ELSE IF NOT ISNULL(ARRAYSUM(fragvlr))  and NOT ISNULL(ARRAYSUM(fragvol_l))  and NOT
ISNULL(ARRAYSUM(fragvol_h))  AND  (ISNULL(ms_h)  OR ISNULL(fs_h)  OR ISNULL(vfs_h)  OR
ISNULL(silth))  THEN sieve_10h/100*(((0.7485*ms_r)+fs_r+vfs_r+siltr+clayr)+(clayh-clayr))  ELSE
ISNULL(ARRAYSUM(fragvlr))  THEN (((0.7485*ms_r)+fs_r+vfs_r+siltr+clayr)+(((ms_h-ms_r)+(fs_h-
fs_r)+(vfs_h-vfs_r)+(silth-siltr)+(clayh-clayr))/5))  ELSE  sieve_10h/100  *(((0.7485*ms_r)
+fs_r+vfs_r+siltr+clayr)  + (((ms_h-ms_r)+(fs_h-fs_r)+(vfs_h-vfs_r)+(silth-siltr)+(clayh-clayr))/5)).

# Compute percent passing #200 sieve (minus pararocks).

DEFINE sieve_200h     IF ISNULL(ARRAYSUM(fragvlr))  AND (ISNULL(vfs_h) OR ISNULL(silth))
THEN (((vfs_r*0.56559)+siltr+clayr)+(clayh-clayr))  ELSE IF NOT ISNULL(ARRAYSUM(fragvlr))
and NOT ISNULL(ARRAYSUM(fragvol_l))  and NOT ISNULL(ARRAYSUM(fragvol_h))  AND
(ISNULL(vfs_h)  OR ISNULL(silth))  THEN sieve_10h/100*(((vfs_r*0.56559)+siltr+clayr)+(clayh-
clayr))
ELSE ISNULL(ARRAYSUM(fragvlr))  THEN IF (vfs_r) < 15 THEN (((vfs_r*0.56559)+
siltr+clayr)+(((vfs_h-vfs_r)+(silth-siltr)+(clayh-clayr))/3))  ELSE
```

```
(((vfs_r*curvenum_h)+siltr+clayr)+(((vfs_h-vfs_r)+(silth-siltr)+(clayh-clayr))/3)) ELSE IF vfs_r < 15
THEN sieve_10h/100*(((vfs_r*0.56559)+siltr+clayr)+(((vfs_h-vfs_r)+(silth-siltr)+(clayh-clayr))/3))
ELSE sieve_10h/100*(((vfs_r*curvenum_h)+siltr+clayr)+(((vfs_h-vfs_r)+(silth-siltr)+(clayh-clayr))/3)).

ASSIGN sieve_10h     IF om_r > 35 OR ISNULL(clayr) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE
sieve_10h.

ASSIGN sieve_4h      IF om_r > 35 OR ISNULL(clayr) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE
sieve_4h.

ASSIGN sieve_40h IF om_r > 35 OR (stratextsflag == 1 AND (ISNULL(clayr) OR ISNULL(siltr) OR
ISNULL(vcos_r) OR ISNULL(cos_r) OR ISNULL(ms_r))) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE
sieve_40h.

ASSIGN sieve_200h     IF om_r > 35 OR (stratextsflag == 1 AND (ISNULL(clayr) OR ISNULL(siltr)
OR ISNULL(vfs_r))) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE sieve_200h.

ASSIGN rockfrag_250h     IF om_r > 35 AND ISNULL(ARRAYSUM(fragvolh)) THEN 0 ELSE IF
(ISNULL(clayr) AND stratextsflag != 1) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE rockfrag_250h.

ASSIGN rockfrag_75h     IF om_r > 35 AND ISNULL(ARRAYSUM(fragvolh)) THEN 0 ELSE IF
(ISNULL(clayr) AND stratextsflag != 1) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE rockfrag_75h.

#---------------------------------------------------------------------------
# Rest of calculation for low values.
#---------------------------------------------------------------------------

# Compute percent passing #10 sieve (minus pararocks).

DEFINE sieve_10ls     IF (fraghard2=="strongly" or fraghard2=="very strongly" or
fraghard2=="indurated" or ISNULL(fraghard2)) AND fragkind2 != "wood" THEN wtRF_row_h ELSE 0.

DEFINE sieve_10l     IF ISNULL(ARRAYSUM(fragvlr))   THEN 100 ELSE 100-
ARRAYSUM(sieve_10ls).

# Compute percent passing #4 sieve (minus pararocks).

DEFINE sieve_4ls     IF (fraghard2=="strongly" or fraghard2=="very strongly" or
fraghard2=="indurated" or ISNULL(fraghard2)) AND fragkind2 != "wood" THEN wtRF5mm_row_h
ELSE 0.

DEFINE sieve_4l     IF ISNULL(ARRAYSUM(fragvlr)) THEN 100 ELSE ARRAYSUM (sieve_4ls) +
sieve_10l.

# Compute percent passing #40 sieve (minus pararocks).

DEFINE sieve_40l     IF ISNULL(ARRAYSUM(fragvlr)) AND (ISNULL(ms_l) OR ISNULL(fs_l) OR
ISNULL(vfs_l) OR ISNULL(siltl)) THEN (((0.7485*ms_r)+fs_r+vfs_r+siltr+clayr)-(clayr-clayl)) ELSE
IF NOT ISNULL(ARRAYSUM(fragvlr)) and NOT ISNULL(ARRAYSUM(fragvol_l)) and NOT
ISNULL(ARRAYSUM(fragvol_h)) AND (ISNULL(ms_l) OR ISNULL(fs_l) OR ISNULL(vfs_l) OR
ISNULL(siltl)) THEN sieve_10l/100*(((0.7485*ms_r)+fs_r+vfs_r+siltr+clayr)-(clayr-clayl)) ELSE
ISNULL(ARRAYSUM(fragvlr)) THEN (((0.7485*ms_r)+fs_r+vfs_r+siltr+clayr)-(((ms_r-ms_l)+(fs_r-
fs_l)+(vfs_r-vfs_l)+(siltr-siltl)+(clayr-clayl))/5)) ELSE sieve_10l/100
```

```
*(((0.7485*ms_r)+fs_r+vfs_r+siltr+clayr)  - (((ms_r-ms_l)+(fs_r-fs_l)+(vfs_r-vfs_l)+(siltr-siltl)+(clayr-
clayl))/5)).

