United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

CORE4 Conservation Practices Training Guide

The Common Sense Approach to Natural Resource Conservation

- **Conservation Tillage**
- **Nutrient Management**
- **Pest Management**
- **Buffers**

CORE4—Key Conservation Practices

Introduction

The purpose of this workbook is to enhance the technical knowledge of Natural Resources Conservation Service (NRCS) personnel and their colleagues in both the public and private sector and to assist them in helping landowners effectively use conservation tillage, nutrient management, pest management, and conservation buffers. These key practices significantly reduce nonpoint sources of pollution from cropland as well as provide opportunities for many other conservation benefits when applied as a system. These few practices do not, however, exclude consideration for other practices or systems designed to protect the natural resources related to cropland agriculture.

In January 1998, the NRCS through the National Conservation Buffer Initiative sponsored a Conservation Buffer Conference in San Antonio, Texas. During this conference several national experts expressed concern about the long-term functioning of conservation buffers without a systems approach to address nutrients, pesticides, and sedimentation.

The CORE4 concept was established by the Conservation Technology Information Center (CTIC) and supporting organizations as an information and marketing plan to promote the voluntary approach to conservation emphasizing conservation tillage, pest management, nutrient management, and conservation buffers. CORE4, to a large degree, is the result of a public survey and a series of public forums designed to capture the opinions and suggestions of farmers and ranchers, as well as other groups with a vested interest in reducing nonpoint sources of pollution on a voluntary basis. The concept is presented as a "common-sense" approach, meaning an easily understood system of conservation practices that solve many of the natural resource concerns associated with cropland agriculture.

NRCS is supporting the CTIC/CORE4 marketing plan in a cooperative effort with many other conservation partners. The objective is to focus on cost-effective systems that can be planned and installed with limited technical and financial assistance. Within NRCS CORE4 is much more. It is

- Providing a team of technical specialists to provide assistance to states.
- Developing job sheets and modifying them to meet application needs.
- Encouraging statewide training to NRCS employees and public and private partners.
- Providing assistance for state conservation practice standard development or revisions.
- Providing support for demonstration projects.

The material in this book is designed to improve user knowledge and understanding of the function, value, and management of this family of practices. In addition to improving water quality, these practices can improve soil quality, air quality, wildlife habitat, and aesthetics. Carbon sequestration is another benefit expected from the widespread application of these practices.

This material is available to partnering agencies, private industry, special-interest groups, and other interested individuals. The job sheets and prepared training materials are presented from a national perspective. Where appropriate, the guidance should be tailored to fit local conditions.

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CORE4 Key Conservation Practices

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Part 1 Conservation Tillage

Barriers to adoption

The barriers to adoption of conservation tillage follow and are in table 1–1 (CTIC 1997a).

- Afraid/unwilling to change (risk)
- Equipment expense
- Crop not easy to farm in conservation tillage
- Weeds
- Greater use of chemicals
- Personal preference

Table 1–1 Barriers to adoption of conservation tillage (CTIC 1997b)

Barrier	No-till	Mulch-till
	% of respondents	
Equipment expense	17	15
Weed problems	13	12
Soil too heavy/cold/wet	11	10
Use more chemicals	11	9
Yield reduction	8	8
Insect problems	6	5
Not interested	6	4
Herbicide costs	7	5
Too much residue to handle	3	5
Disease problems	4	4
Risk of change	4	3
Cost	4	2
Other	19	15
None	15	18
Do not know	13	14

NRCS standards vs. CTIC survey

Natural Resources Conservation Service (NRCS) conservation standards for the Residue Management practices (No-till/Strip-till, Mulch-till, and Ridge-till) do not contain specific minimum criteria for surface residue cover. The amount of residue required is dependent on site-specific level of treatment needed and the other practices that make up the conservation system. Therefore, how should NRCS deal with the 30 percent residue requirement (water erosion) or 1,000 pounds of small grain residue equivalent (wind erosion) being used as the standard for conservation tillage in the Conservation Technology Information Center (CTIC) Core Conservation Practices Marketing Program? The CTIC only counts those acres that meet the 30 percent or 1,000-pound criteria as helping to achieve its goal of 50 percent of the planted acres in conservation tillage by the year 2002.

NRCS changed its conservation tillage standard in fiscal year 1994. However, CTIC has continued to collect field data in its Crop Residue Management Survey on the progress of conservation tillage using the 30 percent and 1,000-pound criteria. The staff continues using the criteria because of the need to establish long-term trends in adoption and to effectively communicate with ag media and others. The CTIC definition has not changed since 1989.

NRCS personnel should view these differences as simply different levels and not as conflicting or competing standards. For example, NRCS might assist a producer in planning and implementing a mulch-till practice requiring only 20 percent surface residue cover after planting. In this example, the acres would not be counted as part of CTIC's goal for conservation tillage because the mulch-till system did not meet or exceed 30 percent surface residue cover.

Table 1–2 gives the acres and percent of planted acres in the United States that are in conservation tillage systems.

Table 1–2 Conservation tillage in the United States (in millions of acres and percent of planted acres)

Conservation tillage types 30% after planting	1990	1994	1998
No-till/strip-till	16.9	38.9	47.8
	6.0%	13.7%	16.3%
Ridge-till	3.0	3.6	3.5
	1.1%	1.3%	1.2%
Mulch till	53.3	56.8	57.8
	19.0%	20.0%	19.7%

Definitions

No-till/Strip-till

Managing the amount, orientation, and distribution of crop and other plant residue on the surface the year-round while growing crops in narrow slots or tilled or residue-free strips in soil previously untilled by full width inversion implements.

