What will be covered in Session II:

A Closer Look at Soil Nutrients

LESSON 1: The Dirt on Soil
LESSON 2: The Nitrogen Cycle
LESSON 3: The Phosphorus Cycle
LESSON 4: The P-Index

Terms to Learn

• cation exchange capacity (CEC)
• nitrate-N
• ammonium-N
• phosphorus index (P-index)

Exercises

1. Calculating Nutrient Availability in Manure
2. P-Index Worksheet
3. Checklist
LESSON II-1

The Dirt on Soil

A NMP starts with understanding what’s in your soil. Do you know what’s in yours? This is the essence of nutrient management. Soil is a complex and intricate system.

Soil varies in its appearance and ability to grow crops. We can tell by looking at these two soils which would be the better one for crops, but what is the real difference?

The real story of soil lies not in its looks, but in its characteristics. Soil has three types of characteristics: physical, chemical, and biological.

Physical

Some physical properties of soil can be seen with the eye or felt between thumb and finger. With the exception of texture, they are all subject to change caused by weather and management.

Color. Color can indicate soil conditions such as organic matter content, drainage conditions, degree of oxidation, and extent of weathering. Darker soils generally contain more organic matter than lighter colored soils.

Texture. Texture depends upon the amount of sand silt and clay particles present. A Covington soil is characterized as a clay and may contain around 65% clay, 30% silt, and 5% sand.

SOIL-STRUCTURE EVALUATION

Good Condition vs – 2

Moderate Condition vs – 1

Poor Condition vs – 0

Good distribution of friable finer aggregates with no significant clodding.

Soil contains significant proportions of both coarse, firm clods and friable, fine aggregates.

Soil dominated by extremely coarse, very firm clods with very few finer aggregates.
**Structure.** The size and arrangement of structural pieces called soil aggregates (the crumbs or chunks of soil) affect the amount and types of pores the soil has, and therefore strongly influence water and oxygen storage and movement through the soil.

**Internal Drainage.** Water drains below the root zone following saturating rains.

**Depth.** This is the distance from the surface to the layer that stops downward growth of plant roots (bedrock or extremely compact layer). Depth affects the capacity for water storage in a soil.

**Susceptibility to Erosion.** Susceptible soils generally have a low amount of stable surface aggregates and/or are poorly drained and/or have high slopes. Soils that have lost part or all of their top-soil layer to erosion are harder to till and not as productive.

**Chemical**

Chemical properties of soil involve the management of soil nutrients at the most basic level.

**pH.** pH measures the relative acidity or alkalinity of a soil solution. This measurement is done on a scale from one to fourteen. At a pH of 7.0, the solution is neutral. Less than 7.0 is acidic and greater than 7.0 is basic. The pH condition of the soil ranks among a number of environmental conditions that affect the quality of plant growth. Most agronomic crops prefer soil pH between 6 and 7. However, some crops such as blueberries and cranberries prefer pH below 5. Because pH is expressed on a logarithmic scale, a difference of one pH unit is a tenfold difference in acidity.

**Cation Exchange Capacity.** Mineral nutrients within the soil have either a positive or negative charge. The nutrients with a positive charge (including calcium, magnesium, potassium, ammonium,
and sodium) are held by negatively charged clay particles and organic matter. Cation exchange capacity (CEC) refers to a soil's ability to retain these nutrients (because organic matter and clays have negative charges), rather than having them leached away. The more clay and organic matter in a soil, at near neutral pH, the higher its CEC.

**Nutrients.** The soil supplies the following essential nutrients for proper plant growth and production. These nutrients can originate from weathered minerals or from decomposing organic matter.

### Nutrients and their plant-available forms:

**Primary Nutrients**
- Nitrate-N \( (NO_3^-) \)
- Ammonium-N \( (NH_4^+) \)
- Phosphorus \( (H_2PO_4^- \text{ and } HPO_4^{2-}) \)
- Potassium \( (K^+) \)

**Secondary Nutrients**
- Calcium \( (Ca^{2+}) \)
- Magnesium \( (Mg^{2+}) \)
- Sulfur \( (SO_4^{2-}) \)

**Micronutrients**
- Iron \( (Fe^{3+}) \)
- Manganese \( (Mn^{2+}) \)
- Boron \( (Bo^{3-}) \)
- Molybdenum \( (MoO_4^{2-}) \)
- Copper \( (Cu^{2+}) \)
- Zinc \( (Zn^{2+}) \)
- Chlorine \( (Cl^-) \)
- Nickel \( (Ni^{2+}) \)
- Cobalt \( (Co^{2+}) \)

The primary nutrients are used in the greatest amount by the plant, and are the ones you are most concerned about when creating the NMP.

- **Nitrogen** is part of the chlorophyll molecule. Plants also require nitrogen in order to produce amino acids for building proteins. When deficient in nitrogen, plants become stunted and yellow coloring appears in older leaves.

- **Phosphorus** is important in developing healthy root systems, normal seed development, uniform crop maturation, photosynthesis, respiration, cell division, and many other processes. Phosphorus deficiency results in stunted plant growth and purple or reddish pigmentation in the older leaves.

- **Potassium** is responsible for the regulation of water usage in plants, disease resistance, stem strength, photosynthesis, and protein synthesis. Deficiency in potassium results in scorching or necrosis of older leaf margins and poor root systems. Potassium deficient plants also develop slowly.

