Soil and Water Competency Area:

Basic Physical Properties

1. Know the most primary processes of soil formation in Pennsylvania and where examples can be found illustrating each ***Read more**: Soil Management Chapter in Agronomy Guide*	Parent material is the primary factor explaining variation in soils in PA. Most soils developed from sedimentary rock, ie. limestone, sandstone, and shale. These soils are common in the Appalachian, Allegheny, and Pittsburgh Plateaus, the Glaciated Low Plateau in the northeast of the state, the Allegheny Mountains, the Ridge and Valley Province, the Conestoga Valley and the Piedmont Upland. Soil developed in alluvial material can be found along lake Erie, along streams, and in the southeastern tip of Pennsylvania around Philadelphia. Soils in the northwest and northeast have been subject to glaciation. (from Agronomy Guide Soil Management Chapter).
2. Know what is soil health (= soil quality)	Soil health or soil quality is the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health. (Doran and Parkin, 1994).
3. Understand soil consistency	**Know the difference between the plastic and liquid limits** The plastic limit is that moisture content above which soil can just be molded into different forms and shapes, in other words, it is in the plastic state. Soil in the plastic state is most sensitive to compaction. The liquid limit is that water content at which soil becomes liquid and flows under gravity. Soil above the liquid limit is not as easy to compact but is very sensitive to rutting. **Know the ball test** A simple field test to determine soil readiness for tillage. A handful of soil is taken and squeezed into a ball. If the soil molds together, it is in the plastic state and too wet for tillage or field traffic (Magdoff and Van Es, 2000).

4. List characteristics of gravel, sand, silt and clay	The size of particles in mineral soil cannot be altered and is considered a basic property of a soil. Groups of soil are defined by particle size. The procedure by which soils are grouped into separates is called mechanical analysis. Mineral particles have the following sizes:

Particle	Size (mm)	Water Holding Capacity	Characteristics
Gravel	=>2	none	
Sand	.05 - 2	low	good drainage and air movement; cannot be molded
Silt	.002 - .05	high	small size; slow water and air movement really are microsand particles, quartz dominating; has adhering film of clay, resulting in stickiness and adsorption; unsatisfactory unless supplemented with sand, clay and organic matter
Clay	< .002	high	slow water and air movement; fine colloidal clay has 10,000 times as much surface area as med-size sand; when wet tends to be sticky; easily molded

Three broad groups of soil textural classes - sands, loams and clays.

Sand group - all soils with sand separates making up 70% or more of the material by weight. Coarse. (sandy, loamy sands)

Loam group - a mixture of sand, silt and clay particles which exhibits light and heavy properties in about equal proportions.

Clay group - clay separates at least 35% and in most cases not less than 40% by weight.

5. Use a textural triangle to determine textural classification of a soil if given the percents of two of the soil separates ***Read more:*** *Soil Management Chapter in Agronomy Guide*	To use the textural triangle locate the percentages on the silt and clay lines. Project the silt value parallel to the clay side and the clay value parallel to the sand side.

6. Identify prismlike, blocklike, platelike and spheroidal structural units	**Prismlike** - Vertically oriented aggregates or pillars which vary in length with different soils and may reach a diameter of 6 or more inches. Commonly occur in subsoil horizons in arid and semiarid regions. **Blocklike -** Aggregates reduced to 6 faced blocks. When subrounding has occurred, aggregates are referred to as subangular blocky. Fragments range from a fraction of an inch to 3 or 4 inches in thickness. Common in heavy subsoils of humid regions. **Platelike** - Aggregates are organized in relatively thin horizontal plates, leaflets or lenses. May occur in any part of profile; at times inherited from the soil material. **Spheroidal** - All rounded aggregates are placed in this category. Ordinarily aggregates are granules and the pattern is granular. However, when granules are especially porous the term crumb is applied. Characteristic of furrow slice. Subject to wide and rapid changes. Factors affecting formation of granules: wetting and drying; freezing and thawing; physical activity of roots and soil animals; influence of decaying organic matter and slimes from microbes; modifying effects of adsorbed cations; and tillage. This is the only type of aggregate commonly influenced by management practices. Aggregates are usually not more than .5 inch in diameter.
7. Describe benefits of well-developed soil aggregation	Soil aggregation affects water movement, heat transfer, aeration, bulk density (determined by the quantity of pore spaces as well as soil solids) and porosity (space occupied by air and water). Soils with good aggregation have good granulation and stability. Benefits - favorable water movement, heat transfer, aeration, bulk density and porosity.
8. Describe how each of the following factors affects soil structure	**tillage** - short-time effect is beneficial to soil structure: implements break up clods, incorporate organic matter and make more favorable seedbed. Long-time effect is detrimental to soil structure: by mixing and stirring soil, oxidation of organic matter is hastened; heavy equipment tends to break down stable aggregates; and compaction occurs. **cropping system -** organic matter has a significant effect on soil structure (promotes granules). Thus, cropping systems that encourage plant residues, encourage good soil structure (granules). A system with a large portion of row crops encourages more rapid loss of organic matter than a system with a large proportion of close-growing or sod crops. This is due to increased aeration and oxidation of organic matter.