Mulch-till

Managing the amount, orientation, and timing of crop or other crop residue on the soil surface year-round while growing crops where the entire field surface is tilled before planting.

Ridge-till

Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while growing crops on preformed ridges alternated with furrows protected by crop residue.

Chapter 2 Impacts of Residue Management Practices

The plow is one of man's most ancient and most valuable inventions, but long before he existed, the land was in fact regularly plowed and still continues to be thus plowed by earthworms.
Charles Darwin , 1881

The residue management practice used in crop production can significantly impact soil quality, water quality, and air quality. Although all the residue management practices can favorably impact soil, water, and air quality, they can vary in the degree of this impact.

Soil quality

Erosion

Sheet and rill erosion
Leaving all or part of the previous crop's residue on the soil surface has three primary roles in reducing sheet and rill erosion. Surface residue:
- Reduces the splash effect of rainfall
- Reduces surface runoff
- Increases infiltration

When rain falls on a bare soil surface, soil particles are dislodged from soil aggregates by the explosive action of falling raindrops. Once the soil particles are dislodged, they can be transported by sheet or concentrated flow across the soil surface. Surface residue cover intercepts the falling raindrop and dissipates its erosive energy (fig. 2–1). Because this energy is dissipated by the residue cover, soil particles are less likely to be dislodged from soil aggregates and, as a result, are much less subject to movement by water flowing across the soil surface.

Surface residue can also form small dams that slow surface runoff. When surface runoff is slowed, it has a greater opportunity time to infiltrate the soil surface. In addition, surface residue reduces the chances for soil crusting, which can significantly impact infiltration and resulting runoff amounts.

The beneficial impacts of surface residue cover on sheet and rill erosion are included in the Revised Universal Soil Loss Equation (RUSLE). The benefit of surface residue in reducing sheet and rill erosion is illustrated in table 2–1.

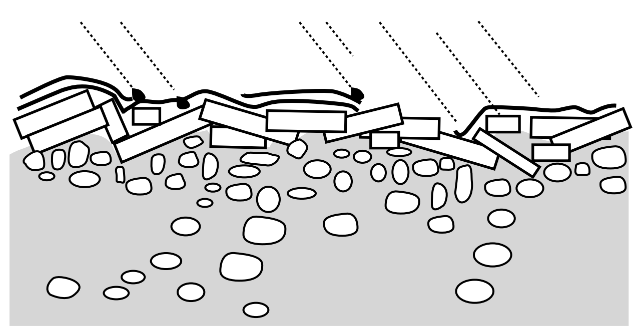
Table 2–1 clearly shows the more residue left on the soil surface, the greater the reduction in sheet and rill erosion. No-till leaves the most surface residue cover of the residue management practices. It is, therefore, the most beneficial of these practices in reducing sheet and rill erosion.

With no-till/strip-till systems, the amount of surface residue cover can approach 80 to 90 percent after high residue crops. This can reduce sheet and rill erosion by 94 percent during the period that amount of surface residue is present. After low residue crops, such as soybeans, cotton, or peas, the surface residue cover is

Table 2–1 Effect of percent residue cover on any day in reducing sheet and rill erosion compared to conventional, clean tillage without residue

Residue cover % on any day	Erosion reduction % while residue present
10	30
20	50
30	65
40	75
50	83
60	88
70	91
80	94

Figure 2–1 Surface residue and the erosion process



significantly less, perhaps no more than 30 to 40 percent cover. In some regions of the country, some residue from the crop 2 years ago may help to increase surface cover. In a corn/soybean rotation when corn follows soybeans, as much as 20 percent corn stalk residue may still be on the surface, which reduces soil erosion. In some climates winter weeds can significantly increase surface residue cover.

Less surface residue cover is generally left on the surface after planting with ridge-till compared to no-till because the planting operation removes the residue from the top of the ridge and places it between the rows. Although this residue is generally not buried between the rows, the distribution of the residue over the field has been affected (bare in the rows, but residue covered between the rows). This allows sheet and rill erosion to occur on the ridges, but has a positive effect between the rows. Two-row cultivations are used during the growing season with ridge-till for the purpose of weed control and rebuilding the ridges for the next year's crop. These cultivations bury some of the surface residue cover. Since most of the surface runoff moves down the row middles where the residue has been placed and the side slopes of the ridges are short, soil erosion is generally not a major concern. Concentrated runoff may break over the ridges and cause gullying. Care must be taken not to run rows up and down steep slopes. This is not a problem until slopes exceed about 7 percent.

With mulch-till, the amount of surface residue remaining can be significantly less than under no-till or ridge-till because full-width tillage is used. When high residue crops are used, mulch-till might retain 30 to 50 percent surface residue cover. With low residue crops, it is more difficult to retain 30 percent of the surface covered unless a cover crop is added to the system.

For surface residue to achieve erosion benefits, the residue needs to be evenly distributed over the field. This can be accomplished by a straw and chaff spreader (see the section on Equipment for Conservation Tillage Systems) that distributes residue over a minimum of 80 percent of the header width. Surface residues decompose over time. If 60 percent cover is present after planting, that amount decreases during the remaining growing season as a result of decomposition. Decomposition of crop residue is accounted for in RUSLE.

