Pollutants Controlled
Calculation and Documentation
for
Section 319 Watersheds
Training Manual *

Revised June 1999

Michigan Department of Environmental Quality
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* The original manual has been modified by EPA in accordance with changes made to the Region 5 load reduction model (see Exhibit 5). The Region 5 model is one option that states can use to estimate load reductions from Section 319 projects, as articulated in EPA's new reporting requirements starting with FY 2002-funded projects. June 2003 and September, 2005

John Engler, Governor
Russell J. Harding, Director

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INTRODUCTION

This document provides instruction to the watershed technician regarding calculating and documenting pollutant reduction for the Surface Water Quality Division's Nonpoint Source Program. It can also be used in other watershed projects that treat the sources of sediment and nutrient pollutants using similar systems of Best Management Practices (BMPs). The purpose is to standardize the progress reporting in order that water quality impacts and statewide achievements can be systematically represented.

It is recognized that this system has limitations, but it does provide a uniform system of estimating relative pollutant loads. The methods are simple in concept and workable within a field office. This document includes instructions and examples regarding the calculation and documentation of pollutant reductions for: 1) sediment; 2) sediment-borne phosphorus and nitrogen; 3) feedlot runoff; and 4) commercial fertilizer, pesticides and manure utilization.

Water quality impacts from wind erosion will not be estimated. The dynamics of wind erosion and resulting atmospheric deposition do not perform similar to water erosion and quantifying these relationships for water quality is currently not possible. Likewise, the impacts of BMPs on ground water quality are not well enough understood to make pollutant reduction estimates feasible.

The following people contributed to this document: Ruth Shaffer, Gary Rinkenberger and Sean Duffey, USDA-NRCS; and John Suppnick and Thad Cleary, Michigan Department of Environmental Quality, Surface Water Quality Division.

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LEARNING OBJECTIVES

At the end of this training manual, the participant will be able to:

1. Define the term “Best Management Practices” (BMPs) and give examples used to treat different kinds of erosion;
2. Define erosion and sediment delivery and explain the difference between these processes;
3. List the assumptions that are used to relate gross erosion to resulting water quality impacts;
4. Calculate sediment and sediment-borne nutrient reductions from installation of conservation practices to control gully erosion;
5. Define Lateral Recession Rate and explain how it is determined in the field;
6. Calculate sediment and sediment-borne nutrient reductions from streambank/ditchbank treatment, livestock exclusion and from roadbank treatment.
7. Define Sediment Delivery Ratio, Nutrient Enrichment, Contributing Area, and how these relate to estimation of sediment delivery from upland agricultural fields.
8. Calculate sediment and sediment-borne nutrient reductions from implementation of conservation practices to control sheet and rill erosion from riparian fields.
9. Calculate additional savings in sediment and nutrients from the establishment of riparian filter strips.
10. Accurately complete the required reporting form for Integrated Crop Management with Nonpoint Source Program quarterly reports.

SEDIMENT REDUCTION

I. Background: Erosion and Sediment Delivery

The implementation of systems of **Best Management Practices (BMPs)** reduces nonpoint source pollution. BMPs are defined as structural, vegetative, or managerial conservation practices, which reduce or prevent detachment, transport and delivery of nonpoint source pollutants to surface or ground waters. The BMPs result in less soil being transported and deposited as sediment as well as fewer nutrients being delivered to the water bodies.

The BMPs in a water quality project must be targeted to **priority fields** within the watershed. Priority fields are cropland, pastureland or hayland that contribute runoff to adjacent hydrologic systems such as lakes, streams, ditches, wetlands and flood plains. Reporting of pollutant reductions will be done for all priority fields where BMPs have been installed.

Sediment and nutrient reduction is estimated by first calculating gross erosion at a site, then calculating the amount of soil and nutrients that are transported to the surface waters. Sediment and sediment-borne nutrients originate from various types of erosion. Each of these erosion types can be estimated by accepted methods of technology to determine gross erosion. The Revised Universal Soil Loss Equation (RUSLE), the Gully Erosion Equation (GEE), and the Channel Erosion Equation will be used to calculate gross erosion. The various types of erosion and the equations used to calculate gross erosion are discussed later in this chapter.

It is important to recognize the difference between "soil loss" as measured by these erosion equations and the sediment delivery to water bodies. **Erosion** is a naturally occurring process, which is defined as the wearing away or disintegration of earth material by the physical forces of moving water and wind. **Sediment delivery** is the amount or fraction of soil that is actually delivered to a water body.

To relate gross soil erosion to water quality impacts, certain assumptions and professional judgments need to be made. Sediment delivery and the nutrient content of the sediment will be estimated using other equations and values from the scientific literature.

Finally, it is important to know how soil loss tolerance relates to water quality. Soil loss tolerance, as measured by equations such as the Revised Universal Soil Loss Equation, is a measure of the amount of soil that can be removed from a site before *soil productivity onsite* is affected. It is a soil quality term, not water quality. It is <u>not</u> a measure of the amount of soil that moves offsite. Other factors such as proximity to a water body and the size of the area contributing sediment to the edge of the field must be considered to determine the amount of sediment that actually reaches water.

The following assumptions will be made when calculating sediment and nutrient reductions:

1. The point of deposition at the edge of field will be the basis for the sediment and nutrient reduction estimates. Sediment can be deposited into a stream, lake, ditch, or a wetland or floodplain adjacent to a stream, lake or ditch. All of these water bodies are important and warrant pollutant protection. Therefore, it will be our intent to represent the sediment and nutrient reduction at the boundary where the agricultural field or site joins these hydrologic systems. The amount of sediment delivered to the edge of the field may be 100% in the case of streambank or gully erosion sites directly on or adjacent to a water body. In the case of upland erosion sites, the percent of soil delivered to the water as sediment will be

less than 100%; we will discuss how to estimate the amount delivered to a water body from upland erosion sites later in this chapter.

2. Once the system of BMPs is established, the stabilized condition is assumed to control all the erosion. Therefore the “before” condition is measured in average annual tons of sediment generated (i.e., without treatment), and the “after” condition is assumed to be negligible.

3. Phosphorus and nitrogen reductions are assumed to come from reduction in *sediment-borne* nutrients. Nutrients that are dissolved and carried by runoff waters are not included.

4. Pollutant reduction savings are reported to the nearest whole number (i.e., 8 instead of 8.23).

Student Exercise 1.

1. Define “erosion” and “sediment delivery”.

2. True or False: The soil loss tolerance is a measure of the amount of soil that is deposited in a water body.

3. The basis for calculating sediment and nutrient reduction estimates will be the point of ________________________________.

Student Exercise 1. - Answers

1. Define “erosion” and “sediment delivery”.

Erosion *is the wearing away or disintegration of earth material by the physical forces of moving wind and water.*

Sediment delivery *is the amount or fraction of soil that is actually delivered to a water body.*

2. True or False: The soil loss tolerance is a measure of the amount of soil that is deposited in a water body.

False. Soil loss tolerance is a measure of the amount of soil that can be removed from a site before soil productivity is affected onsite.

3. The basis for calculating sediment and nutrient reduction estimates will be the point of <u>*deposition at the edge of the field.*</u>

II. Gully Stabilization

The Gully Erosion Equation (GEE) will be used for calculating annual sediment and attached phosphorus and nitrogen reductions. These calculations are based on the NRCS Field Office Technical Guide, Section I-C, Gully Erosion Equation:

Sediment Reduction:

Gully Erosion Equation (GEE) =

$$\frac{\text{Top Width(ft.) + Bottom Width(ft.)/2} \times \text{Depth(ft.)} \times \text{Length(ft)} \times \text{Soil Weight (tons/ft}^3\text{)}}{\text{Number of Years}}$$

Refer to Exhibit 1 in the Appendix for dry density soil weights for different soil textures. The number of years that a gully took to form (listed in the equation's denominator) can be estimated from field records, from discussions with the landowner, or from observation and professional judgment.

The GEE can be used to estimate sediment and nutrient reduction following the installation of the following conservation practices:

1. Grade Stabilization Structure
2. Grassed Waterway
3. Critical Area Planting in areas with gullies
4. Water and Sediment Control Basin

Once the conservation practice is established, the stabilized condition will have controlled all the gully erosion. Therefore, report the average annual tons of gross erosion as sediment delivered at the edge of the field (100% delivery).

Report conservation practices separately. For example, if a grade stabilization structure and grassed waterway are installed together at one site, the GEE should be used to estimate the sediment reduction from each practice and they should be reported separately.

Nutrient Reduction:

Nutrient reduced (lb/yr) =

Sediment reduced (T/yr) x Nutrient conc. (lb/lb soil) x 2000 lb/T x correction factor

The amount of attached phosphorus and nitrogen is calculated using information collected by USDA-ARS researchers (Frere et al., 1980). The estimate starts with an overall phosphorus concentration of 0.0005 lbP/lb of soil and a nitrogen concentration 0.001 lbN/lb of soil. Then a general soil texture is determined, and a correction factor is used to better estimate nutrient-holding capacity (Exhibit 2 in Appendix). A loamy soil has a correction factor of 1.0, while clay and muck soils are greater than 1.0 and sandy soils are less than 1.0. This correction factor reflects the fact that soils with higher clay and organic matter contents have a higher capacity to hold nutrients, while sandier soils have a lower nutrient capacity.

The following example illustrates how to calculate sediment and nutrient reductions.

Example 1.

Farmer Brown installs an aluminum toewall set back 20 feet from the stream, and 480 linear feet of grassed waterway. The soil texture is a loamy sand. The gully can be divided into three reaches A, B and C. Reach A is 8 feet wide at the top, 4 feet deep, 3 feet wide at the bottom and 200 linear feet long. Reach B is 5 feet wide at the top, 2 feet deep, 2 feet wide at the bottom and 150 linear feet. Reach C is 3 feet wide at the top, 1 foot deep, 1 foot wide at the bottom and 130 linear feet. The gully was formed in three years. Calculate the sediment and nutrient reductions for each practice.

Sediment Reduction Calculations:

Grade Stabilization Structure:

$$\text{Sediment} = \frac{(8\text{ft.} + 3\text{ft})/2 \times 4\text{ft} \times 20\text{ft} \times 0.055\ \text{tons/ft}^3}{3\ \text{years}} = 8\ \text{tons/yr.}$$

Grassed Waterway:

Reach A:

$$\text{Sediment} = \frac{(8\text{ft} + 3\text{ft})/2 \times 4\text{ft} \times 200\text{ft} \times 0.055\ \text{tons/ft}^3}{3\ \text{years}} = 80.7\ \text{tons/yr.}$$

Reach B:

$$\text{Sediment} = \frac{(5\text{ft} + 2\text{ft})/2 \times 2\text{ft} \times 150\text{ft} \times 0.055\ \text{tons/ft}^3}{3\ \text{years}} = 19.3\ \text{tons/yr.}$$

Reach C:

$$\text{Sediment} = \frac{(3\text{ft} + 1\text{ft})/2 \times 1\text{ft} \times 130\text{ft} \times 0.055\ \text{tons/ft}^3}{3\ \text{years}} = 4.8\ \text{tons/yr.}$$

Total sediment reduction (grassed waterway) = A + B + C = 104.8 tons/yr.
Round to 105 tons/yr.

Nutrient Reduction Calculation:

Nutrient reduced (lb/yr) =

Sediment reduced (T/yr) x Nutrient conc. (lb/lb soil) x 2000 lb/T x correction factor

The phosphorus reduction is calculated by multiplying the phosphorus concentration by the sediment reduction and correcting for the soil texture. The same method is used to calculate the nitrogen reduction. Use a soil phosphorus concentration of 0.0005 lbP/lb soil, and a soil nitrogen concentration of 0.001 lbN/lb soil (Frere et al., 1980). According to Exhibit 2, a loamy sand is classified as a Sand and has a correction factor of 0.85:

Grade Stabilization Structure:

Reduction in P= 8 tons/yr x 0.0005 lbP/lb soil x 2000 lb/ton x 0.85
= 6.89 lb/yr
Round to 7 lb/yr

Reduction in N= 8 tons/yr x 0.001 lbN/lb soil x 2000 lb/ton x 0.85
= 13.6 lb/yr
Round to 14 lb/yr

Grassed Waterway:

Reduction in P= 104.8 tons/yr x 0.0005 lbP/lb soil x 2000 lb/ton x 0.85
= 89.3 lb/yr
Round to 89 lb/yr

Reduction in N= 104.8 tons/yr x 0.001 lbN/lb soil x 2000 lb/ton x 0.85
= 178.5 lb/yr
Round to 179 lb/yr

Student Exercise 2.

1. A geotextile chute and a critical area planting are installed on a gully that is 10 feet from a county drain. The soil texture is a silty clay loam. The original gully was 3 feet wide at the top, 3 feet deep, 2 feet wide at the bottom and 15 linear feet long. The gully was formed in three years. Calculate the sediment and nutrient reductions for each practice.

2. Explain why the soil phosphorus rate of 0.0005 lbP/lb of soil is modified with a correction factor for soil texture.

Student Exercise 2. - Answers

1. A geotextile chute and a critical area planting are installed on a gully that is 10 feet from a county drain. The soil texture is a silty clay loam. The original gully was 3 feet wide at the top, 3 feet deep, 2 feet wide at the bottom and 15 linear feet long. The gully was formed in three years. Calculate the sediment and nutrient reductions for each practice.