**Biological**

Biological properties of soil relate to the living components. Soil is much more than just lifeless dust; it is composed of living organisms such as earthworms, plant roots, insects, and microorganisms. Microorganisms, in particular, break down the remains of plants and other organisms. This process releases nutrients that support plant and soil life.

Soil has a very diverse biology and forms a delicate relationship with the plants it sustains. Do not treat your soil like dirt! Soil needs food and care, just as cows need grain and comfortable shelter.
The Plant and Soil Ecosystem

Plants depend on soil for air, water, nutrients, and mechanical support. In order to accomplish this, a soil should be maintained in as healthy a condition as possible.

Keep in mind that soil fertility is a delicate balance of the physical, biological, and chemical properties. To maintain a healthy balance of these properties you should try to create a soil that has the following characteristics:

- Good water infiltration and storage
- Good soil tilth
- Low rates of erosion
- Good levels of organic matter
- Contains a high level of biological diversity
- The proper pH for the crops you're growing
- All the essential nutrients in reasonable proportion to crop needs

We will be looking more closely at farming practices that help you maintain a balance of nutrients. The first step in maintaining healthy soil is knowing how much of each nutrient it contains, and how those nutrients behave in the soil.
A good balance of nutrients begins with the big three: nitrogen (N), phosphorus (P), and potassium (K). Let’s get started with nitrogen.

**Forms of Nitrogen in the Soil**

There are several types of nitrogen in the soil:

**Organic Nitrogen.** Organic matter contains carbon. Aside from mineral forms such as calcium carbonate (lime), anything with carbon is either living or was once living. For instance, a field of grass plowed into the soil is considered organic fertilizer because it was once a living organism. Any nitrogen bound to the carbon in the dead grass would be considered, by association, organic nitrogen. This kind of nitrogen is not readily available to the plants. It takes microbes to break down the organic matter into inorganic-N forms that plants can use.

**Inorganic Nitrogen.** Inorganic or mineral nitrogen is present in the soil in many forms:

- **Nitrate-N** ($\text{NO}_3^-$). Plants prefer this type of nitrogen, and almost all N taken up by plants is in this form.

- **Ammonium-N** ($\text{NH}_4^+$). This is the first form of N produced when soil microorganisms convert organic N into mineral N. Usually it is rapidly changed into nitrate.

- **Nitrogen Gas** ($\text{N}_2$). This is the type of nitrogen in the air and is the most abundant form in the world (the air you breathe is 78% $\text{N}_2$). The only plants that can extract N from the air are legumes (such as clover, alfalfa, and birdsfoot trefoil). If you plant legumes, you can make your own nitrogen!

- **Nitric and Nitrous Oxides** ($\text{NO}$ and $\text{N}_2\text{O}$). These are forms of nitrogen that are not utilized by plants but can be utilized by some microbes.

**LESSON II-2**

The Nitrogen Cycle

Amanda Gervais

Legumes have a special relationship with nitrogen fixing bacteria called rhizobia. Like the alfalfa plant in this picture, legumes offer rhizobia sugar in exchange for the nitrogen the bacteria provide to the plant.

**Nitrogen Cycle**

1. **Nitrogen Fixation.** Nitrogen gas from the atmosphere is converted to ammonium-N. This is done by the bacteria living in the nodules on legume roots. Remember the rhizobium? If you inoculate your legume seed with the rhizobium bacteria it will help ensure that atmospheric nitrogen gas is converted into a form that the plant can use. In turn, the plant will pass on some sugar to the bacteria and give the bacteria a place to live. This is how N is “fixed.” It becomes available in the soil for other crops after these legumes or their roots die.

If you give a legume a lot of fertilizer it can become lazy. It will start to take N almost exclusively from the fertilizer.
2. Nitrogen Uptake. This is the process of your plants taking up ammonium-N or, more commonly, nitrate-N. They then use these forms to make amino acids and then proteins or other essential chemicals.

3. Nitrogen Mineralization. Organic N is converted to ammonium-N. In most soils it is converted to nitrate almost immediately. These forms can then be used by plants or other organisms in the soil.

4. Denitrification. Nitrate-N is converted to gas — N₂ or nitrous oxide — which then go into the atmosphere. This happens when the soil is saturated with water or really compacted. The nitrogen will volatilize into the air and your soil loses valuable nitrogen.

5. Ammonia Volatilization. When urea is applied to the soil surface and not quickly incorporated, a significant amount of N may be changed into the form of ammonia-N gas and is lost into the atmosphere.

Nitrogen Deficiency Symptoms

Nitrogen is considered the primary limiting nutrient in many field crops. When corn is N deficient the plants will become pale, yellowish-green in color. Nitrogen is a mobile nutrient in the plant, and therefore symptoms begin on the older, lower leaves and will progress up the plant if the deficiency persists. The symptoms will appear on leaves as a v-shaped yellowing, starting at the tip and progressing down the midrib toward the leaf base. Inadequate fertilization can result in nitrogen deficiencies; however, weather also plays a major role in nitrogen availability for the growing crop. In the early season deficiencies can be seen when the weather is cold.
and the soils are saturated with water. During the mid-season dry soil conditions can result in nitrogen deficiencies. Heavy rainfall during the growing season can result in nitrogen leaching and hence inadequate nitrogen for the crops. Other factors such as flooding can also result in nitrogen losses.