Ephemeral erosion

Ephemeral gully erosion is caused by drainage channel depressions in the field where water concentrates and flows over the field (fig. 2–2). Ephemeral means short lived. Ephemeral gully erosion is short lived since the small gullies can be obliterated with tillage (fig. 2–3). However, ephemeral gully erosion occurs in the same location year after year if not controlled.

When tillage is used to repair ephemeral gullies, soil is pulled from both sides of the gully. If the ephemeral gully is not controlled, more and more soil will be pulled from the adjacent areas to again fill the eroded area. As a result, damage to the soil resource is often affected beyond the initial boundaries of the gully.

As previously described, less runoff occurs as more crop residue is retained on the soil surface. Because no-till has the greatest surface cover compared to the other residue management systems, it has the greatest value in reducing ephemeral gully erosion. Even under no-till, ephemeral erosion control depends on the watershed area involved and subsoil permeability. For small areas, surface residue cover may control this

Figure 2–2 Ephemeral gully erosion

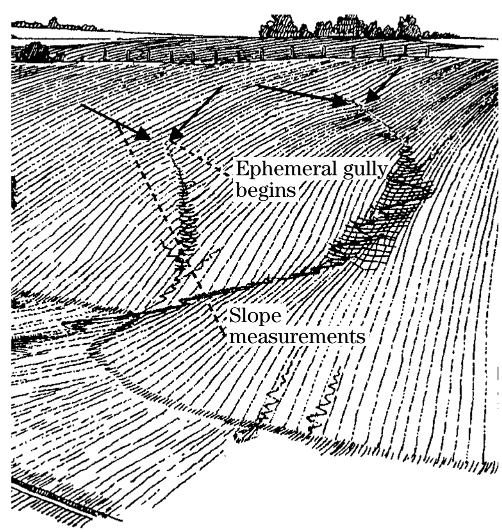
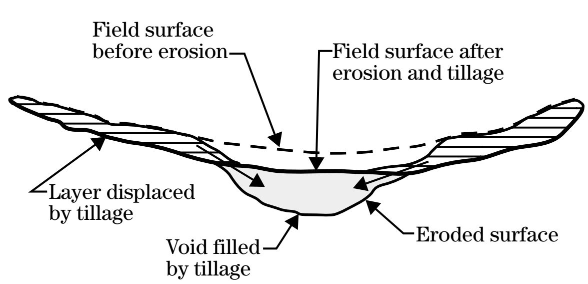


Figure 2–3 Ephemeral gully process



type of erosion. However, for larger watershed areas, a temporary cover may solve the problem or a permanent grassed waterway may be needed to control the ephemeral erosion.

Once an ephemeral gully begins in a no-till field, it may continue to enlarge because the gully is not filled by tillage operations. Corrective action should be taken immediately.

Another problem that may occur in certain years under heavy rainfall is that surface residue can float off the field in these ephemeral areas and accumulate at the fence line or be deposited in culverts or road ditches. Leaving as much of the surface residue intact as possible helps, but under severe storms some residue may float and move with surface flow. If this problem is relatively minor and occurs only occasionally, a temporary structure, such as a snow fence or woven wire fence, across the flow area at intervals down the slope after the crop has been planted helps to alleviate this problem. A grassed waterway is needed in larger areas where this situation occurs year after year.

Wind erosion

Wind erosion is similar to water erosion in some ways. Both are caused by forces flowing over the soil surface. Many of the conservation measures used to reduce erosion by water are also applicable to reducing erosion by the forces of wind.

The threshold wind velocity required to begin the erosion process is higher across surfaces protected by surface residue. The threshold velocity varies depending on many aspects including quantity of surface residue, orientation, and surface roughness. Surface residue is more effective in reducing wind erosion if the residue orientation is standing compared to lying flat. However, in most no-till situations, the orientation of residue is not as critical because large quantities of residue are present. In other systems when some full width tillage is used, not only is surface residue significantly reduced, but upright orientation is changed to flat and effectiveness is drastically reduced. The threshold wind velocity required to begin the erosion process is higher across surfaces roughened by tillage operations.

With low residue crops, residue orientation and row orientation become more important. Residue should be left standing and rows oriented perpendicular to the prevailing wind direction in areas where the forces of wind can cause serious soil erosion or severe crop damage (such as may be the case with many vegetable crops).

When ridge-till is used, every attempt should be made to orient the ridges perpendicular to the prevailing wind direction in areas that are prone to wind erosion.

Soil properties/conditions

Soil organic matter

Soil organic matter is probably the most important soil quality indicator. Residue management practices can have a significant impact on increasing soil organic matter. Excessive tillage significantly reduces the chances for increasing soil organic matter. The largest increases in soil organic matter result from **continuous** no-till. If no-till is alternated with full width tillage, the increase in organic matter will be negligible.

If increasing organic matter in a continuous row cropping system is the primary objective of a grower, using continuous no-till is not only the fastest way, but also probably the only way to achieve that goal.

Organic matter cannot be increased on fields farmed intensively with continuous conventional tillage (less than 15 percent residue remaining after planting). Soil organic matter increases primarily through avoidance of tillage. Leaving the root structure undisturbed is vitally important. Recent research indicates that most of the increase in soil carbon is a result of undisturbed root biomass, not just by leaving crop residue on the surface.