Geotextile Chute Sediment and Nutrient Reduction:

$$\text{Sediment reduced} = \frac{(3ft + 2ft)/2 \;\; x \;\; 3ft \;\; x \;\; 10ft \;\; x \;\; 0.04 \; tons/ft^3}{3 \; yrs} = 1 \; ton/yr$$

Reduction in P = 1 ton/yr x 0.0005 lbP/lb soil x 2000 lb/ton x 1.0
= 1 lb/yr

Reduction in N = 1 ton/yr x 0.001 lbN/lb soil x 2000 lb/ton x 1.0
= 2 lbs/yr

Critical Area Planting Sediment and Nutrient Reduction:

$$\text{Sediment reduced} = \frac{(3ft + 2ft)/2 \;\; x \;\; 3ft \;\; x \;\; 15ft \;\; x \;\; 0.04 \; tons/ft^3}{3 \; yrs} = 1.5 \; tons/yr$$

Round to 2 tons/yr

Reduction in P = 1.5 tons/yr x 0.0005 lbP/lb soil x 2000 lb/ton x 1.0
= 1.5 lbs/yr
Round to 2 lbs/yr

Reduction in N = 1.5 tons/yr x 0.001 lbN/lb soil x 2000 lb/ton x 1.0
= 3 lbs/yr

2. Explain why the soil phosphorus rate of 0.0005 lbP/lb of soil is modified with a correction factor for soil texture.

The correction factor reflects the fact that soils with higher clay and organic matter contents have a higher capacity to hold phosphorus, while sandier soils have a lower phosphorus-holding capacity.

III. Streambank/Ditchbank and Roadbank Stabilization; Livestock Access

Sediment Reduction

The **Channel Erosion Equation (CEE)** is used to calculate the annual average sediment reduction using the direct volume method:

CEE = Length (ft.) x Height (ft.) x LRR (ft./yr.) x Soil weight (ton/ft^3)

where LRR is Lateral Recession Rate. The dry density soil weight is given in Exhibit 1 (in the Appendix). Assume 100% delivery of the eroded soil to the stream.

The Channel Erosion Equation will be used to calculate annual sediment and attached phosphorus and nitrogen reductions following the installation of conservation practices such as:

1. Animal Trails and Walkways
2. Stream Channel Stabilization
3. Streambank Protection

This calculation contrasts the original bank slope with the existing repose. The rate at which bank deterioration has taken place is an important variable to determine. The Lateral Recession Rate (LRR) is the thickness of soil eroded from a bank surface (perpendicular to the face) in an average year. Recession rates are measured in feet per year. However, a channel bank may not erode for a period of years when no major runoff events occur. When a major storm does occur, the bank may be cut back tens of feet for a short distance. It is necessary to assign recession rates to banks with such a process in mind. If ten feet of bank has been eroded, the ten feet must be adjusted to an average annual lateral recession rate rather than a recession rate for one storm.

Selecting the lateral recession rate is the most critical step in estimating channel erosion using the direct volume method. A historical perspective is required in many instances. Old photographs, old survey records, and any information that tells you what a bank looked like at known times in the past are very useful. In most instances, such information is lacking and field observations and judgment are needed to estimate recession rates.

Exposed bridge piers, suspended outfalls or culverts, suspended fence lines, and exposed tree roots are all good indicators of lateral recession rate. Discoloration of bridge piers may show the original channel bottom elevation. Given the date of bridge installation, a recession rate can be calculated for that reach of stream. Culverts are generally installed flush with a bank surface. The amount of culvert exposed and age of the culvert will allow you to calculate a lateral recession rate.

Exposed tree roots are probably the most common field evidence of later recession. Consult references to familiarize yourself with tree height and appearance as related to tree age. Roots will not grow towards a well drained, exposed, eroding channel bank. The amount of root exposed should be increased by at least a factor of 2X to account for soil that was in the bank and that the root was growing in. By multiplying the length of root exposed by at least two and dividing by the age of the tree, an estimated lateral recession rate can be obtained.

As can be seen in the discussion above, there are few instances where you will be able to measure lateral recession rates in the field. Experience and professional judgment are generally required to estimate recession rates for channel erosion. Because of this the following information has been compiled for your use which relates recession rates. Figure 1 relates lateral recession rates to narrative descriptions of streambank or ditchbank erosion. Figure 2 gives lateral recession rates for varying degrees of erosion at roadbanks or road stream crossings.

Figure 1. Lateral Recession Rates of Stream/Ditchbanks as Estimated by Field Observations.

Lateral Recession Rate (ft./yr.)	Category	Description
0.01 - 0.05	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang. No exposed tree roots.
0.06 - 0.2	Moderate	Bank is predominantly bare with some rills and vegetative overhang.
0.3 - 0.5	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross-section becomes more U-shaped as opposed to V-shaped.
0.5+	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross-section is U-shaped and streamcourse or gully may be meandering.

Source: Steffen, L.J., 1982.

Figure 2. Lateral Recession Rates of Roadbanks as Estimated by Field Observations.

Lateral Recession Rate (ft./yr.)	Category	Description
0.01 - 0.05	Slight	Some bare roadbank but active erosion not readily apparent. Some rills but no vegetative overhang. Ditch bottom is grass or noneroding.
0.06 - 0.15	Moderate	Roadbank is bare with obvious rills and some vegetative overhang. Minor erosion or sedimentation in ditch bottom.
0.16 - 0.3	Severe	Roadbank is bare with rills approaching one foot in depth. Some gullies and overhanging vegetation. Active erosion or sedimentation in ditch bottom. Some fenceposts, tree roots, or culverts eroding out.
0.3+	Very Severe	Roadbank is bare with gullies, washouts, and slips. Severe vegetative overhang; fenceposts, powerlines, trees and culverts eroded out. Active erosion or sedimentation in ditch bottoms..

Source: Steffen, L.J., 1982.

To estimate channel erosion, first determine the slope height and length of the eroding banks. By field observation, match the appearance of the eroding areas with the narratives shown to identify what category the erosion is in. Once you have characterized the erosion, note whether all the symptoms discussed in the Description are present or if only a few symptoms occur. If only a few of the symptoms in the Description characterizing the eroding area are evident, you may want to use the low end of the range of recession rates shown for the Category.

When you are actually observing sample areas in the field, you will probably note that eroding areas are mixed in severity and in frequency of occurrence. As an example, a 500- foot long streambank may generally be in the moderate erosion category (0.06 feet/year). A few 50-foot reaches within that 500- foot reach may be eroding very severely (0.5+ feet/year). Since we are interested in the average tons of erosion per year you could increase the lateral recession rate to 0.1 feet/year and use that for the entire 500- foot reach. This simplifies data collection and decreases time in the field, without jeopardizing the level of accuracy of your calculation.

Student Exercise 3.

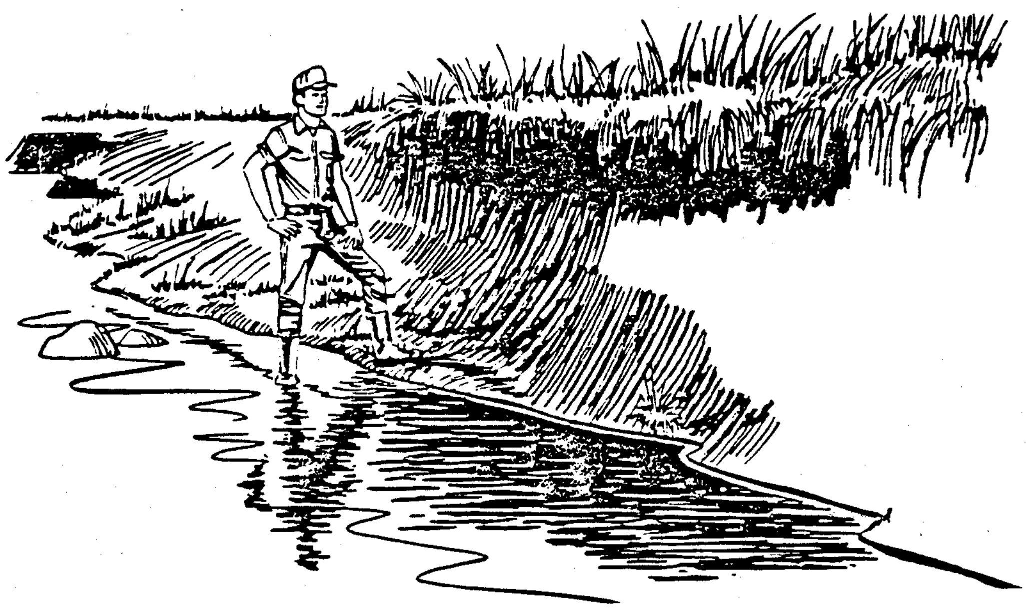
1. Define Lateral Recession Rate____

____

____

2. Name four tools or techniques that can be used to estimate Lateral Recession Rate.

3. The following illustration is of a landowner standing next to a streambank. The landowner complains of losing land, and that his fence corner had to be set back farther from the edge of the stream. Given the illustration and the Descriptions in Figure 1., choose the Categories and range of Lateral Recession Rates that fit the example.



Student Exercise 3. - Answers

1. Define Lateral Recession Rate (LRR)

The ***Lateral Recession Rate (LRR)*** *is the thickness of soil eroded from a bank surface (perpendicular to the face) in an average year. It is given in feet per year.*

2. Name four tools or techniques that can be used to estimate Lateral Recession Rate.

Old photograph, old survey records, observations of exposed bridge piers, suspended outfalls or culverts, suspended fence lines, exposed tree roots, and the Descriptions given in Figures 1 and 2 are all good indicators.

3. The following illustration is of a landowner standing next to a streambank. The landowner complains of losing land, and that his fence corner had to be set back farther from the edge of the stream. Given the illustration and the Descriptions in Figure 1, choose the Categories and range of Lateral Recession Rates that fit the example.

Based on the Descriptions in Figure 1, the landowner categorized this site as Severe (0.3 to 0.5 ft/yr) or Very Severe (0.5+ ft/yr). There is vegetative overhang at the top of the bank, and changes in cultural features (fence corner needing to be moved).

<u>Nutrient Reduction:</u>

Nutrient reduced (lb/yr) =

Sediment reduced (T/yr) x Nutrient conc. (lb/lb soil) x 2000 lb/T x correction factor

To calculate phosphorus and nitrogen reductions, use the same method as used to calculate nutrient reductions from gully erosion treatment. For example, the phosphorus reduction is based on a concentration of 0.0005 lbP/lb of soil, and is calculated by multiplying the reduction in sediment by the phosphorus concentration and correcting for soil texture. Assume 0.001 lbN/lb of soil as well.

Example 2.

Farmer Brown installed 1,000 feet of barbed wire fence to prevent cattle from entering the stream from the west side of the stream. The trodden banks were 4 feet high. The banks were bare and the cross-section was a flat U-shape. Trees were uprooted and fallen. Washouts were evident. The cattle no longer use the east bank of the stream for pasture. Three hundred feet of the east bank and one thousand feet of the west bank were shaped and stabilized with grass vegetation. Prior to these improvements, the cattle had complete access. The soil is a silt clay. Calculate the reduction in sediment and nutrients for this practice.

The technician categorized the annual lateral recession rate as Severe (0.4 ft./yr.). According to Exhibit 2., a silt clay is categorized as a Clay with a 1.15 correction factor.

East Bank and West Bank Sediment Reduction:

Sediment Reduction = Length x Height x LRR x soil weight

West Bank Sediment = 1000ft x 4ft x 0.4ft/yr x 0.04 tons/ft^3
= 64 tons/yr

East Bank Sediment = 300ft x 4ft x 0.4ft/yr x 0.04 tons/ft3
= 19.2 tons/yr

Total Sediment Reduction = 64 + 19.2 = 83.2 tons/yr
Round to 83 tons/yr

Phosphorus and Nitrogen Reduction:

Reduction in P = 83.2 tons/yr x 0.0005 lbP/lb x 2000 lb/ton x 1.15
= 95.68 lb/yr
Round to 96 lb/yr

Reduction in N = 83.2 tons/yr x 0.001 lbN/lb x 2000 lb/ton x 1.15
= 191.36 lb/yr
Round to 191 lb/yr

Student Exercise 4.

1. In the example give in Student Exercise 3., the landowner chose to armor the toe of the streambank with riprap, pull the slope of the bank back to a 2:1 ratio and revegetate the streambank with shrubs and grass. The original bank height was 6 feet, and the length is 150 feet. Based on field observations and information in Figure 1., the technician estimated that the erosion was severe (0.05 ft/yr). The soil texture is a loamy sand.

Calculate the reduction in sediment and nutrients from streambank stabilization.

2. The road commission wants to stabilize a roadbank that is washing out a road into a stream. The roadbank is 4 feet high, and the washout covers a length of 20 feet. The technician estimates from Figure 2 that the erosion rate is severe (0.2 ft/yr). The soil texture is a loamy sand.

Calculate the reduction in sediment and nutrients from roadbank stabilization.

Student Exercise 4. - Answer

1. In the example give in Student Exercise 3., the landowner chose to armor the toe of the streambank with riprap, pull the slope of the bank back to a 2:1 ratio and revegetate the streambank with shrubs and grass. The original bank height was 6 feet, and the length is 150 feet. Based on field observations and information in Figure 1., the technician estimated that the erosion was severe (0.05 ft/yr). The soil texture is a loamy sand.

Calculate the reduction in sediment and nutrients from streambank stabilization.

Sediment reduced = 6ft x 150ft x 0.05 ft/yr x 0.055 tons/ft^3
= 2.475 tons/yr
Round to 2 tons/yr

Reduction in P = 2.475 tons/yr x 0.0005 lbP/lb x 2000 lb/ton x 0.85
= 2.1 lb/yr
Round to 2 lb/yr

Reduction in N = 2.475 tons/yr x 0.001 lbN/lb x 2000 lb/ton x 0.85
= 4.2 lb/yr
Round to 4 lb/yr

2. The road commission wants to stabilize a roadbank that is washing out a road into a stream. The roadbank is 4 feet high, and the washout covers a length of 20 feet. The technician estimates from Figure 2 that the erosion rate is severe (0.2 ft/yr). The soil texture is a loamy sand.

Calculate the reduction in sediment and nutrients from roadbank stabilization.