# Compute percent passing #200 sieve (minus pararocks).

DEFINE sieve_200l     IF ISNULL(ARRAYSUM(fragvlr))  AND (ISNULL(vfs_l) OR ISNULL(siltl))
THEN (((vfs_r*0.56559)+siltr+clayr)-(clayr-clayl))  ELSE IF NOT ISNULL(ARRAYSUM(fragvlr))  and
NOT ISNULL(ARRAYSUM(fragvol_l))  and NOT ISNULL(ARRAYSUM(fragvol_h))  AND
(ISNULL(vfs_l)  OR ISNULL(siltl))  THEN sieve_10l/100*(((vfs_r*0.56559)+siltr+clayr)-(clayr-clayl))
ELSE ISNULL(ARRAYSUM(fragvlr))  THEN IF (vfs_r) < 15 THEN (((vfs_r*0.56559)+siltr+clayr)-
(((vfs_r-vfs_l)+(siltr-siltl)+(clayr-clayl))/3))  ELSE (((vfs_r*curvenum_l)+siltr+clayr)-(((vfs_r-vfs_l)+
(siltr-siltl)+(clayr-clayl))/3))  ELSE IF vfs_r < 15 THEN sieve_10l/100*(((vfs_r*0.56559)+siltr+clayr)-
(((vfs_r-vfs_l)+(siltr-siltl)+(clayr-clayl))/3))  ELSE sieve_10l/100*(((vfs_r*curvenum_l)+siltr+clayr)-
(((vfs_r-vfs_l)+(siltr-siltl)+(clayr-clayl))/3)).

ASSIGN sieve_10l      IF om_r > 35 OR ISNULL(clayr)  OR ISNULL(dbthirdbar_r)  THEN 1/0 ELSE
sieve_10l.

ASSIGN sieve_4l      IF om_r > 35 OR ISNULL(clayr)  OR ISNULL(dbthirdbar_r)  THEN 1/0 ELSE
sieve_4l.
ASSIGN sieve_40l IF om_r > 35 OR (stratextsflag == 1 AND (ISNULL(clayr) OR ISNULL(siltr) OR
ISNULL(vcos_r) OR ISNULL(cos_r) OR ISNULL(ms_r))) OR ISNULL(dbthirdbar_r) THEN 1/0 ELSE
sieve_40l.

ASSIGN sieve_200l      IF om_r > 35 OR (stratextsflag  == 1 AND  (ISNULL(clayr) OR ISNULL(siltr)
OR ISNULL(vfs_r))) OR ISNULL(dbthirdbar_r)  THEN 1/0 ELSE sieve_200l.

ASSIGN rockfrag_250l      IF om_r > 35 AND ISNULL(ARRAYSUM(fragvoll))  THEN 0 ELSE IF
(ISNULL(clayr)  AND stratextsflag  != 1) OR ISNULL(dbthirdbar_r)  THEN 1/0 ELSE rockfrag_250l.

ASSIGN rockfrag_75l      IF om_r > 35 AND ISNULL(ARRAYSUM(fragvoll))  THEN 0 ELSE IF
(ISNULL(clayr)  AND stratextsflag  != 1) OR ISNULL(dbthirdbar_r)  THEN 1/0 ELSE rockfrag_75l.

#--------------------------------------------
# Checks for high values that are lower than the low values and vise versa for rock fragments.
# This occurs when the fragvol_l and fragvol_h  are not different  from fragvol_r.

ASSIGN rockfrag_250l      IF rockfrag_250l > rockfrag_250h  THEN rockfrag_250h  ELSE IF
rockfrag_250l > rockfrag_250r  THEN rockfrag_250r  ELSE rockfrag_250l.

ASSIGN rockfrag_250h      IF rockfrag_250h < rockfrag_250l  THEN rockfrag_250l ELSE IF
rockfrag_250h < rockfrag_250r  THEN rockfrag_250r  ELSE rockfrag_250h.

ASSIGN rockfrag_75l      IF rockfrag_75l > rockfrag_75h  THEN rockfrag_75h  ELSE IF rockfrag_75l >
rockfrag_75r  THEN rockfrag_75r  ELSE rockfrag_75l.

ASSIGN rockfrag_75h      IF rockfrag_75h < rockfrag_75l THEN rockfrag_75l ELSE IF rockfrag_75h <
rockfrag_75r  THEN rockfrag_75r  ELSE rockfrag_75h.

#--------------------------------------------
# Checks that low values  are not < 0 and high  values are not > 100,

# and rounds to whole numbers.

ASSIGN sieve_10l      IF NOT ISNULL(sieve_10l)  AND  sieve_10l < 0 THEN 0 ELSE
```

```
ROUND(sieve_10l,0).
ASSIGN sieve_4l       IF NOT ISNULL(sieve_4l)  AND sieve_4l < 0 THEN 0 ELSE
ROUND(sieve_4l,0).
ASSIGN sieve_40l      IF NOT ISNULL(sieve_40l)  AND sieve_40l < 0 THEN 0 ELSE
ROUND(sieve_40l,0).
ASSIGN sieve_200l     IF NOT ISNULL(sieve_200l)  AND sieve_200l < 0 THEN 0 ELSE
ROUND(sieve_200l,0).
ASSIGN rockfrag_250l IF NOT ISNULL(rockfrag_250l)  AND rockfrag_250l  < 0 THEN 0 ELSE
rockfrag_250l.
ASSIGN rockfrag_75l      IF NOT ISNULL(rockfrag_75l)  AND rockfrag_75l < 0 THEN 0 ELSE
rockfrag_75l.

ASSIGN sieve_10r    ROUND(sieve_10r,0).
ASSIGN sieve_4r     ROUND(sieve_4r,0).
ASSIGN sieve_40r    ROUND(sieve_40r,0).
ASSIGN sieve_200r  ROUND(sieve_200r,0).

ASSIGN sieve_10h     IF NOT ISNULL(sieve_10h)  AND sieve_10h > 100 THEN 100 ELSE
ROUND(sieve_10h,0).
ASSIGN sieve_4h      IF NOT ISNULL(sieve_4h)  AND sieve_4h > 100 THEN 100 ELSE
ROUND(sieve_4h,0).
ASSIGN sieve_40h      IF NOT ISNULL(sieve_40h)  AND sieve_40h > 100 THEN 100 ELSE
ROUND(sieve_40h,0).
ASSIGN sieve_200h     IF NOT ISNULL(sieve_200h)  AND sieve_200h > 100 THEN 100 ELSE
ROUND(sieve_200h,0).
ASSIGN rockfrag_250h IF NOT ISNULL(rockfrag_250h)  AND rockfrag_250h  > 100 THEN 100 ELSE
rockfrag_250h.
ASSIGN rockfrag_75h     IF NOT ISNULL(rockfrag_75h)  AND rockfrag_75h > 100 THEN 100 ELSE
rockfrag_75h.