Even with continuous no-till, the increase in soil organic matter is a slow process. It takes a long time to replenish what Mother Nature originally provided. One long-term, continuous no-tiller in the Central United States reports that organic matter in the top 2 inches increased from 1.8 percent to 3.8 percent after 20 years of continuous no-till on a corn/soybean rotation formerly conventionally tilled. Therefore, it is a slow process, but the advantages of significantly increasing organic matter are worth the wait.

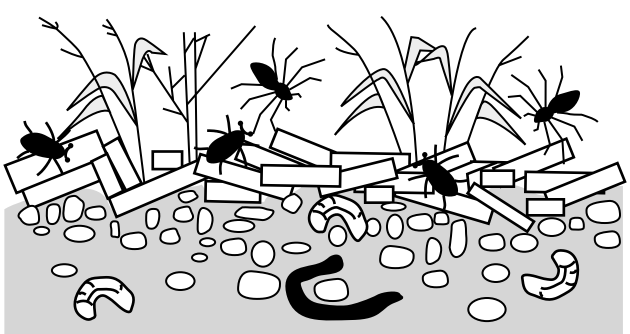
Increasing soil organic matter can increase the cation exchange capacity (CEC) of the soil. This is extremely important because low CEC soils cannot hold as many plant nutrients as those with high CEC. CEC is directly related to the type of clay and the organic matter content of the soil (table 2–2). The type of clay in the soil cannot be changed, but the organic matter content can be changed with proper management. If the organic matter in a soil containing 25 percent kaolinite clay is increased from 1.5 percent to 3 percent, the CEC will increase from about 8 milliequivalents (meq) to 11 milliequivalents per 100 grams of soil. This is an increase of about 37 percent. If the organic matter in a soil containing 25 percent montmorillonite clay is increased from 2 percent to 4 percent, the CEC will most likely change from about 21.5 to 25.5; an increase of 18.6 percent.

Crop residue provides an energy source for micro-organisms (fig 2–4). As surface residue increases, the number of micro-organisms also increases. As these micro-organisms use the surface residue for their life processes, they return humus to the soil, resulting in an increase in soil carbon. The population of micro-organisms in the soil is directly related to the amount of energy or food available. When residue is plowed under, micro-organisms consume it rapidly, leaving little or no energy source available for top-feeding organisms. As a result the energy source is quickly depleted and the beneficial micro-organism processes end. When crop residue is left on the soil surface, micro-organisms use the surface residue more slowly, remain active for longer periods, and significantly contribute to improving soil humus.

Table 2–2 Cation exchange capacity of three clay types and organic matter, in meq/100 grams of soil

Type	CEC meq/100 g
Kaolinite	10 – 20
Mixed clays	20 – 60
Montmorillonite clay	60 – 80
Organic matter	100 – 200

Figure 2–4 Residue increases diversity of plant and animal life in a field; biological activity increases in the residue cover and top few inches of soil



Tilling soil is similar to stirring a smoldering fire. Once the fire (soil) is stirred, the fire is quick to ignite (micro-organism activity increases), and carbon is oxidized. This process releases large amounts of CO_2, which is one of the greenhouse gases, to the atmosphere.

As micro-organisms decompose surface residue, they tie-up some of the available nitrogen in the soil. When the carbon-to-nitrogen ratio (C:N) is greater than 30:1, the rate of nitrogen tie-up is greater than the amount of nitrogen released during decomposition. Carbon is always more plentiful in residue than nitrogen. In some cases, such as small grain residue, the C:N ratio may be as high as 70 or 80:1, compared to alfalfa, which has a 15:1 C:N ratio. With a high C:N ratio, the amount of nitrogen required by micro-organisms during the decomposition process is greater than is contained in the residue. Therefore, micro-organisms use nitrogen from the soil (tie-up).

The decomposition process requires about 25 pounds of nitrogen for each ton of residue added. For most nonlegume crops, 30 to 40 pounds of additional nitrogen at planting should provide adequate nitrogen for decomposition without tying up soil nitrogen. As a continuous no-till system eventually reaches equilibrium, about as much nitrogen is being released by the micro-organisms as is being tied-up. This depends, however, on the crop being grown, precipitation, and soil temperature. Although the nitrogen is temporally tied up, it will be released during the growing season when the micro-organisms complete their life cycle. However, adequate nitrogen may not be available during the early growing season for some crops. In such cases starter nitrogen may need to be applied to help the crop get off to a good start. Under long-term no-till scenarios, nitrogen is released more evenly throughout the growing season compared to conventional systems.

In the Southern United States, the warm, humid climate causes a more rapid decomposition of crop biomass. Additional biomass, such as from cover crops, is often needed to maintain or increase soil organic matter levels.

The preceding information is most appropriate in the more humid areas of the country. In dryer, hotter climates, micro-organism activity is reduced and the impact on soil carbon and nitrogen tie-up is less.

Soil structure

The surface soil becomes more granular and friable when continuous residue management practices are implemented as compared to similar soil under conventional tillage. The extent of this change depends greatly on the residue management practice used. No-till/strip-till and ridge-till result in more rapid changes than mulch-till. These differences are primarily related to the amount of residue left on the surface and the amount of soil disturbance. Changes should be apparent under no-till/strip-till and ridge-till in 3 to 5 years. The kind of soil and climate also strongly influence how fast these changes occur. Improvements in soil structure tend to be more rapid in humid climates on many soils. Sandy soils and soils high in clay respond more slowly.