Sediment reduced = 4ft x 20ft x 0.02 ft/yr x 0.055 tons/ft^3
= tons/yr
Round to 2 tons/yr

Reduction in P = 2.475 tons/yr x 0.0005 lbP/lb x 2000 lb/ton x 0.85
= 2.1 lb/yr
Round to 2 lb/yr

Reduction in N = 2.475 tons/yr x 0.001 lbN/lb x 2000 lb/ton x 0.85
= 4.2 lb/yr
Round to 4 lb/yr

IV. Agricultural Fields

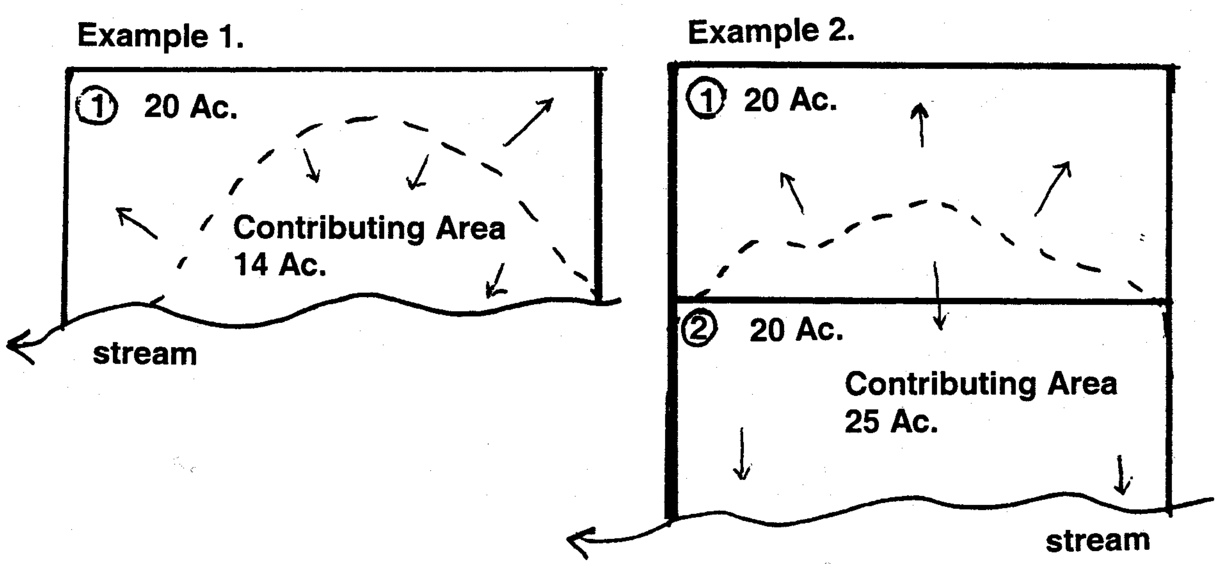
This method will be used to calculate average annual sediment and attached phosphorus and nitrogen reductions following establishment of conservation practices such as these:

Prescribed Grazing
Residue Management, Mulch Till
Conservation Crop Rotation
Conservation Cover
Cover and Green Manure
Critical Area Planting
Stripcropping, Contour
Stripcropping, Field

The methods used to estimate the amount of sediment and nutrients that reach a waterbody from upland areas differs significantly from the methods described earlier. We will first review some of the concepts used to determine sediment delivery and the resulting amount of sediment-borne nutrients.

One of the first steps in determining how much eroded soil reaches a water body is to determine the **contributing area.** The contributing area is the portion of the priority field, which contributes eroded soil to the water body. The contributing area will usually differ in size from the priority field and is defined by the runoff flowpath and by topography. The flowpath is the direction runoff flows, either towards or away from the edge of field adjacent to the hydrologic system (stream, lake, ditch, floodplain, wetland, etc.) that is being protected. The contributing area may be larger than the priority field or smaller than it. See the diagrams below for examples.

Figure 3. Contributing Area Examples



In both examples, the priority field is managed with appropriate Best Management Practices, but only the contributing area is used to calculate sediment and nutrient reductions.

The next step in determining the amount of sediment is to estimate the fraction of eroded soil that will be deposited at the edge of the priority field. This is referred as the **sediment delivery ratio**. The contributing area acts as a subwatershed, with runoff water carrying sediment towards the edge of field. As the size of the contributing area increases, the flowpath increases and the amount of soil that actually reached the field edge decreases, as there is an increased chance of soil dropping out of suspension and being deposited in the field. Figure 4 gives the relationship between the size of the contributing drainage area and the sediment delivery ratio. The relationship between the amount of soil transported and deposited as sediment versus the size of the contributing area is represented by a curve. Note that as the contributing area increases to ten acres, the delivery ratio sharply drops to 0.7 (70% of the original eroded soil). If the contributing area increases to 160 acres, the sediment delivery ratio decreases to 0.5, (i.e., only 50% of the originally eroded soil may reach the edge of the field.).

As soil is carried by overland flow, heavier particles like sand drop out of suspension. Finer particles such as silt and clay particles are carried farther, so that when soil actually reaches a water body and is deposited as sediment, the texture is very different from the original soil from which it was eroded. As we discussed earlier, silt and clay soils have a higher nutrient-holding capacity. This increase in sediment-borne nutrients during sediment delivery is called **nutrient enrichment**. In general, as the contributing area increases, the sediment delivery decreases but the sediment-borne nutrient content in the resulting sediment increases. In this case, therefore, values for nutrient content of soil derived from Frere et al. (1980) (0.0005 lbP/lb soil and 0.001 lbN/lb soil) cannot be used.

Researchers from the USDA-ARS developed algorithms for use in models such as AgNPS and CREAMS, which adjust nutrient content of the sediment as the size of the contributing area increases and the sediment delivery decreases. These equations were based on field and laboratory studies, and are expressed as differential equations, not linear functions. Therefore, the amount of sediment-borne nutrients reduced as sediment delivery is reduced has been put in a table for the technician to use. This look-up table is given in Figure 5.

Figure 4. Sediment Delivery Ratios Based on Contributing Drainage Area.

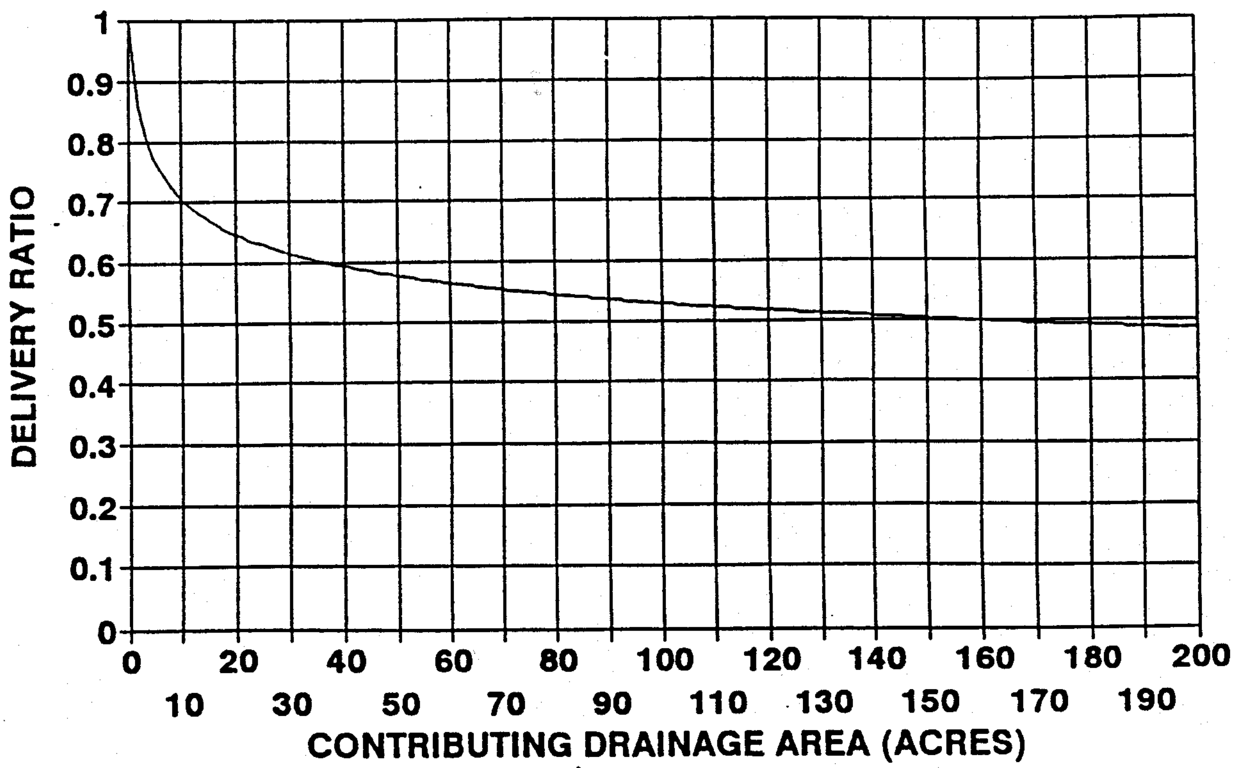


Figure 5. Phosphorus and Nitrogen Content of Sediment Delivered by Sheet and Rill Erosion. (Derived from AGNPS equations in Young <u>et</u> <u>al</u>, 1987).

Sediment Delivery T/AC/YR	Phosphorus (lbs/ac/yr)				Nitrogen (lbs/ac/yr)			
	Clay	Silt	Sand	Peat	Clay	Silt	Sand	Peat
0.01	0.05	0.04	0.03	0.06	0.09	0.08	0.07	0.12
0.02	0.08	0.07	0.06	0.10	0.16	0.14	0.12	0.21
0.03	0.11	0.10	0.08	0.15	0.22	0.19	0.16	0.29
0.04	0.14	0.12	0.10	0.18	0.28	0.24	0.21	0.37
0.05	0.17	0.15	0.12	0.22	0.33	0.29	0.25	0.44
0.06	0.19	0.17	0.14	0.25	0.39	0.34	0.29	0.51
0.07	0.22	0.19	0.16	0.29	0.44	0.38	0.32	0.57
0.08	0.24	0.21	0.18	0.32	0.49	0.42	0.36	0.64
0.09	0.27	0.23	0.20	0.35	0.54	0.47	0.40	0.70
0.1	0.29	0.25	0.22	0.38	0.58	0.51	0.43	0.76
0.2	0.51	0.44	0.38	0.66	1.01	0.88	0.75	1.32
0.3	0.70	0.61	0.52	0.92	1.40	1.22	1.04	1.83
0.4	0.88	0.77	0.65	1.15	1.77	1.54	1.31	2.30
0.5	1.06	0.92	0.78	1.38	2.11	1.84	1.56	2.75
0.6	1.22	1.06	0.90	1.59	2.44	2.12	1.81	3.19
0.7	1.38	1.20	1.02	1.80	2.76	2.40	2.04	3.61
0.8	1.54	1.34	1.14	2.01	3.08	2.67	2.27	4.01
0.9	1.69	1.47	1.25	2.20	3.38	2.94	2.50	4.41
1	1.84	1.60	1.36	2.40	3.68	3.20	2.72	4.80
2	3.20	2.78	2.37	4.18	6.40	5.57	4.73	8.35
3	4.43	3.85	3.27	5.78	8.86	7.70	6.55	11.55
4	5.57	4.85	4.12	7.27	11.15	9.69	8.24	14.54
5	6.66	5.79	4.92	8.69	13.33	11.59	9.85	17.38
6	7.71	6.70	5.70	10.06	15.42	13.41	11.40	20.11
7	8.72	7.58	6.45	11.38	17.44	15.17	12.89	22.75
8	9.70	8.44	7.17	12.66	19.41	16.88	14.35	25.32
9	10.7	9.27	7.88	13.91	21.33	18.55	15.76	27.82
10	11.6	10.09	8.57	15.13	23.20	20.18	17.15	30.26
12	13.4	11.67	9.92	17.51	26.85	23.34	19.84	35.02
13	14.3	12.4	10.6	18.7	28.6	24.9	21.2	37.33
14	15.2	13.2	11.2	19.8	30.4	26.4	22.4	39.61
15	16.0	14.0	11.9	20.9	32.1	27.9	23.7	41.86
16	16.9	14.7	12.5	22.0	33.8	29.4	25.0	44.08
17	17.7	15.4	13.1	23.1	35.5	30.8	26.2	46.27
18	18.6	16.1	13.7	24.2	37.1	32.3	27.4	48.43
19	19.4	16.9	14.3	25.3	38.8	33.7	28.7	50.57
20	20.2	17.6	14.9	26.3	40.4	35.1	29.9	52.69
21	21.0	18.3	15.5	27.4	42.0	36.5	31.0	54.79
22	21.8	19.0	16.1	28.4	43.6	37.9	32.2	56.87
23	22.6	19.6	16.7	29.5	45.2	39.3	33.4	58.93
24	23.4	20.3	17.3	30.5	46.7	40.6	34.5	60.97
25	24.1	21.0	17.8	31.5	48.3	42.0	35.7	62.99
26	24.9	21.7	18.4	32.5	49.8	43.3	36.8	65.00
27	25.7	22.3	19.0	33.5	51.4	44.7	38.0	66.99
28	26.4	23.0	19.5	34.5	52.9	46.0	39.1	68.97
29	27.2	23.6	20.1	35.5	54.4	47.3	40.2	70.93
30	27.9	24.3	20.7	36.4	55.9	48.6	41.3	72.88

Student Exercise 5.

1. Define the following terms:

   contributing area

   sediment delivery ratio

   nutrient enrichment

2. Circle the correct choices:

   "As the size of the contributing area increases, the sediment delivery ratio increases/decreases, and the sediment-borne nutrient content of the resulting sediment increases/decreases".

3. Why can't someone use the methods derived from Frere et al. (1980) to determine sediment-borne nutrient reduction for upland conservation practices?

Student Exercise 5. - Answers

1. Define the following terms:

   contributing area: *the portion of the priority field which contributes eroded soil to the water body.*

   sediment delivery ratio: *The fraction of eroded soil that will be deposited at the edge of the priority field.*

   nutrient enrichment: *The increase in sediment-borne nutrients during sediment delivery.*

2. Circle the correct choices:

   "As the size of the contributing area increases, the sediment delivery ratio increases/***decreases***, and the sediment-borne nutrient content of the resulting sediment ***increases***/decreases".

3. Why can't someone use the methods derived from Frere et al. (1980) to determine sediment-borne nutrient reduction for upland conservation practices?