8. Cont'd	Also, the amount of residue contributed from crops in the system affects organic matter content. Corn for grain furnishes more organic matter than corn for silage. Also, the carbon to nitrogen ratio of the crop residues in the system affect the amount of organic matter Residues with low C to N ratios result in more humus than residues with high C to N ratios. Monoculture, cultivation and crop rotation affect structure. **soil organisms -** aggregate stability is influenced by the temporary (a few weeks or months after fresh organic matter added) mechanical binding action of microorganisms (fungi with mycelia being especially effective); the cementing action of the intermediate products of microbial synthesis and decay, such as microbially produced gums and certain polysaccharides (compounds are called pre-humus constituents and are effective for several months); and cementing action of more resistant stable humus components broken down only very slowly by microorganisms. Earthworms and roots contribute. **soil drainage -** poor soil drainage reduces oxygen in pore spaces available to microbes. When activity of soil organisms is reduced, aggregate stability is reduced.
9. List sources of soil organic matter	Plant tissue is the original source of soil organic matter Animals are a secondary source; as they attack original plant tissues, they contribute waste products and leave their own bodies as their life cycles are ended.
10. Define humus	Definition: humus is a complex and rather resistant mixture of brown or dark brown amorphous and colloidal substances modified from the original tissues or synthesized by the various soil organisms. Amorphous and highly colloidal. CEC ranges from 150 to 300.

11. Describe the relationship between soil organic matter and:	**soil color** - (brown to black) development of a black pigment in humus varies with climate. In northern semiarid regions, the pigment is very dark and abundant; In humid-temperate regions the color is less intense and least pigmentation is found in tropics and semitropics. **soil structure -** humus encourages granulation. It has low plasticity and cohesion. In fine textured soils it helps alleviate unfavorable structural characteristics induced by large quantities of clay. Water holding capacity increased. Organic matter is an organic glue holding peds together. **soil nutrient-supplying ability** - High CEC. (Easily replaceable cations present) Accounts for 30 to 90% of adsorbing power of mineral soils. N, P and S held in organic forms. When humus is saturated with H+ ions it acts like an acid and reacts with soil minerals to extract their bases. Once the exchange is made, the bases are held loosely making them easily available to higher plants.
12. Describe how the carbon:nitrogen ratio of soil organic materials may affect soil nitrogen availability to plants	Carbon is used as an energy source for microbes. C:N > 30 - immobilization, <20 - mineralization It may affect soil N because keen competition for available N results when residues having a high C/N ratio are added to soils. Microbial demand temporarily ties up soil N. As decay of organic matter occurs, the C/N ratio decreases since carbon is being lost and nitrogen conserved. Once easily oxidizable carbon drops off, microbes drop off (releasing N) and nitrification proceeds. There is a temporary elevation of nitrogen and humus.
13. Describe advantages and disadvantages of green manuring	Requires higher degree of management; depletes water. Green manuring helps maintain soil organic matter (may even increase organic matter) As a result, organic matter encourages good soil structure, exchange of N, P and S held in organic forms, increases water holding capacity, etc. Disadvantage is a temporary nitrate depression if high C:N ratio. Limits erosion; some crops pull nutrients out of soil better than other crops; helps manage and alleviate compaction.