**Don’t Treat Your Soil Like Dirt**

The nitrogen cycle is almost entirely biological (controlled by soil organisms), so it is important to maintain the soil biology that drives it. If there is no soil biology then there are no soil organisms, which means your soil is dead. If your soil is dead, then there will be no nitrogen cycle no matter how much fertilizer you use. You must think of your soil as “livestock” that needs to be “fed.” Producing a healthy, biologically active soil is the key to having enough nitrogen for crops.

**Nitrogen and the Environment**

The excessive application or misapplication of nitrogen can have a negative impact on the environment.

Nitrogen can be lost to the environment in the following ways:

**Leaching.** Nitrate-N can leach easily as excess rainwater moves through soil to groundwater. It leaches because it has a negative charge that will repel, rather than bind to, the negative charge of the soil particles. Ammonium-N, on the other hand, has a positive charge so it binds to the soil particles.

**Runoff and Erosion.** When the surface of the soil, fertilizer, and manure erode in a rain storm, they can carry ammonium-N and organic forms of nitrogen into the water.

**Volatilization.** Ammonium-N can volatilize through the air if it is on the surface of the soil, especially in warm weather. If possible, incorporate fertilizer and manure to avoid these types of losses.

**Maximizing the Fertilizer Value of Manure Nitrogen**

Nitrogen is easily lost to the air (volatilized) when ammonium-N in manure is converted into ammonia gas. The amount of ammonia volatilization will vary greatly on both the environmental conditions and management strategies. Losses can range from close to 100% for surface application to only a few percent when manure is incorporated immediately.
into the soil. While we can’t control the weather, we can minimize N losses through various manure management strategies.

If manure is incorporated into the soil, ammonium-N is brought into direct contact with soil organic matter and clay, which attracts ammonium-N and keeps it in the soil. Rapid incorporation of manure also reduces the chance for runoff and erosion into nearby waters. Therefore, the best practice to reduce N losses is to incorporate the manure immediately after spreading. The longer you wait to incorporate manure, the more nitrogen lost to the surrounding environment. The table on page 43 (“Ammonium-N availability from spring- or summer-applied manure,” from Table 15 Nutrient Recommendations for Field crops in Vermont) shows that immediate incorporation with standard tillage equipment or injection can increase N availability considerably.

Generally, in the spring most farmers are rapidly incorporating the manure as soon as it is applied to corn fields. However, even a brief lag between manure application and incorporation can result in a 50% loss in ammonium-N. There are situations, such as on grass fields, where manure incorporation is not possible. In these situations, where manure is primarily surface applied, ammonium-N losses can approach 100% if conditions are prime. Recently, there has been interest in alternative manure incorporation systems such as aerators and various injection systems that could be used on both corn and hay ground. These systems can provide rapid incorporation of manure with reduced or no soil tillage, thus keeping more N in the soil to be made available for plant uptake. There are many types of injection systems available but all work on the same general principle, slice the soil and drop down the manure. There is evidence that deep injection can effectively reduce ammonia losses on hay fields but the practice has also been shown to cause root damage and occasional yield reductions. Aerator systems poke holes in the soil (prior to, or at the time of, application) and most of the manure makes its way into the holes. These systems result in reduced nitrogen runoff and volatilization as compared to surface applied manure. Some studies have also documented yield increases as a result of increased nitrogen availability to the grass and alleviation of compacted layers.

These incorporation systems can also provide a host of other benefits. The advantages of using a rapid manure injection system include: fewer odors, ability to place nutrients directly into the seedbed, and the reduction in nutrient loss via surface runoff. There are some potential drawbacks to the systems such as: they tend to be more expensive and may not be suitable for all soil types found in Vermont including steeply sloping ground or stony soils. Of course, like any new practice you implement, you must weigh all the advantages and disadvantages before deciding whether a manure injection system makes sense for your farm.
What’s in your manure? Before starting this class, you should have submitted a manure sample for nutrient analysis at a testing lab. For information on how to take a manure sample see the instructions at the end of this exercise.

It is necessary to describe your manure and waste handling facility to the state and federal government. Find the form called “Animal Waste Management System Overview” in your binder. When filling out this form, be sure to include each type of manure storage that you have on the farm as well as how the manure is spread onto the fields.

Next we will calculate on-farm nutrients available from manure. The worksheet can be found on the “Manure Analysis Results” in the computer workbook. To fill out the worksheet you will need your manure analysis results. If you did not get a manure sample tested use the “book values,” which are average values found in the table below.

If you only have one manure storage area, you only need to fill out the column called “Storage #1.” If you have two or more separate manure storage areas (two manure pits, or a manure pit and a manure stack), then use a column for each storage.

Typical values for total nutrient content of manure.
(Table 14 from Nutrient Recommendations for Field Crops in Vermont)