Some of the changes expected to occur include improved soil aggregate stability and water holding capacity, increased granular structure at the surface, and less surface ponding. In addition, there are benefits in relation to organic matter as described above and to water infiltration described in the next section.

Infiltration

Increased infiltration is a major benefit from residue management practices. With no-till/strip-till and ridge-till systems, the increase in infiltration is primarily a result of improved soil structure, slowed runoff, and leaving the old root and macropore structure undisturbed. In the case of mulch-till, infiltration increases, but because the macropore structure is destroyed with full-width tillage, the increase will be less than those systems that leave macropores intact. Mulch-till temporarily increases surface roughness and slows runoff, giving water more time to infiltrate. This is especially true immediately following chiseling or ripping operations until the field is smoothed by secondary tillage operations or the soil becomes saturated.

Macropores develop from earthworm burrows and decayed root channels. If these macropores are open to the surface, infiltration may significantly increase. There is some concern that macropores may act as a direct conduit for potential contaminants, especially when the water table is close to the surface. This may be a valid concern; however, macropores developed by earthworms are generally enriched with organic matter that absorbs potential contaminants. Except for the large night crawlers that can burrow vertically up to 4 feet, most earthworms live and maneuver horizontally in the upper 2 feet of the soil. Where full-width tillage is used, the macropores are disturbed to the depth of tillage and are not open to the surface.

With high residue management systems, plant available water can be significantly increased. This is an extremely important benefit, especially in areas where crop moisture stress is common.

Research in the Northern Great Plains showed that high residue management systems could save from 2 to 4 inches of soil moisture annually. Each inch of moisture saved increased wheat yields by about 5 bushels per acre and barley yields by nearly 9 bushels per acre.

Conserving soil moisture is extremely important for crop production in semiarid and arid climates as well as in more humid climates during extended dry periods. Leaving crop residue on the soil surface can effectively reduce evaporation and increase infiltration. Table 2–3 clearly indicates that potential evaporation can be significantly reduced by leaving surface residue. (See Chapter 5, Crop Management, for additional information.)

No-till and other high residue management systems can reduce the amount and frequency of irrigation. In these systems, runoff is slowed and infiltration is increased, surface evaporation is reduced, and the water holding capacity of the soil can increase over time. In addition, surface residue reduces seedbed temperature, which can both positively and negatively affect crop production. Growing small-seeded vegetable crops where high amounts of residue is left on the surface, however, is more difficult under irrigation

Table 2–3 Effectiveness of crop residue in reducing surface evaporation (Linden, 1987)

Surface cover, (%)	Relative potential evaporation
0	1.00
10	0.90
20	0.78
30	0.70
40	0.67
50	0.63
60	0.61
70	0.59
80	0.58

systems because of the need for a fine seedbed. This is generally not a concern where transplants are used. Flow rates in furrow irrigation systems also may be significantly reduced, influencing the amount of water applied at the upper end of the field compared to the lower end.

Compaction

Soil compaction resulting from tillage and vehicle traffic can be corrected in most cases. Other types of compacted layers occur naturally, such as hard pans or fragipans, and, depending on their depth and thickness, may or may not be correctable.

Soil compaction can be an extremely important limiting factor in crop production. Compaction can limit root penetration and reduce water and nutrient uptake by the growing plant. The problem may not be evident for several years after the damage is done if adequate soil moisture is present at shallow depths during the growing season.

If a compaction problem exists, it should be corrected before beginning no-till/strip-till or ridge-till. Once the compacted layer has been broken, heavy equipment should not be used when soils are wet. In addition, care must be taken to keep grain carts and trucks off the field as much as possible during the harvesting period. Controlled wheel traffic in the ridge-till system is an important benefit of this practice. (More information on this item is covered in Chapter 4, Conservation Tillage Equipment.)

Once compaction occurs, it is difficult to repair without deep tillage. Deep tillage destroys benefits previously gained under no-till. If deep tillage is necessary to repair compacted areas in a no-till field, it should be done only in those areas needing treatment.

Because chisel plows are often used in mulch-till, they can help eliminate shallow, compacted layers that may have occurred during tillage the previous year. Once these layers are broken, they can return quickly if heavy equipment is used again, especially if operated on wet soils.

With a no-till/strip-till system, the bulk density of the surface horizon may increase since the soil surface is not disturbed. This increase in bulk density of the surface may require adjustments at planting, such as adjusting down pressure springs or adding weight to the planter. Concern over higher bulk density at the surface with no-till will lessen as organic matter increases and soil structure improves. Generally, with ridge-till and mulch-till, an increase in surface bulk density is less of a concern because these two systems use tillage.

Crusting

Soil crusting can be a serious concern in soil that is low in organic matter. Soil crusting becomes much more prevalent on soil that is excessively tilled with little or no surface residue. As falling rain hits the soil surface directly, it can cause the soil to puddle, and when it dries a crust is formed. Soil crusting can interfere with crop emergence, and if severe enough, may require a rotary hoe operation to break the crust.

Residue management practices, particularly no-till, can significantly reduce crusting problems. The surface residue absorbs the impact of falling raindrops, increases organic matter, and improves soil aggregate stability. Generally speaking, no-till/strip-till and ridge-till practices have less problems with surface crusting compared to mulch-till since more surface residue is left and soil organic matter and soil aggregate stability are generally higher. Soils low in organic matter levels may experience crusting problems for several years even in a continuous no-till system.