#-----------------------------------------------
# Rounding errors (rounds to 1 instead of zero, when < 0.5)

ASSIGN rockfrag_250h      IF NOT ISNULL(rockfrag_250h)  AND rockfrag_250h  > 0.05 and
rockfrag_250h < 1 THEN 1 ELSE rockfrag_250h.
ASSIGN rockfrag_75h       IF NOT ISNULL(rockfrag_75h)  AND rockfrag_75h > 0.05 and rockfrag_75h
< 1 THEN 1 ELSE rockfrag_75h.

#-----------------------------------------------
assign sieve_10l      sieve_10l > sieve_4l ? sieve_4l : sieve_10l.
assign sieve_40l      sieve_40l > sieve_10l ? sieve_10l : sieve_40l.
assign sieve_200l     sieve_200l > sieve_40l ? sieve_40l : sieve_200l.

assign sieve_10h      sieve_10h > sieve_4h ? sieve_4h : sieve_10h.
assign sieve_40h      sieve_40h > sieve_10h ? sieve_10h : sieve_40h.
assign sieve_200h     sieve_200h > sieve_40h ? sieve_40h : sieve_200h.

assign sieve_10r      sieve_10r > sieve_4r ? sieve_4r : sieve_10r.
assign sieve_40r      sieve_40r > sieve_10r ? sieve_10r : sieve_40r.


assign sieve_200r     sieve_200r > sieve_40r ? sieve_40r : sieve_200r.
```

618.105 NASIS Calculation for Estimating Water Content Data

Definition.—This calculation computes the low, representative, and high values for water_one-tenth_bar (0.1 bar H_20), water_one-third_bar (0.33 bar H_2O), water_15_bar (15 bar H_2O), water_satiated (Satiated H_2O), and bulk_density_oven_dry (Db oven dry).

Inputs.—This calculation requires the following data to be populated:

organic_matter_percent	(OM) l,rv,h
rock_frag_greater_than_10_in	(Rock >10) l,rv,h
rock_frag_3_to_10_in	(Rock 3-10) l,rv,h
sieve_number_10	(#10) l,rv,h
bulk_density_one_third_bar	(Db 0.33 bar H2O) l,rv,h or
bulk_density_one_tenth_bar	(Db 0.1 bar H2O) l,rv,h
clay_total_separate	(Total Clay) l,rv,h
linear_extensibility_percent	(LEP) l,rv,h
texture_class	(Texture) or
texture_modifier_and_class	(Tex Mod & Class)*

Limitations.—This calculation computes water contents for organic and mineral layers.

- If no entry is found for rock elements, it is assumed to be zero.
- Missing data in other elements may result in no output.
- Calculation uses texture_class if populated, if not use texture_modifier_and class; however, calculation does not work if texture_modifier_and_class contain SR or modifiers.
- Calculation uses the texture group marked as rv for each horizon and the first texture sequence number within that texture group. If no texture group is marked rv or no sequence number is used, one texture will be selected at random.

Calculation.

```
DEFINE lieutex1     CODENAME(lieutex).

DEFINE oc_r     IF ISNULL(om_r) THEN 1/0 ELSE om_r/1.72.
DEFINE oc_l     IF ISNULL(om_l) THEN 1/0 ELSE om_l/1.72.
DEFINE oc_h     IF ISNULL(om_h) THEN 1/0 ELSE om_h/1.72.

DEFINE db_r     IF ISNULL(dbthirdbar_r) THEN dbtenthbar_r ELSE dbthirdbar_r.
DEFINE db_l     IF ISNULL(dbthirdbar_l) THEN dbtenthbar_l ELSE dbthirdbar_l.
DEFINE db_h     IF ISNULL(dbthirdbar_h) THEN dbtenthbar_h ELSE dbthirdbar_h.

ASSIGN claytotal_l IF claytotal_l == 0 THEN 0.1 ELSE claytotal_l.
ASSIGN fragvol_r    IF ISNULL(fragvol_r) THEN 0 ELSE fragvol_r.
ASSIGN fragvol_l    IF ISNULL(fragvol_l) THEN 0 ELSE fragvol_l.
ASSIGN fragvol_h    IF ISNULL(fragvol_h) THEN 0 ELSE fragvol_h.

# Assume particle density of rock fragments is 2.65 g/cc
DEFINE D_p_gt_2 INITIAL 2.65.

# Try to use single texture if available.
DEFINE tex IF ISNULL(texcl) THEN texgrp ELSE UPCASE(CODENAME(texcl)).

# 1500kPa to clay ratio vaires with bulk density and texture,
```

```
# otherwise assume ratio of 1500KPa to Clay is 0.4
DEFINE F IF claytotal_r >= 40 AND db_r <= 1.60 THEN 0.65 - 0.189*db_r ELSE IF claytotal_r >= 40
AND db_r > 1.6 THEN 0.3 ELSE IF tex == "SCL" OR tex == "CL" OR tex == "SL" THEN 0.42 ELSE
IF tex == "FSL" OR tex == "COSL" OR tex == "LFS" OR tex == "LS" THEN 0.45 ELSE IF tex ==
"VFSL" OR tex == "LCOS" OR tex == "FS" THEN 0.46 ELSE IF tex == "S" THEN 0.44 ELSE IF tex
== "SC" THEN 0.36 ELSE 0.4.

DEFINE F_l IF claytotal_l >= 40 AND db_r <= 1.60 THEN 0.65 - 0.189*db_r ELSE IF claytotal_l >=
40 AND db_r > 1.6 THEN 0.3 ELSE IF tex == "SCL" OR tex == "CL" OR tex == "SL" THEN 0.42
ELSE IF tex == "FSL" OR tex == "COSL" OR tex == "LFS" OR tex == "LS" THEN 0.45 ELSE IF tex
== "VFSL" OR tex == "LCOS" OR tex == "FS" THEN 0.46 ELSE IF tex == "S" THEN 0.44 ELSE IF
tex == "SC" THEN 0.36 ELSE 0.4.