<table>
<thead>
<tr>
<th>Species/type</th>
<th>Dry matter</th>
<th>Total N</th>
<th>NH₄-N</th>
<th>Organic N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>Mg</th>
<th>Ca</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>pounds/1,000 gallons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy, liquid</td>
<td>7</td>
<td>25</td>
<td>12</td>
<td>13</td>
<td>8</td>
<td>20</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Dairy, semi-solid</td>
<td>17</td>
<td>9</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Dairy, solid (&gt;20% DM)</td>
<td>26</td>
<td>9</td>
<td>2</td>
<td>7</td>
<td>4.5</td>
<td>7</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Beef</td>
<td>23</td>
<td>12</td>
<td>3</td>
<td>9</td>
<td>6</td>
<td>12</td>
<td>1.5</td>
<td>—</td>
</tr>
<tr>
<td>Hog</td>
<td>9</td>
<td>14</td>
<td>8</td>
<td>6</td>
<td>11</td>
<td>11</td>
<td>1.5</td>
<td>—</td>
</tr>
<tr>
<td>Sheep</td>
<td>25</td>
<td>23</td>
<td>7</td>
<td>16</td>
<td>8</td>
<td>20</td>
<td>2.5</td>
<td>—</td>
</tr>
<tr>
<td>Poultry, layers</td>
<td>55</td>
<td>50</td>
<td>10</td>
<td>40</td>
<td>50</td>
<td>34</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Poultry, broilers</td>
<td>70</td>
<td>73</td>
<td>19</td>
<td>54</td>
<td>63</td>
<td>46</td>
<td>13</td>
<td>30</td>
</tr>
<tr>
<td>Horse</td>
<td>37</td>
<td>9</td>
<td>1</td>
<td>8</td>
<td>6</td>
<td>11</td>
<td>4</td>
<td>—</td>
</tr>
</tbody>
</table>
Next, for each storage area you use, fill in the amount of waste produced on your farm each year. You can get this number from your NRCS representative. It is calculated using a formula that takes into account many factors on your farm including animal numbers, bedding, water use, and rainfall.

*(Exercise II-1 is continued on the next page)*
Next you will move to the “Manure Storage” tabs in the computer workbook. In these worksheets you will calculate manure N available to crops based on the type of manure, timing of application, and timing of incorporation. You need to fill out one of these for each manure storage facility that you have. Fill out all unshaded boxes in the worksheet. The shaded boxes (on the left side) are filled in for you based on the manure analysis numbers you entered before. You will need to use three different tables found on page 43 and 44 to fill in the middle numbers in each equation. This will allow you to determine the percentage nitrogen available from manure.

### Manure Storage #1 Nitrogen Calculations

<table>
<thead>
<tr>
<th>Surface Applied</th>
<th>Fall</th>
<th>One Year Ago</th>
<th>Two Years Ago</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spring/Summer</strong></td>
<td>NH₄-N Equation</td>
<td>NH₄-N Equation</td>
<td>NH₄-N Equation</td>
</tr>
<tr>
<td>NH₄-N (lbs/1000 gal)</td>
<td>NH₄-N (lbs/1000 gal)</td>
<td>NH₄-N (lbs/1000 gal)</td>
<td>NH₄-N (lbs/1000 gal)</td>
</tr>
<tr>
<td><strong>Organic N Equations</strong></td>
<td>Well Drained N-Credits</td>
<td>Well Drained N-Credits</td>
<td>Well Drained N-Credits</td>
</tr>
<tr>
<td><strong>Incorporated</strong></td>
<td>Fall</td>
<td>NH₄-N Equation</td>
<td>NH₄-N Equation</td>
</tr>
<tr>
<td>NH₄-N (lbs/1000 gal)</td>
<td>NH₄-N (lbs/1000 gal)</td>
<td>NH₄-N (lbs/1000 gal)</td>
<td>NH₄-N (lbs/1000 gal)</td>
</tr>
<tr>
<td><strong>Organic N Equations</strong></td>
<td>Well Drained N-Credits</td>
<td>Well Drained N-Credits</td>
<td>Well Drained N-Credits</td>
</tr>
</tbody>
</table>

**Organic N acts differently in well drained and poorly drained soil, so we calculate the credits separately.**

Calculations for hay fields

Calculations for corn and other annual crops
### Availability of ammonium nitrogen from spring- or summer-applied manure (% fertilizer N equivalent).

*(Table 15 from Nutrient Recommendations for Field Crops in Vermont)*

<table>
<thead>
<tr>
<th>Time to incorporation by tillage or rain</th>
<th>Dairy cattle or other livestock</th>
<th>Poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Liquid or slurry</td>
<td>Thick or semi-solid (&gt; 10% DM)</td>
</tr>
<tr>
<td></td>
<td>Thin (&lt; 5% DM)</td>
<td>Medium (5–10% DM)</td>
</tr>
<tr>
<td>Immediate/1 hour</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>&lt; 8 hours</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>1 day</td>
<td>70</td>
<td>55</td>
</tr>
<tr>
<td>2 days</td>
<td>65</td>
<td>50</td>
</tr>
<tr>
<td>3–4 days</td>
<td>65</td>
<td>45</td>
</tr>
<tr>
<td>5–7 days</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>&gt; 7 days (or non-incorporated)</td>
<td>60</td>
<td>40</td>
</tr>
</tbody>
</table>

### Availability of ammonium nitrogen from fall-applied manure (% fertilizer N equivalent).

*(Table 16 from Nutrient Recommendations for Field Crops in Vermont)*

<table>
<thead>
<tr>
<th>Time to incorporation by tillage or rain</th>
<th>Dairy Cattle or other livestock</th>
<th>Poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Liquid or slurry</td>
<td>Thick or semi-solid (&gt; 10% DM)</td>
</tr>
<tr>
<td></td>
<td>Thin (&lt;5% DM)</td>
<td>Medium (5-10% DM)</td>
</tr>
<tr>
<td>Immediate/1 hr</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>&lt;8 hr</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>1 day</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>2 days</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>3-4 days</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>5-7 days</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>&gt;7 days (or non-incorporated)</td>
<td>25</td>
<td>15</td>
</tr>
</tbody>
</table>
### Availability (% fertilizer N equivalent) of organic N from manure applied in current and past years.