Crusting can occur in the row area if row-cleaning devices are used too aggressively or if the field is in the first year or two of no-till. As organic matter increases and soil structure improves under continuous no-till/strip-till and ridge-till, crusting is generally not a concern.

Water quality

Sediment

Sediment is the number one pollutant in the United States. It not only creates physical problems, but also presents potential hazards to plants and animals.

Residue management practices significantly reduce soil erosion, increase infiltration, improve aggregate stability, and increase organic matter. When all of these benefits occur on a field, the amount of sediment reaching surface water is greatly reduced, resulting in improved water quality.

The greater the amount of surface residue cover, the greater the reduction in soil erosion. If soil erosion is reduced, sediment delivery is also reduced. If reducing sediment is a primary concern, no-till is most likely the best choice if it is adapted to the site.

There is no "silver bullet" for eliminating sediment in continuous row crop systems. However, the application of proper management practices can significantly reduce the amount of sediment that leaves a farm. Occasionally, high intensity, heavy rainfall storms occur that simply overwhelm land treatment measures and cause soil erosion and resulting sediment loads.

Nutrients

Nutrients, such as phosphorus, that attach to soil particles are slow to move in the soil profile, but can move with surface runoff and sediment. Residue management practices reduce erosion, improve infiltration, and reduce runoff. Therefore, they can play a key role in reducing the transport of phosphorus across the surface and potential contamination of surface water. Nutrients that attach to soil fines (clay particles) may not settle out and move with water flowing over the surface. Nutrients that are dissolved, but have not infiltrated the soil can move freely in surface runoff. Again, however, crop residue left on the soil surface slows surface runoff and increases the opportunity time for surface water to infiltrate.

Nitrate-nitrogen can move freely as water percolates through the soil. Care should be taken when applying nitrogen, especially with residue management systems, since water infiltration increases as surface residue increases. If nitrogen is applied in the fall, addition of a nitrification inhibitor should be considered. Applying nitrogen close to the time of greatest crop need is always a good management practice.

When manure is surface-applied as a nutrient source in no-till/strip-till and ridge-till, planning is needed to reduce the chances of surface runoff. Surface application should be applied with caution on frozen ground. Injecting manure with these systems greatly reduces the risk of surface runoff, but care must be taken not to excessively disturb the soil or surface residue cover. (See the section Air quality, Animal manure application—odors.) With the mulch-till system, surface-applied manure can be incorporated. However, to retain the desired residue quantity, another tillage operation may need to be omitted to offset the residue buried with the incorporation of the manure.

The nutrients applied with the manure should be accounted for in the overall nutrient management plan.

Pesticides

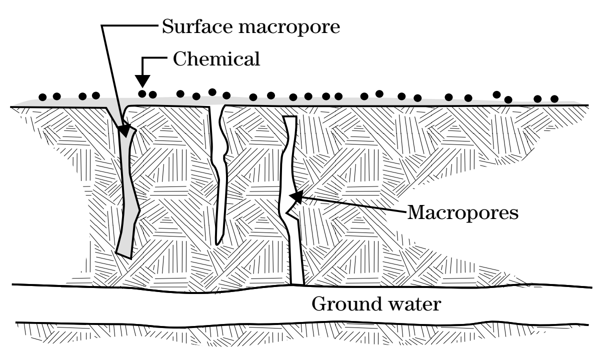
Herbicides and other pesticides can present a potential water quality concern similar to nutrients. Pesticides can either be soluble and move freely in surface runoff or become attached to soil particles and move offsite if the soil erodes. Residue management practices reduce erosion, surface runoff, and sediment delivery, thus reducing potential water quality problems associated with pesticide applications.

If the pesticide is quick to tie-up with soil particles, residue management practices that leave the greatest amount of surface residue cover will have the greatest benefit in reducing potential surface water contamination by the pesticide. If the pesticide is highly soluble, practices that reduce surface runoff and increase infiltration help keep the pesticide from moving offsite via surface flow. However, the potential for ground water contamination may increase, especially where the depth to the water table is shallow.

Extensive macropores (fig. 2–5), especially if open to the surface, have raised some concern about providing a direct conduit to ground water. As pesticides mix with water flowing over the surface, they may enter the large macropores that are open to the surface and move quickly into the soil profile.

Some macropores, especially earthworm channels, contain large amounts of organic matter along their walls. This layer of organic material can absorb some of these chemicals and help retain them in the upper portions of the profile. In addition, these earthworm channels have increased micro-organism activity so

Figure 2–5 Soil macropores



pesticide degradation can occur deeper in the soil profile as compared to fields with few or no macropores. With long-term no-till/strip-till and ridge-till, micro-organism populations can greatly increase. Microfauna can also significantly affect breakdown and degradation of chemicals and reduce their contamination potential.

Another consideration is the timing and amount of precipitation following pesticide application. A half inch rain after application of a soil applied pre-emerge herbicide is ideal to activate the chemical and move it into the soil surface where it is needed to stop weed emergence. If a large storm occurs following this smaller rainfall event, flow across a saturated surface may enter the macropores and move quickly down toward the ground water. In this case the water flowing over the surface is unlikely to pick up the applied herbicide because it has already been moved into the soil profile with previous smaller rainfall event. Consequently, the flow in the macropore is much cleaner than if the herbicide had not been moved into the upper soil surface.