DEFINE F_h IF claytotal_h >= 40 AND db_r <= 1.60 THEN 0.65 - 0.189*db_r ELSE IF claytotal_h >=
40 AND db_r > 1.6 THEN 0.3 ELSE IF tex == "SCL" OR tex == "CL" OR tex == "SL" THEN 0.42
ELSE IF tex == "FSL" OR tex == "COSL" OR tex == "LFS" OR tex == "LS" THEN 0.45 ELSE IF tex
== "VFSL" OR tex == "LCOS" OR tex == "FS" THEN 0.46 ELSE IF tex == "S" THEN 0.44 ELSE IF
tex == "SC" THEN 0.36 ELSE 0.4.

# Assume air entrapment ratio is 0.95
DEFINE air_entrap INITIAL 0.95.

# Determine coefficients p and q for Gregson equation
DEFINE p      if tex=="CL" or tex=="L" or tex=="SICL" or tex=="SIL" then 1.415 else if tex=="COSL"
or tex=="FSL" or tex=="LVFS" or tex=="SCL" or tex=="SI" or tex=="SL" or tex=="VFS" or
tex=="VFSL" or tex=="LCOS" or tex=="LFS" or tex=="LS" then 0.343 else if tex=="S" or tex=="SG" or
tex=="G" or tex=="COS" or tex=="FS" then 0.541 else if tex=="C" or tex=="SC" or tex=="SIC" then
0.879 else 1/0.

DEFINE q      if tex=="CL" or tex=="L" or tex=="SICL" or tex=="SIL" then 0.839 else if tex=="COSL"
or tex=="FSL" or tex=="LVFS" or tex=="SCL" or tex=="SI" or tex=="SL" or tex=="VFS" or
tex=="VFSL" or tex=="LCOS" or tex=="LFS" or tex=="LS" then 1.072 else if tex=="S" or tex=="SG" or
tex=="G" or tex=="COS" or tex=="FS" then 1.469 else if tex=="C" or tex=="SC" or tex=="SIC" then
0.955 else 1/0.

# Compute particle density based on organic matter
#ASSIGN om_r if isnull(om_r) then 0 else om_r.
DEFINE Dp   100 / ((om_r / 1.4) + (100 - om_r)/2.65).

# Compute weight percent of rock fragments based on sieves
ASSIGN fraggt10_r if isnull(fraggt10_r) then 0 else fraggt10_r.
ASSIGN frag3to10_r if isnull(frag3to10_r) then 0 else frag3to10_r.
DEFINE W_gt_2       fraggt10_r + frag3to10_r + (100 - sieveno10_r) * (100 - fraggt10_r - frag3to10_r) /
100.

ASSIGN fraggt10_l if isnull(fraggt10_l) then 0 else fraggt10_l.
ASSIGN frag3to10_l if isnull(frag3to10_l) then 0 else frag3to10_l.
DEFINE W_gt_2_l     fraggt10_l + frag3to10_l + (100 - sieveno10_h) * (100 - fraggt10_l - frag3to10_l) /
100.

ASSIGN fraggt10_h if isnull(fraggt10_h) then 0 else fraggt10_h.
ASSIGN frag3to10_h if isnull(frag3to10_h) then 0 else frag3to10_h.
```

```
DEFINE W_gt_2_h      fraggt10_h + frag3to10_h + (100 - sieveno10_l) * (100 - fraggt10_h -
frag3to10_h) / 100.

# Adjust bulk density for rock fragments
DEFINE D_b         100 / (W_gt_2/D_p_gt_2 + (100 - W_gt_2)/db_r).
DEFINE D_b_l        100 / (W_gt_2_l/D_p_gt_2 + (100 - W_gt_2_l)/db_r).
DEFINE D_b_h        100 / (W_gt_2_h/D_p_gt_2 + (100 - W_gt_2_h)/db_r).

# Compute volume percent of rock fragments
DEFINE V_gt_2       (W_gt_2 * D_b) / D_p_gt_2.
DEFINE V_gt_2_l     (W_gt_2_l * D_b_l) / D_p_gt_2.
DEFINE V_gt_2_h     (W_gt_2_h * D_b_h) / D_p_gt_2.

# -----------15 Bar Water-------------------------------------------

# Compute 15 bar water content uncorrected (by volume and by weight)
DEFINE theta_1500_uc    ((claytotal_r * (1 - om_r/100) * F + om_r) * db_r) / 100.
DEFINE theta_1500_uc_l    ((claytotal_l * (1 - om_l/100) * F_l + om_l) * db_r) / 100.
DEFINE theta_1500_uc_h    ((claytotal_h * (1 - om_h/100) * F_h + om_h) * db_r) / 100.

DEFINE theta_1500_uc_w    (claytotal_r * (1 - om_r/100) * F + om_r) / 100.
DEFINE theta_1500_uc_w_l (claytotal_l * (1 - om_l/100) * F_l + om_l) / 100.
DEFINE theta_1500_uc_w_h  (claytotal_h * (1 - om_h/100) * F_h + om_h) / 100.

# Compute 15 bar water content corrected for rock fragments.
# Convert to percent.
DEFINE theta_1500        theta_1500_uc * (100 - V_gt_2).
DEFINE theta_1500_l       theta_1500_uc_l * (100 - V_gt_2_h).
DEFINE theta_1500_h       theta_1500_uc_h * (100 - V_gt_2_l).

DEFINE theta_1500_w       theta_1500_uc_w * (100 - W_gt_2).
DEFINE theta_1500_w_l     theta_1500_uc_w_l * (100 - W_gt_2_h).
DEFINE theta_1500_w_h     theta_1500_uc_w_h * (100 - W_gt_2_l).

#-----------Satiated Water-------------------------------------------

# Compute saturated water content uncorrected
DEFINE wcs_uc     air_entrap * (1 - db_r / Dp).
DEFINE wcs_uc_l air_entrap * (1 - db_h / Dp).
DEFINE wcs_uc_h   air_entrap * (1 - db_l / Dp).

# Compute saturated water content corrected for rock fragments.
# Convert to percent.
DEFINE wcs      ROUND((wcs_uc * (100 - V_gt_2)),0).
DEFINE wcs_l     ROUND((wcs_uc_l * (100 - V_gt_2_h)),0).
DEFINE wcs_h     ROUND((wcs_uc_h * (100 - V_gt_2_l)),0).

# ----------1/3 Bar Water--------------------------------------------

# Compute RV values
# Compute slope and intercept for the Gregson equation
# Uses volumetric water content
```

```
DEFINE ln_1500 INITIAL 7.31322.
DEFINE ln_theta logn(theta_1500_uc).
DEFINE ln_wcs   logn(wcs_uc).