(Table 17 from *Nutrient Recommendations for Field Crops in Vermont*)

<table>
<thead>
<tr>
<th>Dry matter</th>
<th>Soil drainage</th>
<th>Current year</th>
<th>1 year ago</th>
<th>2 years ago</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tilled</td>
<td>Surface</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>% available</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 or less</td>
<td>Well to moderately well drained</td>
<td>36</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Somewhat poorly to poorly drained</td>
<td>24</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>Well to moderately well drained</td>
<td>30</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Somewhat poorly to poorly drained</td>
<td>20</td>
<td>14</td>
<td>10</td>
</tr>
</tbody>
</table>
EXAMPLE: CALCULATING SPRING/SUMMER SURFACE-APPLIED MANURE N CREDITS

Let’s start by looking at the first equation in the worksheet.

\[
\text{Available } \text{NH}_4-N = \frac{12.0 \times \% \text{NH}_4-N \text{ Avail}}{\text{(lbs/1000 gal)}}
\]

The worksheet tells us that we will be using Table 15 for this equation:

<table>
<thead>
<tr>
<th>Time to incorporation by tillage or rain</th>
<th>Dairy cattle or other livestock</th>
<th>Poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>70</td>
</tr>
<tr>
<td>1 day</td>
<td>70</td>
<td>55</td>
</tr>
<tr>
<td>2 days</td>
<td>65</td>
<td>50</td>
</tr>
<tr>
<td>3–4 days</td>
<td>65</td>
<td>45</td>
</tr>
<tr>
<td>5–7 days</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>&gt; 7 days (or non-incorporated)</td>
<td>60</td>
<td>40</td>
</tr>
</tbody>
</table>

Let’s say that the manure on your farm is liquid dairy with less than 5% dry matter. You will use values in the column for thin liquid manure. Next, we need to decide which row to use based on the time to incorporation of the manure. Since we are doing calculations for surface-applied manure (on hay fields), which is non-incorporated, we use the last row of numbers. Our number is 60. What does this mean? It means that for manure spread in the spring or summer on hay fields, 60% of the ammonium nitrogen will be available for crop use.

Remember to convert percentages to decimals:

\[60\% = 0.60\]

So for each 1000 gallons of manure spread on a hay field, there are 7.2 lbs. of ammonium nitrogen available for the next crop. Do the same thing for each of the other fields, being sure that you use the table indicated. The worksheet will automatically do the calculations for you.
Manure Nutrients Available for Crop Production

The worksheet called “Manure Nutrient Values” will be calculated automatically if you have filled out the previous sheets. Here we calculate the total manure nutrients on your farm that are available for crop use based on your manure nutrient analysis and the amount of manure produced. Notice that phosphorus and potassium are 100% available. Nitrogen availability is not 100% and that is why we calculated it separately. These are the total nutrients that you will be allocating to your fields as you create your nutrient management plan.

<table>
<thead>
<tr>
<th>Manure Storage 1</th>
<th>Phosphorus Availability - 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2O5 (lbs/1,000 gal)</td>
<td>Total gal Produced</td>
</tr>
<tr>
<td>8.0</td>
<td>1,357,007</td>
</tr>
<tr>
<td><strong>Total lbs P2O5 Available For Crops</strong> = 10,856</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Potassium Availability - 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>K2O (lbs/1,000 gal)</td>
</tr>
<tr>
<td>20.0</td>
</tr>
<tr>
<td><strong>Total lbs K2O Available For Crops</strong> = 27,140</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nitrogen Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total N (lbs/1,000 gal)</td>
</tr>
<tr>
<td>7.9</td>
</tr>
<tr>
<td><strong>Total N lbs Available For Crops</strong> = 10,775</td>
</tr>
</tbody>
</table>
A field-by-field nutrient management program requires multiple components to maintain adequate fertility for crop growth and development. Animal manure has long been used as a source of nutrients for crop growth. Standard nutrient values from manure like those obtained from the Nutrient Recommendations for Field Crops in Vermont booklet are reasonable average values, but an individual farm’s manure analyses can vary from those averages by 50 percent or more. Species, age of animal, feed rations, water use, bedding type, management, and other factors make every farm’s manure different. Because every livestock production and manure management system is unique, the best way to assess manure nutrients is by sampling and analyzing the manure at a laboratory. Accurate manure analyses are essential for proper nutrient management planning, but manure analyses are only as good as the sample taken. The 590 Standard requires that a manure analysis be conducted for each storage facility every year.

### How to Sample Liquid Storage

Agitate and thoroughly mix the manure before sampling. Make a dipper by fastening a cup to a broomstick or pole and take a sample or two from the tank spreader and place them in a pail. Do this for multiple loads as the storage is being emptied.

### How to Sample Non-Liquid Storage

Use a garden trowel and pail to collect a sample of manure from various spots on the spreader. Sample the loads for two to three consecutive days. It is recommended to avoid large chunks or pieces of bedding and to select five to ten sub-samples from different places in the spreader.

### How to Sample from Daily Spreading

Use a garden trowel and pail to collect a sample of manure from various spots on the spreader. Sample the loads for two to three consecutive days. It is recommended to avoid large chunks or pieces of bedding and to select five to ten sub-samples from different places in the spreader.