The opposite of this situation can also occur. If a large storm occurs before the pesticide moves into the soil, there is a greater chance that the chemical may go into solution and move offsite with surface runoff. If surface flow is occurring as a result of saturated soil conditions, the pesticide may directly enter macropores. Surface application of a pesticide with a high solubility value should be avoided just before an imminent storm if the pesticide is not immediately incorporated.

Mulch-till provides the opportunity to make a tillage pass to incorporate a pesticide immediately after application. This significantly lowers the risk of pesticide movement by surface flow caused by an intense rainstorm.

Air quality

Particulate matter

Particulate matter of 2.5 or 10 microns (PM-2.5 or PM-10) has been identified as a potential health hazard. These very fine particle sizes can occur during wind erosion events or result from tillage operations.

Surface residue cover significantly reduces soil erosion caused by the forces of wind. No-till/strip-till, ridge-till, and mulch-till practices should provide sufficient residue cover to significantly reduce air quality hazards from PM-2.5 or 10. However, under low residue producing crops, erosion by wind can occur and could present serious problems in all three residue management practices. Cover crops, where practical, can be used to increase surface residue cover. Other supporting practices, such as cross wind trap strips, herbaceous wind barriers, and field windbreaks, can be used to reduce the wind erosion hazard.

In the case of mulch-till, surface roughness may add additional temporary protection that would not be present with no-till/strip-till or ridge-till practices. However, the supporting practices described in this chapter may be necessary when developing a plan to reduce air quality hazards where the mulch-till system is used because less residue is retained on the soil surface.

Animal manure application—odors

With no-till/strip-till and ridge-till practices, odors can present a problem with surface application of animal manure. Consideration should be given to wind direction at the time of application and the nearness of neighbors to help reduce odor concerns. Injecting animal wastes can significantly reduce odors. Injection equipment should be chosen that would not excessively disturb the soil surface and bury too much surface residue. Injecting manure in a no-till/strip-till or ridge-till system should be viewed no differently than knifing-in anhydrous ammonia or other forms of nutrients. Recently developed no-till injectors inject liquid manure with minimal soil and residue disturbance.

The quantity and distribution of manure is important. A large manure application without secondary tillage to mix it with the soil may burn the new crop.

In the case of mulch-till, chisels or disks can be used to incorporate the manure and reduce odor and runoff concerns. Again, care should be taken when incorporating the manure to ensure that sufficient residue is left on the soil surface to meet the erosion reduction goal. For example, a normal tillage trip might be omitted to accommodate the manure incorporation.

Chapter 3 Planning and Design

Part A Preparing Practice Specifications for No-Till and Strip-Till

Background information

The material in part A of chapter 3 will aid users in completing a job sheet for designing and developing specifications for No-till Residue Management on a site-specific field. The job sheet is based on information in the National Practice Standard. It provides background information, design criteria, and a place to record specifications for the site. State and local specialists are encouraged to modify these instructions or replace them with other instructions or directions based on local practice requirements.

Purposes of no-till

No-till has six purposes for which it can be designed and installed. Many of these purposes are instrumental in addressing water quality problems. No-till systems can:

- Reduce sheet and rill erosion.
- Reduce wind erosion.
- Maintain or improve soil organic matter content.
- Conserve soil moisture.
- Manage snow to increase plant available moisture.
- Provide food and escape cover for wildlife

Completing the specification worksheet

Refer to the completed example worksheet on page 15.

Step 1. Complete the Practice purpose section— Place an **X** in one or more of the purpose boxes to designate the purposes for which the practice is being planned and installed. More than one purpose may be served. Use the **Other** block for secondary purposes. Additional specifications may be required to accommodate secondary purposes. Enter them in the **Notes** section of table 1 or add supplement pages.

Step 2. Planned residue management specifications—Table 1 has the specifications for the planned practice. Enter information for each crop in the rotation on a separate line. Fields or tracts sharing a common rotation may be grouped on the same line. Entries for various residue parameters are to be based on erosion prediction calculations and other technology necessary to determine management needed to accomplish the designated practice purposes.

Residue orientation
Enter whether the residue will be standing or flat during the critical times of the year. Standing residue has proven to be more effective for wind erosion control, and flat residue is more effective for water erosion control.

Residue height
Enter the height of the stubble if the residue will be left standing during the critical times of the year. Otherwise enter N/A.

Row width
Enter the row widths of the crop. This information may be useful for erosion prediction.

Percent row width disturbed
Enter the percentage of row width disturbed by soil engaging implements. The no-till practice standard specifies no more than a third of the row width can be disturbed by soil engaging implements.

Pounds of residue
Planned—Enter the minimum amount of residue, in pounds, needed on the soil surface during the critical times of the year to accomplish the practice purpose(s).

Applied—This column may be useful for documentation purposes. Enter the pounds of residue actually present on the soil surface as determined by field estimation.

Percent residue cover
Planned—Enter the planned amount of residue, in percent ground cover, needed during the critical times of the year to accomplish the practice purpose(s).

Applied—This column is useful for documentation purposes. Enter the percent ground cover actually on the soil surface as determined by field estimation.