14. List ways to maintain the organic matter content of an agricultural soil	Use green manures (plowing under of immature, succulent crops) and apply animal manures and composts to soils. Reduce tillage practices. Keep fertility levels high and lime adequate. The amount of soil nitrogen largely determines the amount of organic carbon present when stabilization occurs. Thus, the greater the amount of N present in the original residue, the greater will be the possibility of an accumulation of organically combined carbon. This means organic matter with low C/N ratios will encourage accumulation of humus. Sod crops promote highest possible yields of humus. Cultivated crops encourage rapid rate of organic matter decay.

Soil and Water Competency Area:

Erosion Processes

15. Recognize how the following are used in the Revised Universal Soil Loss Equation (RUSLE):	**Rainfall, duration and intensity** Used to calculate the R factor of RUSLE. Erosivity R increases as duration and intensity increase. A very high percentage of erosion occurs on a few of our larger storms. **Slope percentage** Slope percentage is needed to determine the LS factor. Erosion increases as slope increases. Has a larger impact than length of slope. (field measurement) **Slope length** Slope length is the other factor needed to determine the LS factor. Erosion increases as length increases. Less impact than percentage of slope (field measurement) LS FACTOR = Impacts percentage and length of slope. Influenced by soil consolidation, i.e. if a soil has not been tilled for a min of 7 years, the LS factor increases for short slopes (< 75 ft) and decreases for long slopes (>75 ft).

15. Cont'd	**Soil Texture** Impacts erodibility, K. Sands and clays are less erosive silt loams more erosive. Organic matter also affects K. **Soil Surface Roughness** The greater the roughness the more ponding occurs which reduce both runoff and soil erosion. It is incorporated in the P factor. **Vegetative Canopy and residue cover** Influences C factor. Crop residue and canopy cover reduces dispersion of soil particles (particularly residue) and reduces surface flow velocity resulting in potential increased infiltration. **Wind velocity** Not used in computations of average erosion with RUSLE, although it does impact velocity of raindrops hitting the soil. **Crop rotation** Impacts the C factor, because it influences vegetative cover, crop residues produced, root biomass in top 4 inches. Sequence can impact over winter cover and other conditions. Row spacing and tillage also interact with these factors. **Root Mass** Root mass influences the C factor. Greater amount of root mass in the top 4" of soil increases potential for infiltration and reduces soil erosion. Fibrous roots generally produce more root mass in the top 4 inches (ie grasses and small grains) when compared to tap roots. **Credit for manure** The C factor is reduced by manure applications. If 4000 # of dry matter is applied every other year, the C factor should be multiplied by 0.8. If bedded manure is applied to silage corn stubble to give > 60% residue cover, the C factor should be multiplied by 0.5 The potential to increase soil organic matter with manure over the long term results in a reduction of soil erosion with added manure or other organic materials. This calculation considers the soil profile with a natural good condition, so if compaction occurs over the long term from manure hauling and application, the predicted erosion using RUSLE may be underestimated.

15. Cont'd	**Animal Concentration Areas** (over grazed pastures) Animal concentration areas are only represented in RUSLE in the C factor due to the decreased amount of residue cover there and the lack of root biomass. Erosion in these areas is also likely to increase because of compaction and reduced infiltration, however compaction is not used in RUSLE. **Soil Compaction** Not incorporated in RUSLE. Anytime producer activities impact negatively on the natural soil permeability and infiltration rates RUSLE will underestimate soil erosion.
16. Explain how diversions affect sheet, rill, and gully erosion	Diversions don't affect sheet erosion. They do reduce rill erosion because they break the slope length and reduce the amount of runoff flowing over the field. This also leads to a reduction of gully formation further downhill.
17. Differentiate among the following types of water and wind erosion:	**splash -** this erosion takes place when the rain drop strikes a wet bare soil. On a soil subject to easy detachment, a very heavy torrential rain may splash as much as 100 tons of soil an acre **sheet** - soil is removed more or less uniformly from every part of the slope. (need smooth surface to occur) **rill -** soil is removed from tiny gullies irregularly dispersed, especially on bare land newly planted or in fallow. (sheet and rill happen together frequently) **gully -** soil is removed via large or small ravines by concentrated water. Sheet and rill erosion are probably most detrimental to maintaining soils. **saltation -** wind erosion; movement of soil by a short series of bounces along the surface of the ground (knocking other particles loose). **suspension** -dust particles of a fine sand size and smaller are moved parallel to the ground surface and upward. **surface creep -** rolling and sliding along surface of the larger soil particles