### Handling the Sample

Immediately after sampling the load, thoroughly mix the contents of the sampling pail, remove a small amount with a ladle and place it in a plastic jar, then cap it tightly and freeze immediately. Collect several sub-samples from different loads on different days and add each new sub-sample to the jar of frozen material and refreeze immediately. Repeat until you feel that you have a representative bulk sample. Be sure that the plastic jar is three-quarters full to allow room for expansion. Properly preparing the sample is very important to prevent ammonia loss.

Wipe the container to remove any manure that may have spilled down the sides. The outside of the container should be clean prior to shipping. Secure the lid firmly and label with its name and date.

This method of sampling a manure pit is **not** recommended.
Phosphorus (P) is an essential nutrient for plants and animals. In plants it plays a role in energy transformation, photosynthesis, respiration, and cell growth. Adequate P is needed for early root formation and growth as well as for seed formation. Livestock also require P for proper growth. It is an essential component of bones and teeth. Most of the world’s soils are deficient in P, but excesses are seen in states like Vermont that have areas with a lot of animals, feed imported from other parts of the country, and manure. In general, the total amount of available phosphorus in most Vermont soils was once quite low, therefore it is ingrained in some farmers to add phosphorus to fields every year. Would anyone think of putting on a starter fertilizer that doesn’t contain P?

Forms of Phosphorus in the Soil

Phosphorus exists in many different forms in soil, including organic, soil solution, “bound,” and primary mineral forms. Organic P is bound to carbon compounds in the soil. It was produced from a once living organism. Most of the organic-P in agricultural soils comes from livestock manure applications or crop residues. In order for the organic-P to become plant available it must be released from the carbon bond by microorganisms. Soil solution P is the soluble inorganic form of P, also known as orthophosphates (H$_2$PO$_4^-$ or HPO$_4^{2-}$). This is the form taken up by plants, but it is also the form that accounts for the smallest proportion of the total P in most soils. Bound P makes up a large proportion of the soil P and is unavailable to plants because it is chemically bound to soil particles. P forms insoluble compounds with different minerals in the soil such as iron (Fe), aluminum (Al), or manganese (Mn) in acidic soils, or calcium (Ca) in basic soils. Primary mineral P is unavailable in the form of rocks and minerals.

Phosphorus Cycle

Most P in the soil originates from the weathering of rocks, and from additions in the form of fertilizer or manure. Plants can only absorb P that has become dissolved in the soil solution. The release of P to plant roots is controlled by three chemical and biological processes: 1) when phosphorus-bearing minerals slowly dissolve over long periods of time, 2) when P bound to the surface of soil minerals is uncoupled, and 3) when soil organic matter decomposes. Organic P can be mineralized by microbes into plant available forms. Soil temperatures between 65 and 105°F favor P mineralization of organic P. Most of the P added to the soil as fertilizer and manure can become rapidly bound by the soil minerals in chemical forms that are not subject to rapid release. This can happen one of two ways:
- P reacts with Fe, Al, Mn or Ca (precipitation), or
- P can be held by soil particles.

The availability of P is largely based on soil pH. At a high pH (basic soil), P can precipitate with Ca. For instance, clay soil has lots of calcium or magnesium (also positively charged) that binds quickly with the P. Once again, your P is rendered unavailable to your plants. At lower pH (acidic soil), P tends to be bound to Fe and Al compounds in the soil. Soils that have higher Fe and/or Al contents have the potential to hold more P than other soils. Phosphorus is in its most plant available form when the pH is between 6.2 and 6.5.

Because soil P is so easily bound in unavailable forms in the soil, soil solution P is typically very low, even when plants are able to obtain sufficient quantities. However, at very high soil test levels, P can be available to plants in sufficient quantities, but can also be more prone to runoff and even leaching. In order to assure that plants have sufficient P for growth, a farmer must conduct routine...

Phosphorus is fixed by different soil minerals depending on soil pH. Phosphorus is most available between a pH of 6.2 and 6.5.

Soluble phosphorus is added to the soil and goes into soil solution, where it is highly available to the plant. Available and unavailable P are shown as light circles and dark circles, respectively.

Much of the phosphorus is quickly bound to soil particles and only some of the P is readily available to plant roots.

Nearly all of the phosphorus has been tightly bound to soil particles and is no longer readily available to the plant.
soil tests. The soil tests will allow the farmer to determine if the pH must be adjusted to keep P in a plant-available state. In addition, it will also inform a farmer if additional P should be added in the form of manure or fertilizer.

**Phosphorus Deficiency Symptoms**

Phosphorus deficiency is usually visible on young corn plants. Plants deficient in P will be dark green with reddish-purplish leaf tips and margins on older leaves. The newly emerging leaves will not show the purple coloration. Phosphorus deficient plants will be smaller and grow more slowly than plants with adequate P levels. Deficiency symptoms nearly always disappear when plants grow to three feet or taller. It is important to note that some corn hybrids tend to show purple colors at early stages of growth even though phosphorus nutrition is adequate. Phosphorus is relatively immobile in soils therefore it is important to apply phosphorus where newly emerging plant roots can easily absorb it. Phosphorus deficiency is not always caused by low soil P levels. Phosphorus deficiency can be induced when soils are cold, too wet or too dry. Other factors that can impact phosphorus uptake include restricted root growth in compacted soils; and roots injured by insects, herbicides, fertilizers, or cultivation.