   As soil moves across a land surface and sediment delivery decreases, nutrient enrichment takes place, and the values for nutrient content of soil derived from Frere et al. (1980) (0.0005 lbP/lb soil and 0.001 pbN/lb soil) cannot be used.

Sediment Reduction:

Sediment reduced (T/yr) = (B-A) x DR x CA

where **B** = sheet and rill erosion before treatment (T/ac/yr)
A = sheet and rill erosion after treatment (T/ac/yr)
DR = delivery ratio (a unitless fraction)
CA = contributing area (acres)

There are four steps to calculating the sediment reductions from upland conservation practices.

Step 1:
Calculate the priority field's soil being protected from sheet and rill erosion in tons per acre per year. Section I of the Field Office Technical Guide instructs the technician on how to calculate water erosion using the Revised Universal Soil Loss Equation (RUSLE) for the priority field(s). These computations can be reported as "Before" soil loss ("B"), the erosion in tons per acre per year before the conservation practice(s); and the "After" soil loss ("A"), the erosion in tons per acre per year after the conservation practice(s). The differences between "B" and "A" is the reduction in soil loss in tons per acre per year as a result of installing conservation practices.

Step 2:
Using professional judgement, determine the contributing area (CA) in acres.

Step 3:
Using Figure 4, estimate the delivery ratio from the size of the contributing area. For example, a 14- acre contributing area would have a delivery ratio of 0.68.

Step 4:
Calculate sediment reduced using the equation, **(B-A) x DR x CA**

Nutrient Reduction:

Step 1:
Using Exhibit 2, classify the predominant soil texture from the soil texture triangle illustration. Exhibit 2 groups the various mineral soil classification textures into three families: clay, silt and sand. For example, a loamy clay would be classified as a Clay.

Step 2:
Calculate the sediment-borne phosphorus and nitrogen using Figure 5. To utilize this graph properly, sediment delivery reductions are calculated per acre and then the corresponding nutrient reduction is multiplied by the contributing area. First the "Before" soil loss (B) and the "After" soil loss (A) are individually multiplied by the delivery ratio to calculate the tons of sediment delivered per acre per year. Then using Figure 5, the pounds per acre of nutrients are determined. Next the pounds per acre of nutrients are multiplied by the contributing area for the "B" situation and the "A" situation. Finally, the difference between the product of "B" and "A" is the reduction in nutrient.

Example:
A farmer applied no-till to a 40- acre field directly adjacent to a stream. The soil is a clay loam, the "Before" soil loss is 10 t/ac/yr., and the "After" soil loss is 1 t/ac/yr. The technician determines that the size of the contributing area is 25 acres. Calculate the sediment and sediment-borne phosphorus and nitrogen reduced from upland treatment of sheet and rill erosion.

Sediment Reduction:

Steps 1 and 2 are provided to the reader. B = 10 t/ac/yr. and A = 1 t/ac/yr.; and the contributing area (CA) = 25 acres. Using Figure 4, a CA of 25 acres gives a delivery ratio (DR) of approximately 0.63

Reduction in Sediment Delivery = (B-A) x DR x CA
= (10 - 1) x 0.63 x 25
= 141.75 t/yr. Round to 142 t/yr.

Phosphorus Reduction:

a. "Before" sediment delivery (t/ac/yr) = DR x B
= 0.63 x 10
= 6.3 t/ac/yr. Round to 6 t/ac/yr

Using Exhibit 2, the clay loam is classified as a Clay.

b. From Figure 5, a sediment delivery of 6 t/ac/yr. has 7.71 lb/ac/yr. Attached phosphorus.

c. Total "Before" phosphorus = attached P (from Figure 5) x CA
= 7.71 lb/ac/yr x 25 ac.
= 192.75 lbs/yr

d. "After" sediment delivery (t/ac/yr) = DR x A
= 0.63 x 1.0 t/ac/yr
= 0.63 t/ac/yr. Round to 0.6 t/ac/yr

e. From Figure 5, 0.6 t/ac/yr sediment delivery has 1.22lb/ac attached phosphorus

f. Total "After" phosphorus = attached P (from Figure 5) x CA.
= 1.22 lb/ac/yr x 25 ac.
= 30.5 lb/yr

g. The reduction in phosphorus = 192.75 - 30.5 = 162.25 lb/yr Round to 162 lb P/yr

Nitrogen Reduction:

a. "Before" sediment delivery (t/ac/yr) = DR x B
= 0.63 x 10
= 6.3 t/ac/yr. Round to 6 t/ac/yr

Using Exhibit 2, the clay loam is classified as a Clay.

b. From Figure 5, a sediment delivery of 6 t/ac/yr has 15.42 lb/ac/yr attached nitrogen.
c. Total "Before" nitrogen = attached N (from Figure 5) x CA
= 15.42 lb/ac/yr25 ac.
= 385.5 lbs./yr

d. "After" sediment delivery (t/ac/yr) = DR x A
= 0.63 x 1.0 t/ac/yr
= 0.63 t/ac/yr. Round to 0.6 t/ac/yr

e. From Figure 5, 0.6 t/ac/yr sediment delivery has 2.44lb/ac/yr attached nitrogen.

f. Total "After" nitrogen = attached N (from Figure 5) x CA.
= 2.44 lb/ac/yr x 25 ac.
= 61 lb/yr

g. The reduction in nitrogen = 385.5 - 61 = 324.5 lb/yr Round to 325 lb N/yr.

Student Exercise 6.

A landowner begins using mulch till on an 80- acre cornfield. The erosion rate before residue management was 15 t/ac/yr, and the erosion rate after mulch till was 1.0 t/ac/yr. The soil type is a silty clay loam. Using field observations, the technician determines that the contributing area is only 30 acres. Calculate the sediment and phosphorus reduction from conversion to mulch till.

Student Exercise 6. - Answers

A landowner begins using mulch till on an 80- acre cornfield. The erosion rate before residue management was 15 t/ac/yr, and the erosion rate after mulch till was 1.0 t/ac/yr. The soil type is a silty clay loam. Using field observations, the technician determines that the contributing area is only 30 acres. Calculate the sediment and phosphorus reduction from conversion to mulch till.

<u>Sediment Reduction:</u>

Steps 1 and 2 are provided to the reader: B = 15 t/ac/yr, A = 1 t/ac/yr, and CA = 30 acres. Using Figure 4, a CA of 30 acres gives a delivery ratio (DR) of approximately 0.62

Reduction in Sediment Delivery = (B-A) x DR x CA
= (15 - 1) x 0.62 x 30
= 260.4 t/yr. Round to 260 t/yr.

Using Exhibit 2, the silty clay loam is classified as a Silt.

<u>Phosphorus Reduction:</u>

a. *"Before" sediment delivery (t/ac/yr) = DR x B*
= 0.62 x 15 t/ac/yr
= 9.3 t/ac/yr. Round to 9 t/ac/yr

b. *From Figure 5, a sediment delivery of 9 t/ac/yr has 9.27 lb/ac/yr attached phosphorus.*

c. *Total "Before" phosphorus = attached P (from Figure 5) x CA*
= 9.27 lb/ac/yr x 30 ac.
= 278.1 lbs/yr

d. *"After" sediment delivery (t/ac/yr) = DR x A*
= 0.62 x 1.0 t/ac/yr
= 0.62 t/ac/yr. Round to 0.6 t/ac/yr

e. *From Figure 5, 0.6 t/ac/yr sediment delivery has 1.06 lb/ac/yr attached phosphorus*

f. *Total "After" phosphorus = attached P (from Figure 5) x CA.*
= 1.06 lb/ac/yr x 30 ac.
= 31.8 lb/yr

g. *The reduction in phosphorus = 278.1 - 31.8 = 246.3 lb/yr Round to 246 lb P/yr*

V. <u>Filter Strips</u>

Many watershed projects have filter strip programs. Filter strips further reduce the sediment and nutrient loads delivered to the surface water from upland sources. **The relative gross effectiveness of filter strips for sediment reduction is 65%; for phosphorus is 75%; and for nitrogen is 70%** (Pennsylvania State University, 1992).

Sediment Reduction

To calculate the added reduction of sediment, the "after" soil loss (A) is adjusted to reflect the added 65% reduction. For example, if A without a filter strip is 1 ton/ac/yr, inclusion of a filter strip would reduce sediment delivery to 0.35 ton/ac/yr (0.35 x 1). In other words, if 65% sediment reduction takes place, then 35% is left, which is expressed as a fraction (0.35). The resulting reduction in sediment [(B-A) x DR x CA] is the combined sediment reduction from both the filter strip and upland treatment.

Example:

Farmer Brown adopted no-till and reduced sediment delivery by 86 t/yr, phosphorus by 103 lb. and nitrogen by 205 lb. B = 10 t/ac/yr., and A = 1 t/ac/yr. Soil type is clay loam. CA = 14 acres. If Farmer Brown installs filter strips along Clear Creek along with the no-till, what would be the reduction in sediment and nutrients?

Sediment Reduction

= [tons Before – (fraction delivered to stream x tons After)] x DR x CA

= (10 - (0.35 x 1)) x 0.68 x 14

= 91.8 t/yr. Round to 92 t/yr

The 92 t/yr is the reduction in sediment load from the filter strip and no-till combined. To calculate the reduction in sediment from the filter strip alone:

92t/yr – 86t/yr = 6 t/yr.

Nutrient Reduction

To calculate the additional reduction in nutrients (phosphorus and nitrogen), the "After" soil loss (A) is adjusted to reflect the additional reduction of 75% for phosphorus and of 70% for nitrogen. For example, the "after" soil loss for phosphorus for the combined filter strip and upland treatment would be 0.25 multiplied by the original (upland treatment only) "after" soil loss. The "after" soil loss for nitrogen from both a filter strip and upland treatment would be 0.30 multiplied by the original "after" soil loss. Calculation of the "Before" soil loss (B) is the same as for other upland erosion treatments. The "After" soil loss (A) is adjusted as shown in the example below. The difference between the product of "B" and "A" is the combined reduction in nutrient from the filter strip and upland treatment.

<u>Phosphorus Reduction</u>:

a. "Before" soil loss:

0.68 x 10 t/ac/yr. = 6.8 t/ac/yr; Round to 7 t/ac/yr

Using Exhibit 2, the clay loam is classified as a Clay.

b. From Figure 5: 7 t/ac/yr delivers 8.72 lb/ac/yr attached P

c. “Before” phosphorus is 8.72 lb/ac/yr x 14 ac. = 122 lbs./yr

d. “After” soil loss:
0.68 x (0.25 x 1t/ac/yr) = 0.17 t/ac/yr; Round to 0.2 t/ac/yr

e. From Figure 5: 0.2 t/ac/yr sediment delivers 0.5 lb/ac/yr attached P

f. “After” phosphorus is: 0.5 lb/ac/yr x 14 ac. = 2.8 lbs./yr; Round to 3 lbs./yr

g,. The difference between the “Before” and “After” is the reduction in phosphorus from both the filter strip and no-till, or: 122lb/yr - 3 lb/yr = 119 lbs. P/yr

The reduction in the phosphorus load by the filter strip alone:
119lbs/yr - 103 lbs/yr = 16 lbs/yr

Nitrogen Reduction:

a. “Before” soil loss:
0.68 x 10 t/ac/yr = 6.8 t/ac/yr; Round to 7 t/ac/yr

Using Exhibit 2, the clay loam is classified as a Clay.

b. From Figure 5: 7 t/ac/yr sediment delivers 17.44 lb/ac/yr nitrogen

c. “Before” nitrogen is: 17.44 lb/ac/yr x 14 ac. = 244 lbs./yr

d. “After” soil loss:
0.68 x (0.30 x 1 t/ac/yr) = 0.2 t/ac/yr

e. From Figure 5: 0.2 t/ac/yr sediment delivers 1.01 lb/ac/yr nitrogen

f. “After” nitrogen is: 1.01 lb/ac/yr x 14 ac. = 14 lbs./yr

g. The difference between the “Before” and “After” is the reduction in nitrogen from both the filter strip and no-till, or:
244 lb/yr. - 14 lb/yr = 230 lbs./yr.

The addition of the filter strip to the no-till reduces the nitrogen load by:
230lb/yr - 205 lb/yr = 25 lbs./yr.

Student Exercise 7.

The landowner from Student Exercise 6 installs a filter strip at the edge of the 80- acre cornfield along a county drain and continues to apply residue management in the cornfield. The erosion rate was 15 t/ac/yr, and the erosion rate after establishment of the filter strip and residue management was 1.0 t/ac/yr. The soil type is a silty clay loam. Using field observations, the technician determines that the contributing area is only 30 acres. Calculate the sediment and phosphorus reduction from the combined filter strip and upland treatment. What amount of sediment and phosphorus is due to the filter strip alone?

Student Exercise 7. - Answers

The landowner from Student Exercise 6 installs a filter strip at the edge of the 80- acre cornfield along a county drain and continues to apply residue management in the cornfield. The erosion rate was 15 t/ac/yr, and the erosion rate after establishment of the filter strip and residue management was 1.0 t/ac/yr. The soil type is a silty clay loam. Using field observations, the technician determines that the contributing area is only 30 acres. Calculate the sediment and phosphorus reduction from the combined filter strip and upland treatment. What amount of sediment and phosphorus is due to the filter strip alone?

<u>Sediment Reduction (residue management plus filter strip):</u>

Steps 1 and 2 are provided to the reader: B = 15 t/ac/yr, A = 1 t/ac/yr, and CA = 30 acres. Using Figure 4, a CA of 30 acres gives a delivery ratio (DR) of approximately 0.62. The reductions of sediment from residue management is 260 t/yr., and 246 lb/yr. Phosphorus (answer to Student Exercise 6).

Sediment reduced = (15 - (0.35 x 1)) x 0.62 x 30
= 272.49 t/yr. Round to 272.

The amount of sediment reduced from the filter strip alone is 272 t/yr – 260 t/yr = 12 t/yr.