18. List physical factors which affect rate of erosion	**Water erosion -** total and intensity of rainfall; seasonal distribution; nature of soil (infiltration capacity and structural stability; texture; organic matter content; amount of swelling of clays; soil depth; presence of impervious layers); degree of slope, length of slope, topography of drainage area; presence of channels; vegetative cover; erosion control practices. **Wind erosion -** a dry weather phenomenon involving two processes; detachment and transportation. Affected by moisture content of soils; wind velocity and turbulence; soil surface condition (less where soil surface is rough); soil characteristics (mechanical stability of dry soil clods, presence of stable soil crust and bulk density and size of erodible soil fractions); nature and orientation of vegetation.
19. Know how to estimate percent residue using the line-transect method	Use any line that is equally divided into 100 parts. A 50-foot nylon rope with 100 knots or marks, six inches apart will work. Stretch the line diagonally across crop rows. Count the number of marks that have residue under the leading edge when sighting from directly above the mark. Don't count residue smaller than 1/8 inch in diameter. Determine percentage. Repeat at least 3 times and average findings. (If not large enough to intercept rain drop, don't count.) To qualify for conservation tillage must have at least 30% residue.
20. In a given situation, make economically sound management recommendations that will result in soil conservation	**Conservation tillage** sharply reduces sheet and rill erosion. It is the lowest cost conservation method per ton of soil saved. The effectiveness depends on a rough surface and the amount of residues left on the soil surface, especially during the critical period before the crop canopy fills in. At least 30% of soil surface should be covered by mulch at planting. **Crop rotation** reduces erosion if a close-growing crop like small grains or forages is included. Close-growing crops reduce the detachment and transport energy of water. Also it improves soil's physical properties so that water seeps into the soil better. **Grassed waterway** carries excess water off the field safely. They can prevent gullying, collect excess water from tillage contours and may serve as outlet for terraces. Contour tillage works best on permeable soils in areas of low intensity rainfall. Moderate slopes suffering from rill erosion benefit most from contour tillage.

20. Cont'd	**Strip-cropping** can be used in all conditions along with contour tillage. Strips of close-growing crops slow down runoff and filter out soil eroded from row-cropped strips. Strip-cropping works best in areas of moderate rainfall, on permeable soils and on uniform slopes. **Improve organic matter** - moisture seeps into soils with organic matter more quickly. **Terraces -** used where strip cropping cannot halt erosion. Long steep slopes on impermeable soil require terraces. Terraces are costly to install. **Diversions -** large capacity terraces covered with grass that divert runoff from higher elevations. **Alternate land use** - intensive grazing.

Soil and Water Competency Area:

Compaction

21. Know effects of soil compaction on soil physical, chemical and biological properties	**Physical**: Soil compaction increases soil density, decreases porosity, increases penetration resistance, and degrades soil structure. It leads to decreased infiltration and reduced soil drying. **Chemical**: Soil compaction can cause an increase in denitrification because of increased soil wetness, a decrease in soil organic nitrogen mineralization, decreased nitrate losses, increased nitrogen losses in runoff, and slower diffusion of nutrients to plant roots. It can also result in increased ammonia losses due to decreased infiltration of liquid manure. Plants can exhibit phosphorus and potassium deficiencies because of restricted root systems. **Biological**: Soil compaction reduces root growth and crop yield and generally affects larger soil fauna (such as earthworms) negatively. It may also lead to more frequent anaerobic conditions in the soil.
22. Explain the influence of axle load and contact pressure on compaction	Axle load determines subsoil compaction, whereas contact pressure determines surface compaction.

23. Know the importance of soil moisture content for compaction	Soil is most compactable between the plastic and liquid limit. If soil is drier than the plastic limit it is less compactable. Above the liquid limit soil is susceptible to rutting.
24. Know strategies to reduce subsoil compaction ***Read more:*** *Avoiding Soil Compaction* *http://soilmanagement.psu.edu/*	Subsoil compaction can be reduced by reducing the load or by increasing the number of axles.
25. Know strategies to reduce surface compaction	Surface compaction can be reduced by minimizing tire pressure, using flotation tires, tracks or duals, using radial-ply instead of bias-ply tires, and balancing vehicles.
26. Know strategies to make soil more resistant to compaction	Increase organic matter content, use continuous no-tillage, rotate crops with different growth periods to enable root growth when soil moisture content is high, and rotate crops with different root architectures, such as taprooted crops and fibrous rooted crops.
27. Know ways to alleviate compaction	Use vertical tillage to alleviate compaction. Tillage is only needed to slightly below the depth of compaction, which can be determined with a penetrometer. If soil is not severely compacted, it has not been shown to be beneficial to use any tillage for crop production on well-drained soil in the state. Another way to alleviate compaction is to grow winter (cover) crops or deep-rooted crops.