DEFINE cpslope (ln_1500 - p) / (ln_theta + q).
DEFINE cpintercept ln_1500 - (cpslope * ln_theta).

# Compute field capacity uncorrected
DEFINE fc_uc_10 exp((logn(10) - cpintercept) / cpslope).
DEFINE fc_uc_33 IF tex == "C" THEN exp(0.237*LOGN(claytotal_r)-1.26*db_r+4.162)*db_r/100
ELSE exp((logn(33) - cpintercept) / cpslope).

# Monotonicity check: field capacity between theta_1500_uc and wcs_uc
DEFINE cpslope_adj      IF not isnull(fc_uc_10) and (fc_uc_10 <= 1.1 * theta_1500_uc or fc_uc_10 >=
.95 * wcs_uc) then ln_1500 / (ln_theta - ln_wcs) else cpslope.

DEFINE cpintercept_adj    IF not isnull(fc_uc_10) and (fc_uc_10 <= 1.1 * theta_1500_uc or fc_uc_10 >=
.95 * wcs_uc) then 0 - (cpslope * ln_wcs) else cpintercept.

ASSIGN fc_uc_10   exp((logn(10) - cpintercept_adj) / cpslope_adj).

ASSIGN cpslope_adj   IF not isnull(fc_uc_33) and (fc_uc_33 <= 1.1 * theta_1500_uc or fc_uc_33 >= .95
* wcs_uc) then ln_1500 / (ln_theta - ln_wcs) else cpslope.

ASSIGN cpintercept_adj IF not isnull(fc_uc_33) and (fc_uc_33 <= 1.1 * theta_1500_uc or fc_uc_33 >=
.95 * wcs_uc) then 0 - (cpslope * ln_wcs) else cpintercept.

ASSIGN fc_uc_33 IF not isnull(fc_uc_33) AND claytotal_r > 40 THEN fc_uc_33 ELSE exp((logn(33) -
cpintercept_adj) / cpslope_adj).

# Correct field capacity for rock fragments.
# Convert to percent.
DEFINE wtenth_r    if tex=="LCOS" or tex=="LFS" or tex=="LS" or tex=="S" or tex=="SG" or
tex=="G" or tex=="COS" or tex=="FS" THEN fc_uc_10 * (100 - V_gt_2) ELSE 1/0.
DEFINE wthird_r fc_uc_33 *(100 - V_gt_2).

# Compute low values --------------------------
# Compute slope and intercept for the Gregson equation
# Uses volumetric water content
DEFINE ln_theta_l logn(theta_1500_uc_l).
DEFINE ln_wcs_l  logn(wcs_uc_l).

DEFINE cpslope_l (ln_1500 - p) /  (ln_theta + q).
DEFINE cpintercept_l  ln_1500 - (cpslope_l * ln_theta_l).

# Compute field capacity uncorrected
DEFINE fc_uc_10_l  exp((logn(10) - cpintercept_l) / cpslope_l).
DEFINE fc_uc_33_l IF tex == "C" THEN exp(0.237*LOGN(claytotal_l)-1.26*db_r+4.162)*db_r/100
ELSE exp((logn(33) - cpintercept_l) / cpslope_l).

# Monotonicity check: field capacity between theta_1500_uc_l and wcs_uc_l
```

```
DEFINE cpslope_adj_l IF not isnull(fc_uc_10_l) and (fc_uc_10_l <= 1.1 * theta_1500_uc_l or
fc_uc_10_l >= .95 * wcs_uc_l) then ln_1500 / (ln_theta_l - ln_wcs_l) else cpslope_l.

DEFINE cpintercept_adj_l IF not isnull(fc_uc_10_l) and (fc_uc_10_l <= 1.1 * theta_1500_uc_l or
fc_uc_10_l >= .95 * wcs_uc_l) then 0 - (cpslope_l * ln_wcs_l) else cpintercept_l.

ASSIGN fc_uc_10_l   exp((logn(10) - cpintercept_adj_l) / cpslope_adj_l).

ASSIGN cpslope_adj_l IF not isnull(fc_uc_33_l) and (fc_uc_33_l <= 1.1 * theta_1500_uc_l or
fc_uc_33_l >= .95 * wcs_uc_l) then ln_1500 / (ln_theta_l - ln_wcs_l) else cpslope_l.

ASSIGN cpintercept_adj_l IF not isnull(fc_uc_33_l) and (fc_uc_33_l <= 1.1 * theta_1500_uc_l or
fc_uc_33_l >= .95 * wcs_uc_l) then 0 - (cpslope_l * ln_wcs_l) else cpintercept_l.

ASSIGN fc_uc_33_l IF not isnull(fc_uc_33_l) AND claytotal_l > 40 THEN fc_uc_33_l ELSE
exp((logn(33) - cpintercept_adj_l) / cpslope_adj_l).

# Correct field capacity for rock fragments.
# Convert to percent.
DEFINE wtenth_l if tex=="LCOS" or tex=="LFS" or tex=="LS" or tex=="S" or tex=="SG" or tex=="G"
or tex=="COS" or tex=="FS" THEN fc_uc_10_l * (100 - V_gt_2_h) ELSE 1/0.
DEFINE wthird_l fc_uc_33_l * (100 - V_gt_2_h).

# Compute high values ------------------------
# Compute slope and intercept for the Gregson equation
# Uses volumetric water content
DEFINE ln_theta_h logn(theta_1500_uc_h).
DEFINE ln_wcs_h  logn(wcs_uc_h).

DEFINE cpslope_h       (ln_1500 - p) /  (ln_theta_h + q).
DEFINE cpintercept_h  ln_1500 - (cpslope_h * ln_theta_h).

# Compute field capacity uncorrected
DEFINE fc_uc_10_h   exp((logn(10) - cpintercept_h) / cpslope_h).
DEFINE fc_uc_33_h IF tex == "C" THEN exp(0.237*LOGN(claytotal_h)-1.26*db_r+4.162)*db_r/100
ELSE exp((logn(33) - cpintercept_h) / cpslope_h).

# Monotonicity check: field capacity between theta_1500_uc and wcs_uc
DEFINE cpslope_adj_h IF not isnull(fc_uc_10_h) and (fc_uc_10_h <= 1.1 * theta_1500_uc_h or
fc_uc_10_h >= .95 * wcs_uc_h) then ln_1500 / (ln_theta_h - ln_wcs_h) else cpslope_h.