<u>Phosphorus Reduction (residue management plus filter strip):</u>

a. "Before" soil loss:
0.62 x 15 t/ac/yr. = 9.3 t/ac/yr; Round to 9 t/ac/yr

Using Exhibit 2, the clay loam is classified as a Clay.

b. From Figure 5: 9 t/ac/yr delivers 10.7 lb/ac/yr attached P

c. "Before" phosphorus is 10.7 lb/ac/yr x 30 ac. = 321 lbs./yr.

d. "After" soil loss:
0.62 x (0.25 x 1t/ac/yr) = 0.15 t/ac/yr; Round to 0.2 t/ac/yr

e. From Figure 5: 0.2 t/ac/yr sediment delivers 0.5 lb/ac attached P

f. "After" phosphorus is: 0.5 lb/ac/yr x 30 ac. = 15 lbs./yr

g,. The difference between the "Before" and "After" is the reduction in phosphorus from both the filter strip and no-till, or: 321lb/yr - 15 lb/yr. = 306 lbs./yr.

The reduction in the phosphorus load by the filter strip: 306lbs/yr. - 246 lbs/yr. = 60 lbs/yr.

FEEDLOT POLLUTION REDUCTION

An animal lot refers to an open lot or combination of open lots intended for confined feeding, breeding, raising or holding animals. It is specifically designed as a confinement area in which manure accumulates or where the concentration of animals is such that vegetation cannot be maintained.

Runoff from feedlots contains many agents that can be considered potential pollutants, including disease carrying organisms, organic matter, nutrients and suspended inorganic solids. These agents affect receiving waters by increasing the nutrient and suspended solid concentration, decreasing dissolved oxygen content of water, and in some cases, even threaten human and animal health. For nonpoint source watershed project progress reporting, we have selected chemical oxygen demand (COD) and phosphorus (P) as representative pollutant indicators to represent pollutant reduction.

Chemical Oxygen Demand (COD) is a measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water. It can be used as a lumped parameter that reasonably appears to represent the degree of pollution in effluent. Phosphorus (P) is found in animal manure and is a major contributor to eutrophication of surface waters and is therefore an important pollutant indicator.

The purpose of these calculations is to represent the COD and P reductions after an animal waste system is installed. This method has two assumptions: 1) the feedlot is adjacent to a receiving hydrologic system without any buffering areas; and 2) installing the animal waste system will prevent any further pollutants from the lot from reaching the hydrologic system. Therefore the mass load of the COD and P calculated for the before situation will be the reduction in pollutants.

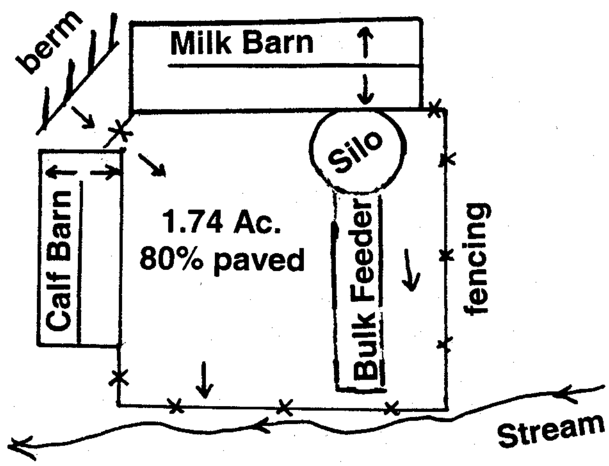
There may be feedlot sites where small buffers between the feedlot and waterbody already exist. Each of these situations should be handled individually with NPS Staff assistance. Feedlots that cannot show impact to the hydrologic system being protected should not be evaluated with this computation. An example of this would be a feedlot that does not have runoff reaching the hydrologic system, but is receiving technical assistance in order that waste utilization can be applied at agronomic rates. In this case, the impact would be reported using the ICM report for priority fields.

There are 12 steps involved in this calculation process. Use the worksheet given as Exhibit 3 in the Appendix as we go through the following example.

Example: Farmer Brown milks 70 dairy cows and has 30 replacement cows and 30 young stock. All the animals are confined in 80% paved feedlot. The feedlot is adjacent to Clear Creek and discharges into it. Determine the reduction in COD and P for the feedlot after the Waste Management System is installed.

Figure 6. Sample Feedlot

(Arrows indicate direction of runoff flow)



The following steps will calculate the COD and P loading reductions for installation of the Waste Management System.

Step 1: Carefully study the animal lot before the installation of the Waste Management System. Briefly describe the discharge point(s) using the name of the receiving water. All calculations will be based on feedlot situation before any improvements were made.

Step 2: On the back of the worksheet, sketch the feedlot. (Figure 6 gives a sketch of Farmer Brown's feedlot.) From field measurements determine the perimeter dimensions of the area contributing polluted water to the discharge point(s). This is the **contributing area (CA).** If the lot was partly paved and partly earthen, determine the proportion of the total that is paved.

Contributing Area (CA) = 75,620 ft^2 X 1 ac/43560 ft^2 = 1.74 ac
Percent paved = 80%

Step 3: Determine the **design rainfall (R)** from the rainfall map, Figure 7, for a 25-year, 24-hour rainfall. Federal regulations governing discharge of surface runoff from animal lots require 25-year, 24-hour storm events. This is consistent with NRCS standards and specifications.

R = 4.0 inches

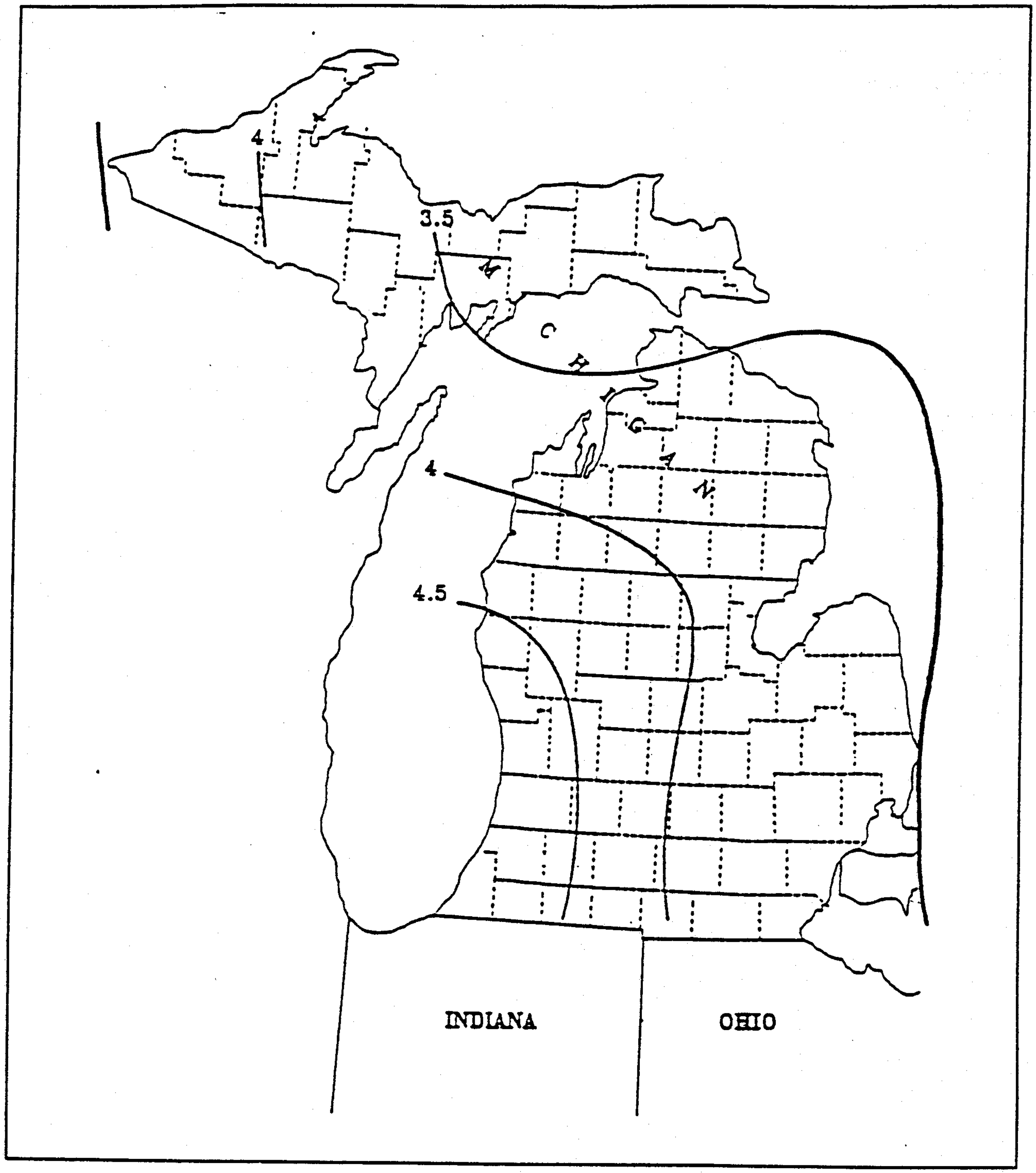
Step 4: Determine the **soil cover complex number (CN)** for the feedlot based on Figure 8.

Figure 8. Curve Numbers for Feedlots

Percent Paved	0 – 24%	25 – 49%	50 – 74%	75 – 100%
CN	91	92	93	94

In this example, CN = 94

Figure 7. 25-Year, 24-Hour Rainfall for Michigan.



Source: MDNR, 1992.

Step 5: Enter the number of animals in the lot and the animal type factors from Figure 9 for the COD and P. Animal types, number and weights utilized in this step should be consistent with those used in the design for the animal waste storage system. Interpolation of values should be based on the maximum weight animals would be expected to reach.

Animal Type

Dairy Cow — Number of Animals = 100
COD factor = 1.96
P factor = 0.92

Young Dairy — Number of Animals = 30
COD factor = 0.70
P factor = 0.33

Figure 9. Ratio of Chemical Oxygen Demand (COD) and total phosphorus (P) produced by various animals to that produced by a 1,000 pound slaughter steer.

Animal Type	Design Weight[1]	COD Ratio	P Ratio
	Pounds		
Slaughter Steer	1,000	1.00	1.00
Young Beef	500	.50	.51
Dairy Cow	1,400	1.96	.92
Young Dairy Stock	500	.70	.33
Swine	200	.17	.27
Feeder Pig	50	.04	.07
Sheep	100	.18	.06
Turkey	10	.02	.03
Chicken	4	.01	.01
Duck	4	.01	.01
Horse	1,000	.42	.42

Step 6: Calculate the runoff using the following equations:

$$\mathbf{S = \frac{1000}{CN} - 10} \qquad \mathbf{Q = \frac{(R-0.2S)^2}{R + 0.8S}}$$

where **S** = an empirical model coefficient
CN = soil cover complex number (Step 4)
R = design rainfall in inches (Step 3)
Q = runoff in inches

$$S = \frac{1000}{94} - 10 \qquad Q = \frac{[4.0 - 0.2(0.6383)]^2}{4.0 + 0.8(.0.6383)}$$

S = 0.6383 Q = 3.32 in.

Step 7: Calculate the **runoff volume (V)** using the following equation:

V = Q x CA

where **V** = runoff volume in acre-inches
Q = runoff in inches (Step 6)
CA = contributing area in acres (Step 2)

V = 3.32 x 1.74 = 5.78 acre-in.

Step 8: Because animal species differ in their relative production of wastes, this step equates amount of waste to the standard 1000 lb. feeder steer. Thus the amount of pollutant produced by a beef animal is represented as one, with the amount produced by all other animals being a fraction relative to that. Calculate the **equivalent animal unit (EAU)** for COD and P using information from Step 5 in the following equation:

No. x Factor = EAU

where **No.** = number of animals (Step 5)
Factor = ratio of COD and P produced (Step 5)

	Animal Type	No. of Animals	x	Factor	=	EAU
COD:	Dairy Cow	100	x	1.96	=	196.0
	Young Dairy	30	x	0.70	=	21.0
P:	Dairy Cow	100	x	0.92	=	92.0
	Young Dairy	30	x	0.33	=	9.9

Step 9: When animal density is high, such as in a confined feedlot, almost all of the rainfall and runoff in and from the lot comes in contact with animal waste before leaving the lot. When animal density is low, some runoff may escape contact with manure and thus not be contaminated. Calculate the **Animal Unit Density (AUD)** and **percent manure pack** using the following equations:

EAU / CA = AUD

where **EAU** = Equivalent Animal Units (step 8)
CA = contributing area (Step 2)

If AUD < 100, percent manure pack = AUD;
If AUD > 100, percent of manure pack = 100%.

The assumption is that AUDs greater than 100 have a pollutant concentration that reaches a maximum level independent of the number of animal units.

COD: 217.0 / 1.74 = 124.7 AUD; assume manure pack = 100%
P: 101.9 / 1.74 = 58.6 AUD; manure pack = 58.6%

Step 10: Calculate the **concentration of COD and P** in the feedlot runoff using the following equations:

Fraction of manure pack x Constant = concentration mg/l

where **Fraction of manure pack** = Step 9 /100
COD constant = 4500 mg/l
P constant = 85 mg/l

(The constants were developed from USDA-Agricultural Research Service ARM-NC-17, April 1982, based on 100% manure pack.)

COD: 1.00 x 4500 mg/l = 4500 mg/l
P: 0.586 x 85 mg/l = 49.8 mg/l

Step 11: Calculate the **mass load of pollutants in the runoff** using the equation:

Concentration x Volume x Conversion factor = Mass Load

where **concentration** = mg/l (Step 10)
Volume = acre-inches (Step 7)
Conversion factor = 0.227

COD: 4500 mg/l x 5.78 x..0.227 = 5904 lb.
P: 49.8 mg/l x 5.78 x 0.227 = 65.3 lb

Step 12: Report reductions in COD and P to the nearest whole number. Therefore, after the Waste Management System is installed and the feedlot runoff no longer enters the surface water, the reduction in COD is 5904 lbs., and the reduction in P is 65 lbs..

A blank copy of the Feedlot Pollutant Reduction Worksheet is given in the Appendix (Exhibit 3).