Soil and Water Competency Area:
Tillage and Residue Management

28. Describe the components of sustainable no-tillage systems	These systems include continuous no-tillage with high residue cover, diverse crop rotations, and cover crops.

29. Know ways to manage manure in no-till	Odor may be the only real common drawback especially where homes are close by and down wind Compaction must be avoided by not applying when soil is too wet Odor problems can also be minimized with timing of application Ideally manure could be injected if subsequent tillage is not needed to level the field Nitrogen losses may be minimized with timing of application In most cases, (even with consideration of soluble P)reduction in soil erosion will offset build up of P in the soil surface which does increase losses of soluble P. Surface applied manure when applied on cover crops and on heavy residues tends to provide microbial food and enhance the soil microbial activity near the soil surface Runoff may be a problem in some instances, especially where soils are very poorly, poorly or somewhat poorly drained. Manure should be applied on a growing crop or on residue levels exceeding 50 %, preferably 75% or more.
30. Explain the relationship of tillage to:	**Manure** It is possible to surface apply manure, but it is possible to loose a substantial amount of the nitrogen if surface application is followed by dry, hot and windy conditions. There is also potential for surface water pollution if surface manure application is followed by heavy rainfall that results in runoff. Odor nuisance can be substantial with surface manure application. Swine and veal manure have the strongest odor, followed by poultry and dairy manure. If manure must be incorporated it can either be injected or tilled in. Injection with no following tillage is more consistent with maintaining the benefits of no-till. Manure can also be incorporated by moldboard plowing, chisel plowing, or disking as primary operations. **Residue cover** More tillage means less cover. The moldboard reduces residue cover most, followed by twisted shank 3 inch chisels, or offset disks, next straight shanks, lighter regular disks, followed by chisels using sweeps and finishing disks. Field cultivators with sweeps as a secondary tool is best for secondary operations and can resurface previously buried residues. **Water contamination** Soil erosion: In general, permanent no-till minimizes soil erosion. Other forms of conservation tillage that leave more than 30% residue cover after planting also substantially protect soil from erosion.

30. Cont'd	Nutrients: Organic nitrogen losses are reduced with no-till or other forms of conservation tillage. Nitrate leaching losses have not been shown to be greater with no-till than with tillage, despite the presence of greater by-pass flow in permanent no-till. Total phosphorus losses to surface waters is reduced with no-till or other forms of conservation tillage because most phosphorus moves with sediment. However, there is now concern soluble phosphorus losses may be high in no-till, especially if manure is surface-applied. **Nutrient loss** Nitrogen losses through ammonia volatilization may be high if manure or urea-fertilizer is surface applied in no-till. Other nutrient loss pathways are covered under Water contamination.

Soil and Water Competency Area:

Regulations and Policy

31. Explain the type of soil and water information available from the following sources:	**Manure Management Manual for Environmental Protection** (published by The Pennsylvania Department of Environmental Protection, DEP) This manual provides guidelines that allow farmers to comply with DEP regulations concerning animal manures. Farmers who do not follow these requirements need to obtain a DEP approval or a water quality permit. Farmers who do not meet these requirements may be in violation of state or federal water pollution control. **Pennsylvania Technical Guide (published by USDA-NRCS)** This Guide assists in the diagnosis of soil erosion and the design of soil conservation practices. **Agronomy Guide (Penn State)** The current (2005-2006) Agronomy Guide gives information about major soil types of Pennsylvania, soil quality, tillage and residue management and the management of cover crops. **Soil Erosion and Sediment Control Manual** This manual provides guidance regarding the erosion and sedimentation control responsibilities of farmers under Pennsylvania's rules and regulations. The manual describes what farmers need to do to comply with the Clean Streams Law. They need to either have a conservation plan or erosion and sedimentation plan implemented.