DEFINE cpintercept_adj_h IF not isnull(fc_uc_10_h) and (fc_uc_10_h <= 1.1 * theta_1500_uc_h or
fc_uc_10_h >= .95 * wcs_uc_h) then 0 - (cpslope_h * ln_wcs_h) else cpintercept_h.

ASSIGN fc_uc_10_h   exp((logn(10) - cpintercept_adj_h) / cpslope_adj_h).

ASSIGN cpslope_adj_h IF not isnull(fc_uc_33_h) and (fc_uc_33_h <= 1.1 * theta_1500_uc_h or
fc_uc_33_h >= .95 * wcs_uc_h) then ln_1500 / (ln_theta_h - ln_wcs_h) else cpslope_h.

ASSIGN cpintercept_adj_h    IF not isnull(fc_uc_33_h) and fc_uc_33_h <= 1.1 * theta_1500_uc_h or
fc_uc_33_h >= .95 * wcs_uc_h) then 0 - (cpslope_h * ln_wcs_h) else cpintercept_h.
```

```
ASSIGN fc_uc_33_h IF not isnull(fc_uc_33_h) AND claytotal_h > 40 THEN fc_uc_33_h ELSE
exp((logn(33) - cpintercept_adj_h) / cpslope_adj_h).

# Correct field capacity for rock fragments.
# Convert to percent.
DEFINE wtenth_h    if tex=="LCOS" or tex=="LFS" or tex=="LS" or tex=="S" or tex=="SG" or
tex=="G" or tex=="COS" or tex=="FS" THEN fc_uc_10_h * (100 - V_gt_2_l) ELSE 1/0.

DEFINE wthird_h     fc_uc_33_h * (100 - V_gt_2_l).


#--------------------------------------------------------
# Additional calculations for when water contents exceed satiated water contents using the gregson
model.
# This generally occurs for compacted or dense soil layers.

ASSIGN wtenth_r      IF om_r >20 OR ((wtenth_r >= wcs) AND (NOT ISNULL(wtenth_r) OR NOT
ISNULL(theta_1500) OR NOT ISNULL(wcs))) THEN 1/0 ELSE wtenth_r.

ASSIGN wthird_r     IF om_r <= 20 AND ((wthird_r >= wcs) AND (NOT ISNULL(wthird_r) OR NOT
ISNULL(theta_1500) OR NOT ISNULL(wcs))) THEN IF claytotal_r < 40 THEN
(exp(logn(theta_1500_uc_w*100)*0.515  - 0.619*db_r + 2.696))/100 * db_r * (100 - V_gt_2) ELSE
exp(0.237*LOGN(claytotal_r)-1.26*db_r+4.162)*db_r/100  * (100 - V_gt_2) ELSE IF om_r > 20 THEN
1/0 ELSE wthird_r.

ASSIGN wthird_r      IF ((wthird_r >= wcs) AND (NOT ISNULL(wthird_r) OR NOT
ISNULL(theta_1500) OR NOT ISNULL(wcs))) THEN wcs-(0.05*wcs) ELSE wthird_r. IF om_r <= 20
AND ((theta_1500 > wcs OR theta_1500 > wthird_r) AND (NOT ISNULL(wthird_r) OR NOT
ISNULL(theta_1500) OR NOT ISNULL(wcs))) THEN wthird_r-(0.1*wthird_r) ELSE IF om_r > 20
THEN 1/0 ELSE theta_1500.

ASSIGN wtenth_l      IF om_r >20 OR ((wtenth_l >= wcs_l) AND (NOT ISNULL(wtenth_l) OR NOT
ISNULL(theta_1500_l) OR NOT ISNULL(wcs_l))) THEN 1/0 ELSE wtenth_l.

ASSIGN wthird_l     IF om_r <= 20 AND ((wthird_l >= wcs_l) AND (NOT ISNULL(wthird_l) OR NOT
ISNULL(theta_1500_l) OR NOT ISNULL(wcs_l))) THEN IF claytotal_l < 40 THEN
(exp(logn(theta_1500_uc_w_l*100)*0.515  - 0.619*db_r + 2.696))/100 * db_r * (100 - V_gt_2_h) ELSE
exp(0.237*LOGN(claytotal_l)-1.26*db_r+4.162)*db_r/100  * (100 - V_gt_2_h) ELSE IF om_r > 20
THEN 1/0 ELSE wthird_l.

ASSIGN wthird_l      IF ((wthird_l >= wcs_l) AND (NOT ISNULL(wthird_l) OR NOT
ISNULL(theta_1500_l) OR NOT ISNULL(wcs_l))) THEN wcs_l-(0.05*wcs_l) ELSE wthird_l.

ASSIGN theta_1500_l      IF om_r <= 20 AND ((theta_1500_l > wcs_l OR theta_1500_l > wthird_l)
AND (NOT ISNULL(wthird_l) OR NOT ISNULL(theta_1500_l) OR NOT ISNULL(wcs_l))) THEN
wthird_l-(0.1*wthird_l) ELSE IF om_r > 20 THEN 1/0 ELSE theta_1500_l.

ASSIGN wtenth_h     IF om_r >20 OR ((wtenth_h >= wcs_h) AND (NOT ISNULL(wtenth_h) OR NOT
ISNULL(theta_1500_h) OR NOT ISNULL(wcs_h))) THEN 1/0 ELSE wtenth_h.

ASSIGN wthird_h      IF om_r <= 20 AND ((wthird_h >= wcs_h) AND (NOT ISNULL(wthird_h) OR
NOT ISNULL(theta_1500_h) OR NOT ISNULL(wcs_h))) THEN IF claytotal_h < 40 THEN
```

```
(exp(logn(theta_1500_uc_w_h*100)*0.515  - 0.619*db_r + 2.696))/100 * db_r * (100 - V_gt_2_l)  ELSE
exp(0.237*LOGN(claytotal_h)-1.26*db_r+4.162)*db_r/100  * (100 - V_gt_2_l)  ELSE IF om_r > 20
THEN 1/0 ELSE wthird_h.

ASSIGN wthird_h    IF ((wthird_h >= wcs_h) AND (NOT ISNULL(wthird_h) OR NOT
ISNULL(theta_1500_h) OR NOT ISNULL(wcs_h))) THEN wcs_h-(0.05*wcs_h) ELSE wthird_h.