INTEGRATED CROP MANAGEMENT REPORTING FOR PESTICIDES, COMMERCIAL FERTILIZER, and MANURE UTILIZATION

Section 319 watershed projects are required to practice Integrated Crop Management (ICM) on all priority fields. The Water Quality Resource Management Plan (WQRMP) must include ICM as a required component for the landowner to be eligible for cost-share on other practices using 319 funds. The WQRMP should reference the ICM plan.

The goal of ICM is to improve the management practices used by the producer, to bring the level of management to another level for better water quality protection. For example, a producer who is not currently using soil tests on the priority fields would include soil testing in his/her ICM plan. A producer who is currently using soil tests to set yield goals could incorporate other nutrient management techniques such as nitrate testing, split application of fertilizer, or other practices to better manage nutrients. The Water Quality Resource Management Plan (WQRMP) must include ICM as a required practice for cost-share eligibility, and should reference the ICM plan.

An ICM plan should be prepared for priority fields, documenting the pest and nutrient management practices that the landowner is implementing on these fields. The ICM plan is to be customized to the individual farm plan for the watershed's targeted pollutants. For example, if the watershed is to reduce sediment and phosphorus from entering the stream, the ICM plan would specify what ICM practices the landowner is using to address phosphorus. An ICM plan would differ for a livestock producer, cash crop producer, or a fruit producer.

A livestock producer's ICM plan would emphasize manure utilization and fertilizer management. Pesticide management would not include time and effort consuming activities such as scouting. However, the WQRMP would reference Pesticide Management as requiring the farmer to follow pesticide label restrictions and directions.

A cash crop farmer's ICM plan would include both integrated pest and fertilizer management. Integrated Pest Management (IPM) would be planned and applied depending on the technician's overall workload and availability. The technician may delegate IPM planning and training to MSU Extension personnel or private consultants. Or the technician may organize IPM training for participants in the watershed as a method of applying pest management. (It should be noted that EPA rules prohibit the use of 319 funds to fund ICM practices. Incentive funds may be available through the USDA's Environmental Quality Incentives Program.)

A fruit producer's ICM plan would include both IPM and fertilizer management.

The format for ICM plans and documentation is not formalized in water quality projects. The documents should be understandable by the producers, so that they understand what practices are required and how they are carried out. Documentation in the WQRMP should be specific enough for a reviewer to assess what practices are being used, when they are scheduled for implementation, and that they have been applied properly to meet water quality goals. The MSU Extension service and private firms offer forms and computer programs for producing ICM plans.

Attempts to quantify water quality impacts of ICM have been largely ineffective. Progress reporting has largely been based on tracking the number and acres of ICM practices applied to priority fields. Attached is an example of an ICM quarterly summary report, to document ICM activities within the watershed project. Progress is cumulative for the entire project and is to be reported with quarterly reports. For example, if at the end of the first quarter the project had three participants and added one participant in the second quarter, the project's current status is four participants. Therefore 1a of the Integrated Crop Management Quarterly Report for the Second Quarter would be 4 (Figures 10 and 11). The second and subsequent year progress is accumulated in the same manner. Progress is never double or triple counted on the same people or acres.

Some projects have found the Individual Farm ICM Quarterly Summary to be an effective means to keep records of priority fields. Each participant has an ICM record sheet so that the technician may track progress. This can be kept in the case file or in a separate notebook specific to 319 ICM.

A blank copy of the ICM Quarterly Report is given as Exhibit 4 in the Appendix.

Figure 10. First Quarter ICM Report.

(Progress reporting is cumulative to date for the project.)

Project: Clear Creek Quarter: April 1 – June 30

1.	Total number of participants with priority fields		
	a.	Participating in the watershed project	3
	b.	that have ICM plans	1
	c.	that have applied ICM fields	0
2.	Total amount of acres in priority fields		
	a.	planned for ICM	200
	b.	that have had ICM applied	0
3.	Total number of ICM plans requiring modification		0
4.	Total number of nutrient/pesticide applicators calibrated		
	a.	fertilizer	1
	b.	pesticide	1
	c.	manure	1
5.	Total amount of acres of irrigation scheduling		
	a.	planned for scheduling	0
	b.	that have had scheduling	0
6.	Total amount of acres of pest scouting		
	a.	planned for scouting	40
	b.	that have been scouted	0
7.	Total amount of acres of manure utilization		80
	a.	on priority fields	80
	b.	on non-priority fields	100
8.	Total amount of acres fertilized according to current soil tests on priority fields.		0

Figure 11. Second Quarterly ICM Report.

(Progress reporting is cumulative to date for the project.)

Project: Clear Creek   Quarter: July 1 – September 31

1. Total number of participants with priority fields
   a. Participating in the watershed project 4
   b. that have ICM plans 3
   c. that have applied ICM fields 0
2. Total amount of acres in priority fields
   a. planned for ICM 320
   b. that have had ICM applied 0
3. Total number of ICM plans requiring modification 0
4. Total number of nutrient/pesticide applicators calibrated
   a. fertilizer 1
   b. pesticide 1
   c. manure 1
6. Total amount of acres of irrigation scheduling
   a. planned for scheduling 0
   b. that have had scheduling 0
6. Total amount of acres of pest scouting
   a. planned for scouting 80
   b. that have been scouted 0
7. Total amount of acres of manure utilization
   a. on priority fields 160
   b. on non-priority fields 200
9. Total amount of acres fertilized according to current soil tests on priority fields. 0

GLOSSARY

Best Management Practice (BMP): structural, vegetative or management conservation practices which reduce or prevent detachment, transport and delivery of nonpoint source pollutants to surface or ground waters.

Channel Erosion Equation (CEE): a formula to calculate the soil loss from streambank erosion, erosion from road stream crossings, or other similar types of erosion.

Contributing Area (CA): the portion of the priority field, which contributes eroded soil to the water body.

Erosion: the wearing away or disintegration of earth material by the physical forces of moving wind and water.

Gully Erosion Equation (GEE): a formula to calculate the soil loss from concentrated flow, gullies or other similar types of erosion

Integrated Crop Management (ICM): a system of pest and nutrient management practices that will minimize entry of nutrients, manure and/or pesticides to surface and ground water while optimizing crop and forage yields.

Integrated Pest Management (IPM): a system of chemical, physical and biological practices to control pests, that will minimize entry of pesticides to surface and ground water while optimizing crop and forage yields.

Lateral Recession Rate (LRR): the thickness of soil eroded from a bank surface (perpendicular to the face) in an average year, given in feet per year. Used in the Channel Erosion Equation.

Nutrient enrichment: the increase in sediment-borne nutrients during sediment delivery.

Priority field: cropland, pastureland or hayland that contribute runoff to adjacent hydrologic systems such as lakes, streams, ditches, wetlands and flood plains.

Revised Universal Soil Loss Equation (RUSLE): an erosion model predicting long-term, average annual soil loss resulting from raindrop splash and runoff from specific field slopes in specified cropping and management systems and from rangeland.

Riparian: of or pertaining to the edge of a water body

Sediment delivery: the amount or fraction of earth material that is actually delivered to a water body.

Sediment Delivery Ratio (DR): the fraction of eroded soil that will be deposited at the edge of the priority field. Used in equations to calculate sediment and nutrient reduction from upland BMPs.

Soil loss tolerance: a measure of the amount of soil that can be removed from a site before soil productivity onsite is affected.

Water Quality Resource Management Plan (WQRMP): a record of the BMPs chosen by the landowner, which will address the sources of pollutants.

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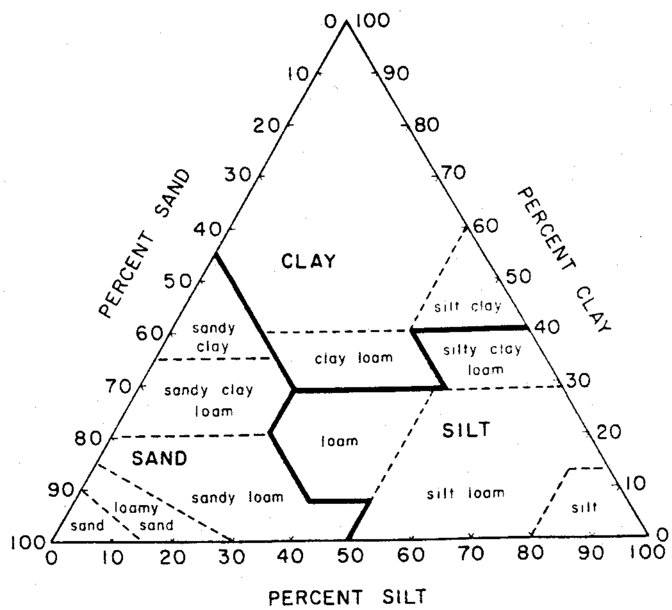
EXHIBITS

Exhibit 1
Dry Density Soil Weights

SOIL TEXTURAL CLASS	DRY DENSITY
	Tons/Ft3
Sands, loamy sands	.055
Sandy Loam	.0525
Fine sandy loam	.05
Loams, sandy clay loams, sandy clay	.045
Silt loam	.0425
Silty clay loam, silty clay	.04
Clay loam	.0375
Clay	.035
Organic	.011

Exhibit 2
Soil Texture Triangle



Correction Factors for Soil Texture

Soil Texture	Correction Factor
Clay	1.15
Silt	1.00
Sand	.85
Peat	1.50

Exhibit 3
Feedlot Pollution Reduction Worksheet

The following steps will calculate the COD and P reduction loadings for installation of the Waste Management System.

Step 1: Carefully study the animal lot before the installation of the Waste Management System. Briefly describe the discharge point(s) using the name of the receiving water. All calculations will be based on feedlot situation before any improvements were made.

Step 2: On the back of this form, sketch the feedlot. From field measurements determine the perimeter dimensions of the area contributing polluted water to the discharge point(s). This is the contributing area (CA). If the lot was partly paved and partly earthen, determine the proportion of the total that is paved.

Contributing Area (CA) = ______ ft^2 X 1 ac./43560 ft^2 = ____ acres
Percent Paved = ____

Step 3: Determine the design rainfall (R) from the rainfall map, Figure 1, for a 25-year, 24-hour rainfall. Figure 1 is at the end of this worksheet.

R = ________ inches

Step 4: Enter the soil cover complex number (CN) for the feedlot based on the following Table I.

Table I

Percent Paved	0 – 24%	25 – 49%	50 – 74%	75 – 100%
CN	91	92	93	94

CN = ________

Step 5: Enter the number of animals in the lot and the animal type factors from the Table II for chemical oxygen demand (COD) and total phosphorus (P).

Animal Type

_________________ Number of Animals = ________
COD Factor = ________
P Factor = _________

_________________ Number of Animals = ________
COD Factor = _________
P Factor = _________

_________________ Number of Animals = _________
COD Factor = _________
P Factor = _________

Table II

Ratio of COD and P produced by various animals to that produced by a 1,000 pound slaughter steer.

Animal Type	Design Weight[1]	COD Ratio	P Ratio
	Pounds		
Slaughter Steer	1,000	1.00	1.00
Young Beef	500	.50	.51
Dairy Cow	1,400	1.96	.92
Young Dairy Stock	500	.70	.33
Swine	200	.17	.27
Feeder Pig	50	.04	.07
Sheep	100	.18	.06
Turkey	10	.02	.03
Chicken	4	.01	.01
Duck	4	.01	.01
Horse	1,000	.42	.42

[1]Interpolation of values should be based on the maximum weight animals would be expected to reach.

Step 6: Calculate the runoff using the following equations:

$$S = \frac{1000}{CN} - 10 \qquad Q = \frac{(R-0.2S)^2}{R + 0.8S}$$

Were S = an emp
CN = soil cover complex number (Step 4)
R = design rainfall in inches (Step 3)
Q = runoff in inches

Q = __________ inches

Step 7: Calculate the runoff volume (V) using the following equation:

V = Q X CA

Where V = runoff volume in acre-inches
Q = runoff in inches (Step 6)
CA = contributing area of acres (Step 2)

V = ____________ X ____________
V = ____________ acre-in

Step 8: Calculate the equivalent animal units (EAU) for COD and P using information from Step 5 using the following equation:

No. X Factor = EAU

Where No. = Number of Animals (Step 5)
Factor = ratio of COD and P produced (Step 5)

	Animal Type	No. of Animals	x	Factor	=	EAU
COD:	__________	__________	x	_______	=	_____________
	__________	__________	x	_______	=	_____________
	__________	__________	x	_______	=	_____________
				TOTAL	=	_____________

Step 9: Calculate the Animal Unit Density (AUD) and % manure pack using the following equation:

EAU - CA = AUD

EAU = (Step 8)
CA = (Step 2)

COD: ________ - ________ = ________ AUD*

P: ________ - ________ = ________ AUD*

* If AUD < 100, percent manure pack = AUD
If AUD > 100, percent manure pack = 100%

Manure pack (COD) = ________%

Manure pack (P) = ________%

Step 10: Calculate the concentration of COD and P in the feedlot runoff using the following equations:

Fraction of manure pack x Constant = concentration mg/l

Fraction of manure pack = Step 9/100
COD Constant* = 4500 mg/l
P Content* = 85 mg/l

*Constants developed from USDA-Agricultural Research Service, ARM-NC-17 April 1982, based on 100% manure pack.