**Phosphorus and the Environment**

Most P loss to the environment occurs during field runoff events. Phosphorus in runoff is either sediment-bound (attached to soil particles) or dissolved in water. Sediment-bound phosphorus makes up the major proportion of P transported from tilled soils. Runoff from grass fields carries little sediment, and is generally dominated by the dissolved form. Leaching of P is very rare but is possible under some conditions, especially in fields that have been recently tiled, or on well structured soil with many large pores.

As soil test P increases, the potential for sediment and dissolved P transport in runoff also increases.

The soil is not an infinite sink for P. We can reach a saturation point at which the risk of P loss is high. Once saturated, the soluble phosphorus is free to flow and can run into the surrounding water. P can even leach into the groundwater — something we didn’t used to think could even happen. The soil only needs 0.2 to 0.3 milligrams/liter of phosphorus. Algae in the lake only needs one tenth of that amount. It doesn’t take much high-P runoff to start causing problems.

You have to be careful about the way you manage phosphorus. This is especially true with manure application. If you are applying manure to increase your nitrogen content, keep in mind that the manure is rich in phosphorus content as well. So
as you apply it to increase your nitrogen, you also increase your soil’s P. You could end up doubling your amount of P to reach the required amount of nitrogen. The problem with excess P is that it is much easier to build up than to use up after high levels are reached.

One of the goals of our NMP is to reduce P losses from agriculture to surface waters. This goal can be reached by minimizing inputs of P in feed and fertilizer, consistent with modern dairy cow and crop management, and by balancing inputs with outputs in crop and animal products. The buildup of P to excessive levels in soils can occur when any P source, including commercial fertilizer and manure, is over-applied for a long period of time. The greatest concern is the addition of P to land from manure applications.

In the Northeast, most animal operations are located in grain-deficient areas and require that grain for animal feed be imported. This type of production system represents a net import of nutrients into Vermont due to the combined inputs of P-enriched feed, dietary feed supplements, and fertilizer. Manure is then applied near the point of generation and most commonly within the boundaries of the “home farm.” Primary outputs of P from these farms include crop and animal products that are removed and utilized off-farm. The flow of nutrients onto the farm is generally out of balance with the flow of nutrients off the farm. Simply put, more P is entering the farm boundary than is exiting in the form of salable products. The greatest problems with excess P occur on farms with relatively low acreage for the number of animals. In this situation, the amount of manure generated exceeds the needs of the land.

**Phosphorus Movement and Pollution**

Phosphorus moves in two ways:

- Runoff and erosion (the major forms of movement)
- Leaching (less common)

There are two types of P that can erode or run off:

**Sediment-bound Phosphorus.** This is phosphorus bound to soil. When soil erodes, the phosphorus bound to that soil is moved into water. 80 to 90% of all P loss happens as a result of erosion. If you can greatly reduce erosion, you can significantly decrease P pollution. P is a limiting nutrient for algae just as nitrogen is the limiting nutrient for corn. (P can be a limiting nutrient for crops — although it is not as common as N limitation.) Algae cannot grow without phosphorus.

**Dissolved phosphorus.** This type of P moves freely in solutions such as water and is readily available. It is difficult to control runoff of dissolved P. The best management strategy is to make sure that it infiltrates into the ground immediately.

Sources of P for potential runoff include both the phosphorus added to the surface from manure and fertilizer as well as dissolved and sediment-bound phosphorus from the soil.
The phosphorus index is a tool developed to assess the potential for phosphorus runoff from individual fields based on soil and field characteristics and on management practices. Use of the P-index provides a way to identify fields that have a high P runoff potential and require conservation practices or limitations of manure or fertilizer P. The P index provides a way to prioritize nutrient management practices to the fields that have the highest potential P loss.

The index is based on two variables:

- Potential erosion and sediment P
- Potential for dissolved P to runoff.

This is influenced by the following factors:

**Type of soil (i.e. clay or sandy).** Some soil types are more prone to runoff or flooding than others.

**Soil phosphorus and aluminum levels.** The amount of P and Al in your soil will affect the likelihood of P loss.

**Water.** Which part of Vermont are you in? Are you at a high elevation that receives more rainfall?

**Soil erosion rate.** This uses the RUSLE2 number for the rotation you chose.

**Timing and rate of manure application.** Are you applying manure in the fall or in the spring or both?

**Method and timing of manure incorporation.** Do you minimize applied manure’s exposure to rain?

**Method, timing and rate of fertilizer P application.** Is the fertilizer broadcasted or injected at planting?

**What’s growing.** Are you growing a hay crop or corn? How well is the soil protected by crop residue?

**Buffer width.** What is the distance, in feet, of grass or other vegetated buffer between the field edge and a waterway or area of seasonal concentrated flow.

The P-index gives a relative rating for risk of P loss from a field. It is better to use the P-index to determine losses than to rely on soil P levels alone because it takes into account the above factors that affect P movement.

Each of your fields will fall into one of four categories, which are described below.

**Low** potential for P movement from site. If farming practices are maintained at the current level there is a low probability of an adverse impact to surface waters from P loss.

**Medium** potential for P movement from site. A chance for adverse impacts to surface water exists.

**High** potential for P movement from the site and for an adverse impact on surface waters to occur unless remedial action is taken. Soil and water conservation as well as P management practices are necessary to reduce the risk of P movement and water quality degradation.

**Very high** potential for P movement from the site and for an adverse impact on surface waters. Remedial action is required to reduce the risk of P movement. Soil and water conservation practices, plus a P management plan must be put in place to reduce potential for water quality degradation.