ASSIGN theta_1500_h      IF om_r <= 20 AND ((theta_1500_h > wcs_h OR theta_1500_h > wthird_h)
AND (NOT ISNULL(wthird_h) OR NOT ISNULL(theta_1500_h) OR NOT ISNULL(wcs_h))) THEN
wthird_h-(0.1*wthird_h) ELSE IF om_r > 20 THEN 1/0 ELSE theta_1500_h.

#-------------Organic Soils, 1/3 and 15 bar Water--------------------------------

DEFINE theta_1500_org_w       IF om_r <= 20 THEN 1/0 ELSE IF (lieutex1 == "mpt" OR lieutex1 ==
"mpm") THEN (2.019*oc_r+10.54) *0.75 ELSE IF (lieutex1 == "muck" OR lieutex1 == "hpm") THEN
(1.731*oc_r+8.863) *0.75 ELSE IF (lieutex1 == "peat" OR lieutex1 == "spm") THEN
(2.122*oc_r+10.539) *0.75 ELSE 1/0.

ASSIGN theta_1500      IF ISNULL(theta_1500_org_w) THEN theta_1500 ELSE
theta_1500_org_w*db_r / 100 *(100 - fragvol_r).

DEFINE theta_1500_org_w_l      IF om_r <= 20 THEN 1/0 ELSE IF (lieutex1 == "mpt" OR lieutex1 ==
"mpm") THEN (2.019*oc_l+10.54) *0.75 ELSE IF (lieutex1 == "muck" OR lieutex1 == "hpm") THEN
(1.731*oc_l+8.863) *0.75 ELSE IF (lieutex1 == "peat" OR lieutex1 == "spm") THEN
(2.122*oc_l+10.539) *0.75 ELSE 1/0.

ASSIGN theta_1500_l      IF ISNULL(theta_1500_org_w_l) THEN theta_1500_l ELSE
theta_1500_org_w_l*db_r / 100 *(100 - fragvol_h).

DEFINE theta_1500_org_w_h       IF om_r <= 20 THEN 1/0 ELSE IF (lieutex1 == "mpt" OR lieutex1 ==
"mpm") THEN (2.019*oc_h+10.54) *0.75 ELSE IF (lieutex1 == "muck" OR lieutex1 == "hpm") THEN
(1.731*oc_h+8.863) *0.75 ELSE IF (lieutex1 == "peat" OR lieutex1 == "spm") THEN
(2.122*oc_h+10.539) *0.75 ELSE 1/0.

ASSIGN theta_1500_h      IF ISNULL(theta_1500_org_w_h) THEN theta_1500_h ELSE
theta_1500_org_w_h*db_r / 100 *(100 - fragvol_l).

DEFINE ln_theta_1500      LOGN(theta_1500_org_w).
DEFINE ln_theta_1500_l     LOGN(theta_1500_org_w_l).
DEFINE ln_theta_1500_h      LOGN(theta_1500_org_w_h).
DEFINE ln_db_r     LOGN(db_r).
DEFINE   ln_oc_r    LOGN(oc_r).
DEFINE    ln_oc_l    LOGN(oc_l).
DEFINE ln_oc_h    LOGN(oc_h).
ASSIGN wthird_r      IF om_r <= 20 THEN wthird_r ELSE IF (lieutex1 == "mpt" OR lieutex1 ==
"mpm") THEN EXP(0.360*ln_theta_1500-1.076*ln_db_r+2.236) * db_r / 100 *(100 - fragvol_r) ELSE
IF (lieutex1 == "muck" OR lieutex1 == "hpm") THEN EXP(0.142*ln_theta_1500-1.047*ln_db_r+3.340)
* db_r / 100 *(100 - fragvol_r) ELSE IF (lieutex1 == "peat" OR lieutex1 == "spm") THEN
EXP(0.427*ln_theta_1500-0.852*ln_db_r+2.282) * db_r / 100 *(100 - fragvol_r) ELSE 1/0.

ASSIGN wthird_l    IF om_r <= 20 THEN wthird_l ELSE IF (lieutex1 == "mpt" OR lieutex1 == "mpm")
THEN EXP(0.360*ln_theta_1500_l-1.076*ln_db_r+2.236) * db_r / 100 *(100 - fragvol_h) ELSE IF
```

```
(lieutex1  == "muck" OR lieutex1  == "hpm") THEN EXP(0.142*ln_theta_1500_l-1.047*ln_db_r+3.340)
* db_r / 100 *(100 - fragvol_h)  ELSE IF (lieutex1  == "peat" OR lieutex1  == "spm") THEN
EXP(0.427*ln_theta_1500_l-0.852*ln_db_r+2.282)  * db_r / 100 *(100 - fragvol_h)  ELSE 1/0.

ASSIGN  wthird_h    IF om_r <= 20 THEN wthird_h ELSE IF (lieutex1  == "mpt" OR lieutex1  ==
"mpm") THEN EXP(0.360*ln_theta_1500_h-1.076*ln_db_r+2.236)  * db_r / 100 *(100 - fragvol_l)
ELSE IF (lieutex1  == "muck" OR lieutex1  == "hpm")  THEN EXP(0.142*ln_theta_1500_h-
1.047*ln_db_r+3.340)  * db_r / 100 *(100 - fragvol_l)  ELSE IF (lieutex1  == "peat" OR lieutex1  ==
"spm") THEN EXP(0.427*ln_theta_1500_h-0.852*ln_db_r+2.282)  * db_r / 100 *(100 - fragvol_l)  ELSE
1/0.

ASSIGN  theta_1500      IF om_r > 13 AND om_r <= 20 AND  (lieutex1  == "mpt" OR lieutex1  == "mpm"
OR lieutex1  == "muck" OR lieutex1  == "hpm" OR lieutex1  == "peat" OR lieutex1  == "spm") THEN
(EXP(0.673*ln_oc_r + 1.618)*0.75) * db_r / 100 *(100 - fragvol_l)  ELSE theta_1500.

ASSIGN  theta_1500_l      IF om_r > 13 AND om_r <= 20 AND  (lieutex1  == "mpt" OR lieutex1  ==
"mpm" OR lieutex1  == "muck" OR lieutex1  == "hpm" OR lieutex1  == "peat" OR lieutex1  == "spm")
THEN (EXP(0.673*ln_oc_l + 1.618)*0.75) * db_r / 100 *(100 - fragvol_h)  ELSE theta_1500_l.