COD: ________ X 4500mg/l = ________mg/l

P: ________ X 85 mg/l = ________mg/l

Step11: Calculate the mass load of pollutants in the runoff using the following equation:

Concentration X Volume X Conversion Factor = Mass Load

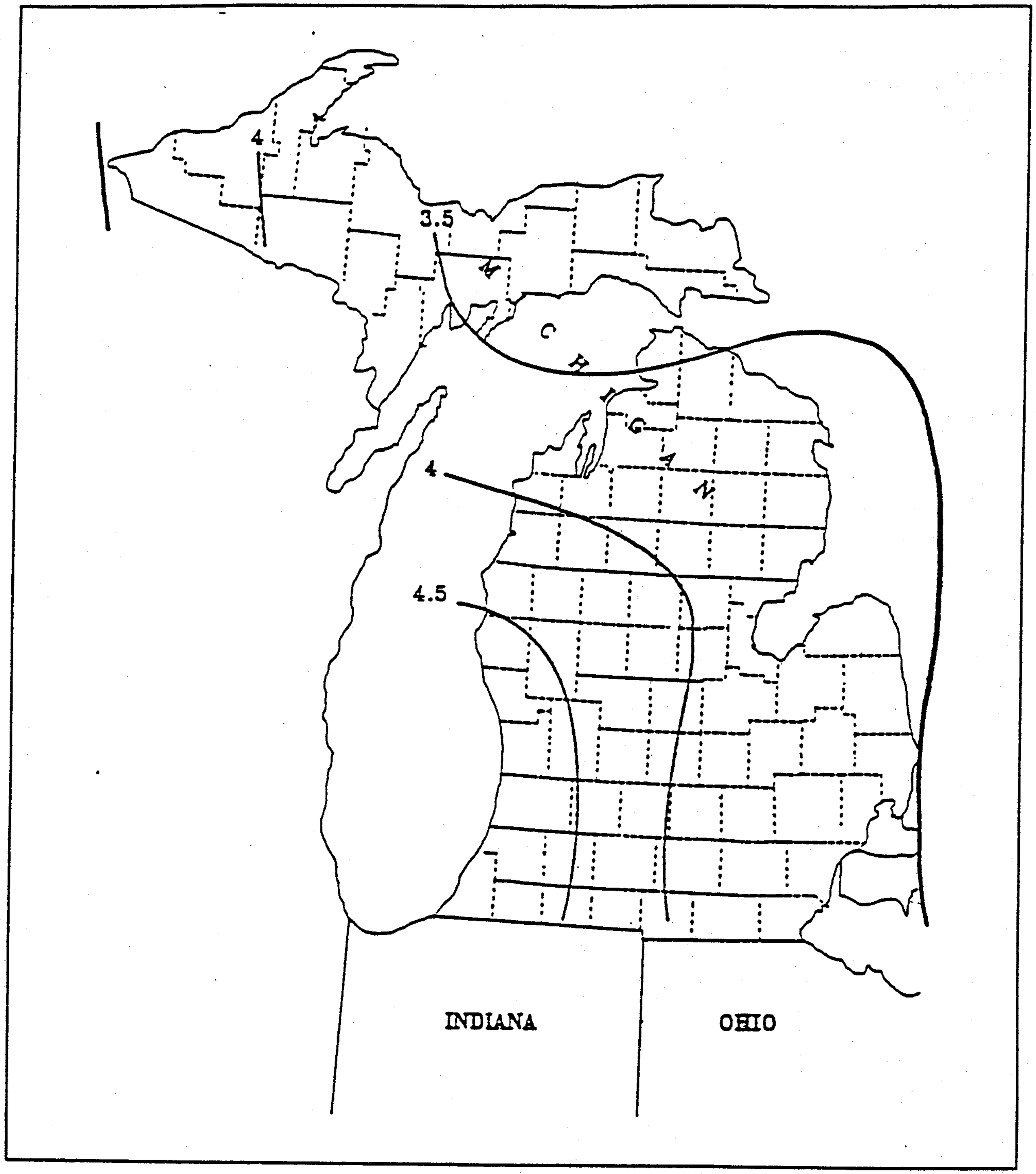
Concentration = mg/l (Step 10)
Volume = acre-inches (Step 7)

Conversion factor = 0.227

COD	________	X	________	X 0.227	=	________ lb.
P	________	X	________	X 0.227	=	________ lb.

Step 12: Therefore, after the Waste Management System is installed and the feedlot runoff no longer enters the surface water, the reduction in COD is _______ lbs. and the reduction in P is _______ lbs.

Figure 1. 25-Year, 24-Hour Rainfall for Michigan



Source: MDNR, 1992.

Exhibit 4

INTEGRATED CROP MANAGEMENT QUARTERLY SUMMARY REPORT

(Progress reporting is cumulative to date for the project.)

Project ______________________________ Quarter ____________________________

1) Total number of participants with priority fields

a. Participating in the watershed project ________
b. that have ICM plans ________
c. that have applied ICM plans ________

2) Total amount of acres in priority fields

a. planning for ICM ________
b. that have had ICM applied ________

3) Total number of ICM plans requiring Modification ________

4) Total number of nutrient/pesticide applicators calibrated

a. fertilizer
b. pesticide
c. manure

5) Total amount of acres of irrigation scheduling

a. planned for scheduling ________
b. that have had scheduling ________

6) Total amount of acres of pest scouting

a. planned for scouting ________
b. that have been scouted ________

7) Total amount of acres of manure utilization

a. on priority fields ________
b. on non-priority fields ________

8) Total amount of acres fertilized according to Current soil tests on priority fields -------

Exhibit 5
Load Reduction Estimating Workbook

A load reduction estimating workbook in Microsoft Excel® has been developed based on this document to provide a gross estimate of sediment and nutrient load reductions from the implementation of agricultural best management practices (BMPs). The methodology for the gross estimate of sediment and other constituent load reductions from the implementation of urban BMPs is based on reduction efficiencies and calculations developed by Illinois Environmental Protection Agency.

The original version (developed in 1999) of the load reduction estimating workbook was comprised of the following worksheets:

- Introductions
- Gully Stabilization
- Bank Stabilization
- Agricultural Fields and Filter Strips
- Feedlots
- Urban Runoff

A new worksheet—CountyData—was added to the workbook in 2002. The CountyData worksheet contains a collection of state and county names, precipitation data (annual amount and number of rain days) and correction factors (rainfall and number of rain days were adjusted to account for the runoff-producing events only), and USLE parameter values summarized from the 1997 National Resources Inventory database. Using the precipitation data and USLE parameter values, two of the original worksheets, Agricultural Fields and Filter Strips, and Feedlots, were modified. In addition, Gully and Bank Stabilization worksheets were also modified to allow users to specify the BMP efficiencies.

Worksheet Modifications: Gully Stabilization and Bank Stabilization

- Users may choose the default soil P and N concentrations or enter their own concentrations.
- Users may specify a sediment load reduction efficiency instead of using the default efficiency.

Worksheet Modifications: Agricultural Fields and Filter Strips

- Users may choose a state and a county from the pull-down combo boxes in the worksheet to obtain the default county-level USLE parameter values. If the local USLE or RUSLE parameter values are available, users should input the local values in the worksheet instead of using the default values.

- Users may click-check either or both of the BMP boxes to obtain the load reduction results as follows:
  a. If the Agricultural Field Practices box is checked, the load reduction is calculated for the agricultural field practices only.
  b. If the Filter Strips box is checked, the load reduction is calculated for the filter strips only.
  c. If both boxes are checked, the load reduction is calculated for both the agricultural field practices and filter strips.

Worksheet Modifications: Feedlots

The fundamental methodology of this worksheet is based on the section of "Feedlot Pollution Reduction" in this document. However, the methodology was modified to calculate annual runoff and load through inclusion of precipitation data. In addition,biochemical oxygen demand (BOD), phosphorus (P), and nitrogen (N) constants used in this worksheet were derived from EPA's Spreadsheet Tool for Estimating Pollutant Load (STEPL) model, developed by Tetra Tech, Inc. to enhance consistency between the methods.

- Users may select a state and a county to calculate the average runoff per rain day.
- Users may select a BMP to calculate the effect of BMP on load reduction.

Algorithm through an Example: Feedlots Worksheet

An animal lot refers to an open lot or combination of open lots intended for confined feeding, breeding, raising or holding animals. It is specifically designed as a confinement area in which manure accumulates or where the concentration of animals is such that vegetation cannot be maintained.

Runoff from feedlots contains many agents that can be considered potential pollutants including disease-carrying organisms, organic matter, nutrients and suspended inorganic solids. These agents affect receiving waters by increasing the nutrient and suspended solid concentration, decreasing dissolved oxygen content of water, and in some cases, threatening human and animal health. For nonpoint source watershed project progress reporting, we have selected BOD, N, and P as indicators to represent pollutant reduction.

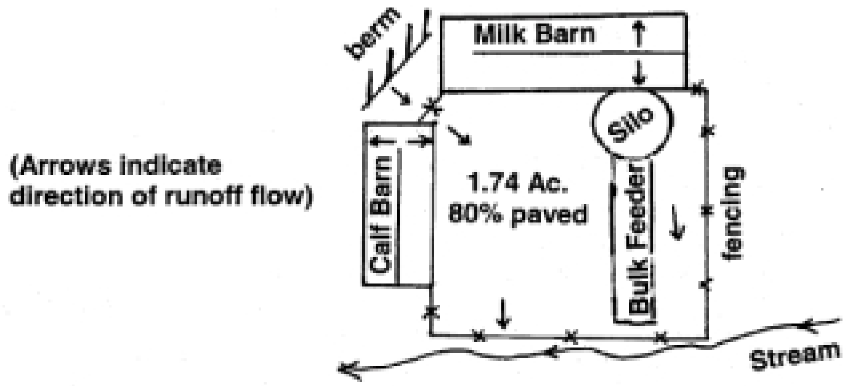
Biochemical oxygen demand is a measure of the amount of oxygen required to decompose organic matter by microorganisms such as bacteria. BOD in this section refers to BOD5—amount of oxygen required to decompose organic matter by microorganisms over a 5-day period. It can be used as a lumped parameter that reasonably appears to represent the degree of pollution in effluent. N and P are found in animal manure and are major contributors to eutrophication of surface waters and are therefore important pollutant indicators.

The purpose of these calculations is to represent the BOD, N, and P reductions after a BMP is implemented, or an animal waste system is installed. The effectiveness of each BMP or animal waste system can be represented by the pollutant-removal efficiency. Therefore the reduction in pollutants is calculated as the product of the BMP efficiencies and the mass load of the BOD, N, and P.

There are 14 steps involved in this calculation process. Below is an example that illustrates the calculation steps and algorithm.

Example: Farmer Brown milks 70 dairy cows and has 30 replacement cows and 30 young stock. All the animals are confined in 80 percent paved feedlot. The feedlot is adjacent to Clear Creek and discharges into it. Determine the reduction in BOD, N, and P for the feedlot after the installation of a Waste Management System.

Figure E5-1. Sample feedlot.



The following steps will calculate the BOD-, N-, and P- loading reductions for the implementation of the BMP.

Step 1: Carefully study the animal lot before the installation of the Waste Management System. Briefly describe the discharge point(s) using the name of the receiving water.

Step 2: On the back of the worksheet, sketch the feedlot. (Figure E5-1 gives a sketch of Farmer Brown's feedlot.) From field measurements determine the perimeter dimensions of the area contributing polluted water to the discharge point(s). This is the **contributing area (CA).** If the lot was partly paved and partly earthen, determine the proportion of the total that is paved.

CA = $\underline{75{,}620\ ft^2}$ x 1 ac/43560 ft^2 = $\underline{1.74\ ac}$
Percent paved = $\underline{80\%}$

Step 3: Determine the **average rainfall (R) per day** by selecting the state and county in which the feedlot is located and the nearest weather station. R is calculated as:

$$\frac{\textbf{Annual rainfall x Precipitation correction factor}}{\textbf{Annual rain days x Correction factor for number of rain days}}$$

For example, select state of Michigan and Alcona County with the default weather station.

R = $\underline{0.2848\ inches}$

Step 4: Determine the **soil cover complex number (CN)** for the feedlot based on Figure E5-2.

Figure E5-2. Curve Numbers for Feedlots

Percent Paved	0%–24%	25%–49%	50%–74%	75%–100%
CN	91	92	93	94

In this example, CN = 94

Step 5: Enter the number of animals in the lot and the animal type factors from Figure E5-3 for the BOD, N, and P. Animal types, number, and weights used in this step should be consistent with those used in the design for the animal waste storage system. Interpolation of values should be based on the maximum weight animals would be expected to reach.

Animal Type

Dairy Cow
Number of Animals = 100
BOD factor = 1.4
N factor = 1.91
P factor = 0.92

Young Dairy
Number of Animals = 30
BOD factor = 0.5
N factor = 0.55
P factor = 0.33

Figure E5-3. Ratio of BOD, total N, and total P produced by various animals to that produced by a 1,000 pound slaughter steer.

Animal Type	Design Weight (lbs)	BOD Ratio	N Ratio	P Ratio
Slaughter Steer	1,000	1.00	1.00	1.00
Young Beef	500	.50	.45	.51
Dairy Cow	1,400	1.4	1.91	.92
Young Dairy Stock	500	.5	.55	.33
Swine	200	.388	.25	.27
Feeder Pig	50	.097	.06	.07
Sheep	100	.075	.14	.06
Turkey	10	.013	.02	.03
Chicken	4	.008	.01	.01
Duck	4	.0011	.01	.01
Horse	1,000	1.063	.85	.42

Step 6: Calculate the runoff using the following equations:

$$S = \frac{1000}{CN} - 10 \qquad Q = \frac{(R-0.2S)^2}{R + 0.8S}$$

where **S** = an empirical model coefficient
CN = soil cover complex number (Step 4)
R = design rainfall in inches (Step 3)
Q = runoff in inches

$$S = \frac{1000}{94} - 10 \qquad Q = \frac{[0.2848 - 0.2(0.6383)]^2}{0.2848 + 0.8(.0.6383)}$$

$S = \underline{0.6383}$ $\qquad$ $Q = \underline{0.03103}$ in.

Step 7: Calculate the **runoff volume (V)** using the following equation:

V = Q x CA

where **V** = runoff volume in acre-inches
Q = runoff in inches (Step 6)
CA = contributing area in acres (Step 2)

V = 0.2555 x 1.74 = 0.0540 acre-in.