During the next session, we will discuss what these categories mean for your NMP. You will be filling out a P-index for each field on your farm, so let’s look more closely at the worksheet.
### EXERCISE II-2

#### P-Index Worksheet

Fill out a column for each of your fields.

<table>
<thead>
<tr>
<th>VT P Index – Version 5.2 12-31-2008</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field messages:</strong></td>
<td></td>
</tr>
<tr>
<td>Field Name:</td>
<td>back</td>
</tr>
<tr>
<td>Tract &amp; Field #:</td>
<td>345-11</td>
</tr>
<tr>
<td>P Index:</td>
<td>43</td>
</tr>
<tr>
<td>Interpretation:</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Pathway I: Sediment-bound P</strong></td>
<td>24</td>
</tr>
<tr>
<td><strong>Pathway II: Dissolved P in surface runoff</strong></td>
<td>19</td>
</tr>
<tr>
<td>1 Location (Vermont county)</td>
<td>NV (Addison, Chittenden, Franklin)</td>
</tr>
<tr>
<td>2 Elevation zone, feet</td>
<td>&lt; 600</td>
</tr>
<tr>
<td>3 Soil test P, ppm (Mod. Morgan's)</td>
<td>13</td>
</tr>
<tr>
<td>4 Reactive soil aluminum, ppm</td>
<td>24</td>
</tr>
<tr>
<td>5 Fall manure, lb P2O5/acre</td>
<td>40</td>
</tr>
<tr>
<td>6 Fall application method</td>
<td>Chisel</td>
</tr>
<tr>
<td>7 Fall time to incorporation</td>
<td>4-7 days</td>
</tr>
<tr>
<td>8 April manure, lb P2O5/acre</td>
<td>40</td>
</tr>
<tr>
<td>9 April application method</td>
<td>Chisel</td>
</tr>
<tr>
<td>10 April time to incorporation</td>
<td>4-7 days</td>
</tr>
<tr>
<td>11 Summer manure, lb P2O5/acre</td>
<td>0</td>
</tr>
<tr>
<td>12 Summer application method</td>
<td>None applied</td>
</tr>
<tr>
<td>13 Manure type</td>
<td>Dairy</td>
</tr>
<tr>
<td>14 Fertilizer rate, lb P2O5/acre</td>
<td>10</td>
</tr>
<tr>
<td>15 Fertilizer method/timing</td>
<td>Inj. or subsurf. banded</td>
</tr>
<tr>
<td>16 Erosion rate (RUSLE, tons/acre)</td>
<td>1.2</td>
</tr>
<tr>
<td>17 Soil type or series &amp; HydrGrp</td>
<td>Adams (A)</td>
</tr>
<tr>
<td>18 Surface cover %</td>
<td>0 - 20 %</td>
</tr>
<tr>
<td>19 Crop / Vegetation type</td>
<td>Corn &amp; other row crops</td>
</tr>
<tr>
<td>20 TOTAL distance to stream, feet</td>
<td>25</td>
</tr>
<tr>
<td>21 Vegetated buffer width, feet</td>
<td>25</td>
</tr>
<tr>
<td>22 Manure spreading setback, feet</td>
<td>0</td>
</tr>
<tr>
<td>23 Sediment trap structure or other erosion control</td>
<td>None</td>
</tr>
</tbody>
</table>

The P-Index for this field is “Medium.”

Do not fill in these boxes. They will be automatically calculated.

Enter from soil test results

The total lbs. of P in the manure applied will be calculated. Example:

- 5000 gal. manure x 8 lbs. P/1000 gal. = 40 lbs. P

Use the RUSLE2 number from the rotation you chose.

Corn and row crops: 0–20% cover
Hay: >20% cover

See the illustration on page 53 explaining “Total distance to stream” and “Vegetative buffer width.”

If you need help calculating fertilizer rates, see page 87.

Understanding Soil Nutrients / 53
Here are three different scenarios showing how the distance to stream and vegetated buffer width would be entered in the Phosphorus Index.

**Field 1: Hay**
Total distance to stream = 25 ft.
Vegetated buffer width = 25 ft.
(minimum required)
Manure spreading setback = 25 ft.
(within field)

**Field 2: Hay**
Total distance to stream = 300 ft.
Vegetated buffer width = 25 ft.
Manure spreading setback = 0 ft.

**Field 3: Corn**
Total distance to stream = 25 ft.
Vegetated buffer width = 25 ft.
(minimum required)
Manure spreading setback = 25 ft.
(within field)

**Manure spreading setback:**
Although not required under regulation, the addition of a manure spreading setback is implemented to better protect water resources.

**Total distance to stream:**
Although the stream may be directly adjacent to a field, installation of the required buffer increases total distance to stream to 25 ft.
Here is a list of items that you should have completed before you go on to the next session. Those items found in the computer workbook are listed in blue.

**SESSION I**
- Farm information worksheet
- Maps (proximity, conservation plan, nitrate leaching, topographic, environmental concerns, soils)
- Soil fact sheets
- Soil test results organized
- Soil test interpretation and planning strategy
- Soil test schedule
- RUSLE2 (with your crop rotation indicated)
- Field inventory
- Manure application schedule

**SESSION II**
- Animal waste system overview sheet
- Calculation of amount of manure produced
- Manure test for each storage
- Manure analysis worksheet
- Manure storage nitrogen calculations (one for each manure storage)
- Manure nutrient values
- P-index