ASSIGN  theta_1500_h  IF  om_r  >  13  AND  om_r  <=  20  AND  (lieutex1  ==  "mpt"  OR  lieutex1  ==
"mpm"  OR  lieutex1  ==  "muck"  OR  lieutex1  ==  "hpm"  OR  lieutex1  ==  "peat"  OR  lieutex1  ==  "spm")
THEN (EXP(0.673*ln_oc_h + 1.618)*0.75) * db_r / 100 *(100 - fragvol_l)  ELSE theta_1500_h.

DEFINE   ln_theta_1500_A   LOGN(EXP(0.673*ln_oc_r   +   1.618)   *0.75).
DEFINE   ln_theta_1500_A_l   LOGN(EXP(0.673*ln_oc_l  +  1.618)   *0.75).
DEFINE  ln_theta_1500_A_h      LOGN(EXP(0.673*ln_oc_h + 1.618) *0.75).

ASSIGN  wthird_r      IF om_r > 13 AND om_r <= 20 AND  (lieutex1  == "mpt" OR lieutex1  == "mpm"
OR lieutex1  == "muck" OR lieutex1  == "hpm" OR lieutex1  == "peat" OR lieutex1  == "spm") THEN
EXP(0.267*ln_theta_1500_A  - 1.141*ln_db_r + 2.821) * db_r / 100 *(100 - fragvol_r)  ELSE wthird_r.

ASSIGN  wthird_l      IF om_r > 13 AND om_r <= 20 AND  (lieutex1  == "mpt" OR lieutex1  == "mpm"
OR lieutex1  == "muck" OR lieutex1  == "hpm" OR lieutex1  == "peat" OR lieutex1  == "spm") THEN
EXP(0.267*ln_theta_1500_A_l  - 1.141*ln_db_r + 2.821) * db_r / 100 *(100 - fragvol_h)  ELSE wthird_l.

ASSIGN  wthird_h       IF om_r > 13 AND om_r <= 20 AND  (lieutex1  == "mpt" OR lieutex1  == "mpm"
OR lieutex1  == "muck" OR lieutex1  == "hpm" OR lieutex1  == "peat" OR lieutex1  == "spm") THEN
EXP(0.267*ln_theta_1500_A_h  - 1.141*ln_db_r + 2.821) * db_r / 100 *(100 - fragvol_l)  ELSE wthird_h.

#-------------Oven Dry Bulk Denisty----------------------------------------------

# Compute oven dry bulk density
DEFINE bdrdr    IF NOT ISNULL(lep_r)  THEN (((lep_r/100)  / (1 - V_gt_2/100)  + 1) ** 3) * db_r ELSE
1/0.
DEFINE bdrdl    IF NOT ISNULL(lep_l)  THEN (((lep_l/100)  / (1 - V_gt_2/100)  + 1) ** 3) * db_r ELSE
1/0.
DEFINE bdrdh    IF NOT ISNULL(lep_h)  THEN (((lep_h/100)  / (1 - V_gt_2/100)  + 1) ** 3) * db_r
ELSE 1/0.

ASSIGN  bdrdl     IF NOT ISNULL(lep_l)  AND bdrdl > db_l THEN bdrdr - (db_r - db_l) ELSE bdrdl.
ASSIGN  bdrdh    IF NOT ISNULL(lep_h)  AND bdrdh < db_h THEN bdrdr + (db_h - db_r) ELSE bdrdh.
```

```
# Values for median bulk density differences between 1/3 bar and oven-dry divided by the total clay.
DEFINE dbdiff     IF tex == "L" OR tex == "SCL" OR tex == "SIL" OR tex == "FSL" OR tex ==
"COSL" OR tex == "SL" OR tex == "VFSL" OR tex == "SI" OR tex == "LVFS" THEN 0.004 ELSE IF
tex == "CL" OR tex == "S" OR tex == "LFS" OR tex == "FS" OR tex == "LS" THEN 0.005 ELSE IF tex
== "SICL" OR tex == "LCOS" OR tex == "COS" THEN 0.006 ELSE IF tex == "C" OR tex == "SIC"
THEN 0.007 ELSE IF tex == "SC" THEN 0.002 ELSE IF tex == "VFS" THEN 0.003 ELSE 0.004.

ASSIGN bdrdr     IF (bdrdr - db_r) > 0.75 OR bdrdr > 2.1 THEN dbdiff*claytotal_r  + db_r ELSE bdrdr.

ASSIGN bdrdl     IF ((bdrdl - db_r)*(-1)) > 0.75 OR bdrdl > 2.1 THEN dbdiff*claytotal_l  + db_r ELSE
bdrdl.

ASSIGN bdrdh     IF (bdrdh - db_r) > 0.75 OR bdrdh > 2.1 THEN dbdiff*claytotal_h  + db_r ELSE
bdrdh.

ASSIGN bdrdr IF bdrdr > 2.1 OR om_r > 20 THEN 1/0 ELSE bdrdr.
ASSIGN bdrdl IF bdrdl > 2.1 OR om_r > 20 THEN 1/0 ELSE bdrdl.
ASSIGN bdrdh    IF bdrdh > 2.1 OR om_r > 20 THEN 1/0 ELSE bdrdh.

DEFINE bdrdr2 IF bdrdr > bdrdh THEN bdrdh ELSE bdrdr.
ASSIGN bdrdh IF bdrdr > bdrdh THEN bdrdr ELSE bdrdh.
ASSIGN bdrdr  bdrdr2.

DEFINE store2 IF bdrdl > bdrdr THEN bdrdl ELSE bdrdr.
ASSIGN bdrdl IF bdrdl > bdrdr THEN bdrdr ELSE bdrdl.
ASSIGN bdrdr    store2.
```

618.106 References

A. Evans, I.S. 1979. An integrated system of terrain analysis and slope mapping. Final Report on Grant DA-ERO-591-73-G0040, Department of Geography, University of Durham, England, p 192.

B. X. Shi, A. Zhu, J. Burt, W. Choi, R. Wang, T. Pei, B. Li, and C. Qin. 2007. An experiment using a circular neighborhood to calculate slope gradient from a DEM. Photogrammetric Engineering and Remote Sensing 73:143-157.

C. X. Shi, L. Girod, R. Long, R. Dekett, J. Philippe, and T. Burke. 2012. A comparison of LiDAR-based DEMs and USGS-sourced DEMs in terrain analysis for knowledge-based digital soil mapping. Geoderma 170:217-226.

D. Zevenbergen, L.W., and C.R. Thorne. 1987. Quantitative analysis of land surface topography. Earth Surface Processes and Landforms 12:47-56.