Step 8: Because animal species differ in their relative production of wastes, this step equates amount of waste to the standard 1000 lb. feeder steer. Thus the amount of pollutant produced by a beef animal is represented as one, with the amount produced by all other animals being a fraction relative to that. Calculate the **equivalent animal unit (EAU)** for BOD, N, and P using information from Step 5 in the following equation:

No. x Factor = EAU

Where, **No.** = number of animals (Step 5)
Factor = ratio of BOD, N, and P produced (Step 5)

	Animal Type	No. of Animals	x	Factor	=	EAU
BOD:	Dairy Cow	100	x	1.4	=	140.0
	Young Dairy	30	x	0.5	=	15.0
N:	Dairy Cow	100	x	1.91	=	191.0
	Young Dairy	30	x	0.55	=	16.5
P:	Dairy Cow	100	x	0.92	=	92.0
	Young Dairy	30	x	0.33	=	9.9

Step 9: When animal density is high, such as in a confined feedlot, almost all of the rainfall and runoff in and from the lot comes in contact with animal waste before leaving the lot. When animal density is low, some runoff may escape contact with manure and thus not be contaminated. Calculate the **Animal Unit Density (AUD)** and **percent manure pack** using the following equations:

EAU / CA = AUD

Where: **EAU** = Equivalent Animal Units (step 8)
CA = contributing area (Step 2)

If AUD < 100, percent manure pack = AUD;
If AUD > 100, percent of manure pack = 100%.

The assumption is that AUDs greater than 100 have a pollutant concentration that reaches a maximum level independent of the number of animal units.

BOD: 155.0 /1.74 = 89.1 AUD; assume manure pack = 89.1%
N: 207.5 /1.74 = 119.3 AUD; assume manure pack = 100%
P: 101.9 /1.74 = 58.6 AUD; assume manure pack = 58.6%

Step 10: Calculate the **concentration of BOD, N, and P** in the feedlot runoff using the following equations:

Fraction of manure pack x Loading constant = Concentration mg/l

Where: **Fraction of manure pack** = Step 9 /100
BOD constant = 2000 mg/l
N constant = 1500 mg/l
P constant = 300 mg/l
(The constants were developed from the references provided at the end of this section.)

BOD: 0.89 x 200 mg/l = 1780 mg/l
N: 1.0 x 1500 mg/l = 1500 mg/l
P: 0.586 x 300 mg/l = 175.8 mg/l

Step 11: Calculate the **mass load of pollutants in the runoff** using the equation:

Concentration x Volume x Conversion factor = Mass Load

Where: **Concentration** = mg/l (Step 10)
Volume = acre-inches (Step 7)
Conversion factor = 0.227

BOD: 1780 mg/l x 0.054 x 0.227 = 21.84 lb.
N: 1500 mg/l x 0.054 x 0.227 = 18.39 lb.
P: 175.8 mg/l x 0.054 x 0.227 = 2.15 lb.

Step 12: Calculate the **annual average mass load** of pollutants in runoff using the following equation:

Annual average mass load = **Mass load x Rain days per year x Correction factor for number of rain days**

BOD: 21.84 lb x 117.1 x 0.6 = 1534.3 lb/yr
N: 18.39 lb x 117.1 x 0.6 = 1291.8 lb/yr
P: 2.15 lb x 117.1 x 0.6 = 151.3 lb/yr

Step 13: Select the BMP (for example: Waste Management System) (Figure E5-4), and calculate the load reduction:

Load reduction after BMP = Annual average mass load x BMP pollutant removal efficiency

BOD: 1534.3 lb/yr x no data (ND) = NA
N: 1291.8 lb/yr x 0.8 = 1033.4 lb/yr
P: 151.3 lb/yr x 0.9 = 136.2 lb/yr

Figure E5-4. Pollutant removal efficiency of selected feedlot-related BMP*.

Best Management Practices	Pollutant Removal Efficiency		
	N	P	BOD
No BMP	0	0	0
Diversion	0.45	0.7	ND
Filter Strips	ND	0.85	ND
Runoff Mgmt System	ND	0.825	ND
Terrace	0.55	0.85	ND
Waste Mgmt System	0.8	0.9	ND
Waste Storage Facility	0.65	0.6	ND
Solids Separation Basin	0.35	0.31	ND
Solids Separation Basin w/Infiltration Bed	ND	0.8	0.85

ND = No data.
* Values in the table were derived from the references listed at the end of this section.

Reductions in BOD, N, and P should be rounded to the nearest whole number. Therefore, after the installation of the Waste Management System, and the feedlot load reduction in N is 1033 lbs/yr and the reduction in P is 136 lbs/yr.

Step 14: Average annual pollutant load after installing the Waste Management System can be calculated as: **Load before BMP – Load reduction**

BOD: 1534.3 lb/yr - no data (ND) = NA
N: 1291.8 lb/yr - 1033.4 = 258 lb/yr
P: 151.3 lb/yr - 136.2 = 14 lb/yr

References

(Loading constant)

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(BMP efficiency)

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8. U.S. Environmental Protection Agency (EPA). 1993. *Guidance specifying management measures for sources of nonpoint pollution in coastal waters.* EPA-840-B-92-002. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

(STEPL)

9. Tetra Tech, Inc. 2002. *User's guide: Spreadsheet tool for the estimation of pollutant load (STEPL). Version 2.01.* Prepared for U.S. Environmental Protection Agency, Washington, DC. (The current User's Guide is for STEPL version 3.1, 2005)

Exhibit 6
Algorithm through an Example: Urban Runoff Worksheet

Urban runoff can be attributed to many things, including the amount of rainfall, the soil conditions, and the degree of urbanization. Urban areas usually have high percentages of hard, impermeable surfaces. Fields and forests allow for the rainwater to soak into the soil where it falls, but parking lots, roofs, streets, and other impervious surfaces of an urban environment cause the rainwater to collect, and it must be forced out through a storm drain system. If the drainage system does not connect to a wastewater treatment facility, the rainwater and everything in it travels into local streams and rivers.

Urban runoff contributes many pollutants to the nearby streams and lakes. Some of these pollutants are nitrogen, phosphorus, sediment, lead, zinc, copper, cadmium, chromium, and arsenic. In addition to contributing pollutants, urbanization affects other water quality characteristics. These characteristics include water temperature, pH, dissolved oxygen, alkalinity, hardness, and conductivity.

Implementing best management practices (BMPs) in urban areas can reduce the pollutants carried by runoff to the nearby steams and lakes. The following example illustrates how to calculate pollutant load from a hypothetical urban area and the load reduction after implementing a BMP.

Example: Determine the reduction in total nitrogen (TN) and total phosphorus (TP) loadings for an urban area (**contributing/drainage area**) after the implementation of vegetated filter strips.

We use the Load Reduction Estimating Workbook (see Exhibit 5) to illustrate the calculation steps.

The land use characteristics for the hypothetical area are as follows:

Land Use	Area with storm water sewers (acres)	Area without storm water sewers (acres)
Commercial	50	0
Transportation	5	2

Step 1: Select a best management practice you want to implement in the contributing/drainage area.

Select the first option from the BMP list: Vegetated filter strips.

Step 2: Estimate the area in acres with and without storm water sewers for every land use type in the contributing/drainage area.

Commercial area with storm water sewers = 50 acres
Transportation area with storm water sewers = 5 acres
Transportation area without storm water sewers = 2 acres

Step 3: Calculate the **load before BMP** implementation for TN and TP in the contributing/drainage area.

Load before BMP =
Average pollutant loading rates by land use x Area by land use

Average pollutant loading rates by land uses are obtained from Figure E6-1.

Hence, the loads before BMP implementation are:

TN = 21 lb/ac/yr x 50 ac (Commercial sewered) +
13 lb/ac/yr x 5 ac (Transportation sewered) +
7.7 lb/ac/yr x 2 ac (Transportation unsewered) = 1,130.4 lb/yr

TP = 1.3 lb/ac/yr x 50 ac (Commercial sewered) +
1.8 lb/ac/yr x 5 ac (Transportation sewered) +
1.1 lb/ac/yr x 2 ac (Transportation unsewered) = 76.2 lb/yr

Figure E6-1. Average Pollutant Loading Rates by Urban Land Use Types (lb/ac/yr) *

Land Use**	Com-mercial	Industrial	Institu-tional	Trans-portation	Multi-Family	Resi-dential	Agri-culture	Vacant	Open Space
BOD (Sewered)	85	50	52	50	52	22		2	1
BOD (Unsewered)	75	40	31	30	42	11	3	0.9	0.4
COD (Sewered)	589	260	320	881	320	140		64	46
COD (Unsewered)	520	230	190	518	260	71	28	26	15
TSS (Sewered)	1180	1240	1320	2260	1320	309		100	61
TSS (Unsewered)	1040	1080	790	1330	1050	154	153	40	20
TN (Sewered)	1.03	1.58	0.37	2.67	0.37	0.23		0.03	0.02
TN (Unsewered)	0.90	1.39	0.22	1.57	0.29	0.12	0.00	0.01	0.01
COPPER (Sewered)	0.2	0.21	0.1	0.56	0.1	0		0.01	0.01
COPPER (Unsewered)	0.18	0.18	0.061	0.33	0.08	0	0.0044	0.004	0.002
TP (Sewered)	1.6	1.3	0.57	3.2	0.57	0.9		0.1	0.08
TP (Unsewered)	1.4	1.2	0.34	1.9	0.46	0.5	0.069	0.06	0.03
TDS (Sewered)	2830	1290	623	6060	623	436		1210	724
TDS (Unsewered)	2500	1130	374	3565	498	218	89.2	483	241
TN (Sewered)	21	14	11	13	11	6		1	1
TN (Unsewered)	18	12	6.5	7.7	8.6	3.1	2.4	0.5	0.2
TKN (Sewered)	6.9	4	6.4	18	6.4	3.2		2.2	1.3
TKN (Unsewered)	6.1	4	3.8	11	5.1	1.6	0.91	0.88	0.44
DP (Sewered)	0.69	0.86	0.61	0.2	0.61	0.3		0.1	0.08
DP (Unsewered)	0.61	0.75	0.36	0.1	0.48	0.1	0.08	0.05	0.03
TP (Sewered)	1.3	1.5	1.4	1.8	1.4	0.8		0.22	0.39
TP (Unsewered)	1.2	1.3	0.8	1.1	1.1	0.4	0.18	0.088	0.13
CADMIUM (Sewered)	0.008	0.03	0.0037	0.021	0	0		0.0003	0.0002
CADMIUM (Unsewered)	0.0071	0.02	0.0022	0.012	0	0	0.0002	0.0001	0.0001

* Northeastern Illinois Planning Commission. 1983. Unit area pollutant load estimates for Lake County, Illinois Lake Michigan watersheds.
**Sewered or unsewered refer to the urban areas with or without storm sewers.

Step 4: Calculate the **load after BMP** implementation.

Load after BMP = Load before BMP x (1 - BMP pollutant removal efficiency)

BMP pollutant removal efficiencies (vegetated filter strips) for TN and TP pollutants are obtained from Figure E6-2.

Hence, the loads after BMP implementation are:

TN = 1130.4 lbs/yr x (1 - 0.4) = 678.24 lb/yr
TP = 76.2 lbs/yr x (1 - 0.4525) = 41.7195 lb/yr

Figure E6-2. BMP Pollutant Removal Efficiencies (Maximum Efficiency = 1)

BMP Types	Ref*	BOD	COD	TSS	LEAD	COPPER	ZINC	TDS	TN	TKN	DP	TP	CADMIUM
Vegetated Filter Strips	A&B	0.505	0.4	0.73	0.45	U	0.6	U	0.4	U	U	0.4525	U
Grass Swales	A,B&C	0.3	0.25	0.65	0.7	0.5	0.6	U	0.1	U	U	0.25	0.5
Infiltration Devises	A	0.83	U	0.94	U	U	U	U	U	U	U	0.83	U
Extended Wet Detention	A&B	0.72	U	0.86	0.4	U	0.2	U	0.55	U	U	0.685	U
Wetland Detention	A&B	0.63	0.5	0.78	0.65	U	0.35	U	0.2	U	U	0.44	U
Dry Detention	A&B	0.27	0.2	0.58	0.5	U	0.2	U	0.3	U	U	0.26	U
Settling Basin	A	0.56	U	0.82	U	U	U	U	U	U	U	0.515	U
Sand Filters	A	0.4	U	0.83	U	U	U	U	U	U	U	0.375	U
WQ Inlets	A&B	0.13	0.05	0.37	0.15	U	0.05	U	0.2	U	U	0.09	U
Weekly Street Sweeping	A	0.06	U	0.16	U	U	U	U	U	U	U	0.06	U
Infiltration Basin	B&D	U	0.65	0.75	0.65	U	0.65	U	0.6	U	U	0.65	U
Infiltration Trench	B&D	U	0.65	0.75	0.65	U	0.65	U	0.55	U	U	0.6	U
Porous Pavement	B	U	0.8	0.9	1	U	1	U	0.85	U	U	0.65	U
Concrete Grid Pavement	B	U	0.9	0.9	0.9	U	0.9	U	0.9	U	U	0.9	U
Sand Filter/Infiltration Basin	B	U	0.55	0.8	0.6	U	0.65	U	0.35	U	U	0.5	U
WQ Inlet w/ Sand Filter	B	U	0.55	0.8	0.8	U	0.65	U	0.35	U	U	U	U
Oil/Grit Separator	B	U	0.05	0.15	0.15	U	0.05	U	0.05	U	U	0.05	U
Wet Pond	B	U	0.4	0.6	0.75	U	0.6	U	0.35	U	U	0.45	U
Agriculture Filter Strip	C	U	U	U	U	U	U	U	0.5325	U	U	0.6125	U

U = Data unavailable
* References:

A Northeastern Illinois Planning Commission (NIPC). 1994. Model best management practice selection methodology & Lake County decision-making framework. NIPC, Chicago, Illinois.

B U.S. Environmental Protection Agency (EPA). 1993. Guidance specifying management measures for sources of nonpoint pollution in coastal waters. EPA-840-B-92-002. Office of Water, Washington, DC. <http://www.epa.gov/OWOW/NPS/MMGI/Chapter4/index.html>.

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Note: Took middle value of ranges for conflicting results

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Step 5: Calculate the **load reduction** after the BMP implementation.

Load reduction = Load before BMP – Load after BMP

TN Reduction: 1,130.4 – 678.24 = 452.16 lb/yr
TP Reduction: 76.2 – 41.72 = 34.48 lb/yr