Step 3. Table 1 Soil conditioning index—The soil conditioning index (SCI) is a procedure in the NRCS National Agronomy Manual Part 508C to estimate the trend in soil quality expected to occur under specific crop and management scenarios. Refer to that manual for instructions to calculate SCI for a specific management system. If the trend appears to be negative, a change in crops, tillage, or management is recommended for sustained soil condition and productivity. This is an important component of the plan when soil improvement is a concern. SCI is an excellent tool to illustrate the potential for soil improvement with no-till systems.

Step 4. Table 2 Worksheet for estimating crop residue produced—This table is optional, but provides valuable information that may be needed to complete table 1. Table 2 is based on residue/yield ratios that indicate approximately how much crop residue is left above the soil surface compared to the crop yield. Local data are recommended for accuracy.

Step 5. Table 3 Design worksheet for residue budget—Table 3 is for optional use to estimate the effects of tillage and other field operations. It is sometimes referred to as a residue budget and is based on the implements used and the amount of residue left after a field operation is performed. Each operation requires another line of data. The final entry in the right hand column is an estimate of residue left on the surface after planting the crop. Figure 2 is provided to record local data that reflect residue reduction figures for applicable implements.

Residue retention values for various machines are in appendix A of the Conservation Tillage section of this document. These values represent the reduction in percent ground cover following a single pass of the implement. The percent ground cover, before each operation, multiplied by the retention value provides an estimate of cover remaining after the tillage operation. Ground cover estimates may be calculated any time during the year.

If residue amounts are expressed as pounds rather than percent cover, different retention values are necessary. Sources other than the National Agronomy Manual must be used.

Example field situation

A 40-acre field in southeast Nebraska is comprised of Pawnee clay loam and Wymore silty clay loam soils on slopes ranging from 7 to 9 percent slope. Slope lengths range from 150 to 200 feet (fig. 3–1). Several concentrated flow areas are in the field. They drain into larger tributaries that feed into a recreation lake downstream. For this reason, runoff from agriculture land, sedimentation, and soil erosion are concerns. Maintaining soil productivity is also a concern.

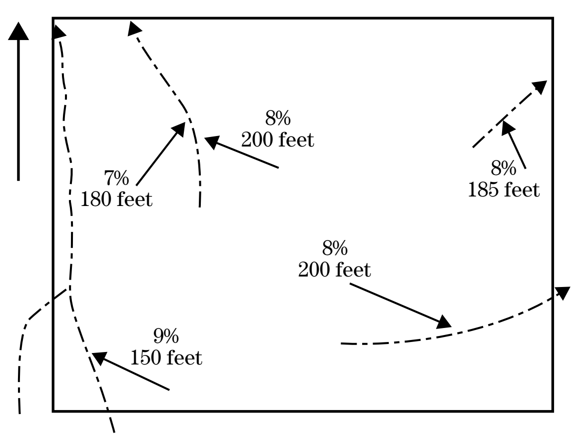
Erosion prediction calculations indicate a properly designed no-till system that has a corn-soybean rotation will reduce erosion to an acceptable level. After going through the erosion calculations, and discussing crops and yields it was determined that adequate amounts of residue will be available to provide the necessary cover (see tables 2 and 3). The calculations indicate 30 percent ground cover after planting is sufficient for the corn crop and 50 percent ground cover after planting is sufficient for the soybean crop (see table 1). Using no-till these residue levels should be easily accomplished.

The farmer is familiar with conservation tillage and has the equipment to carry out a no-till system.

Information in tables 2 and 3 of the job sheet and the SCI procedure indicate adequate amounts of residue will be left on or near the soil surface to significantly improve the soil condition.

Buffer practices, such as grassed waterways, field borders, filter strips, and riparian forest buffers, will protect the drainage areas and reduce potential water pollution downstream.

Figure 3–1 Field sketch for example



No-Till and Strip-Till Residue Management

Conservation Practice Job Sheet *329A*

Natural Resources Conservation Service (NRCS) *August 1998*

Landowner____

What is No-till and Strip-till?

No-till and strip-till are similar systems that can be described as managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year round, while growing crops in narrow slots or tilled strips in previously undisturbed residue. More specifically the systems are:

No-till: The residue is left undisturbed from harvest through planting except for narrow strips that cause minimal soil disturbance, such as injecting anhydrous ammonia. No-till is also referred to as zero-till, slot-till, direct seeding, or slot plant.

Strip-till: The residue is often left undisturbed from harvest through planting except for strips up to a third of the row width. These strips are cleared of residue or tilled for warming and drying purposes either before or during the planting operation. This practice is also referred to as row-till, zone-till, strip-till, or fall strip-till.

Purposes

Residue management systems can be designed to accomplish one or more of the following:

- Reduce water erosion
- Reduce wind erosion
- Maintain or increase soil organic matter content
- Conserve soil moisture
- Manage snow to increase plant available moisture or reduce plant damage form freezing or desication
- Provide food and escape cover for wildlife

Secondary Benefits

- Water quality improves both onsite and offsite.
- Air quality improves both onsite and offsite.
- Sedimentation is reduced.

Conservation Management Systems

Residue management systems, such as no-till and strip-till, are established as a component of a resource management system. Crop rotation, pest management, nutrient management, various structures, and buffer practices are used in resource management planning to address the natural resource concerns identified during the planning process.

Practice Specifications

Practice specifications are provided to assure the residue management system meets the resource needs and producer's objectives. The specifications are based on the amount, timing, and orientation of crop residue left on the soil surface. These planned requirements are recorded in table 1. Supporting information is included in tables 2 and 3 along with figures 1 and 2.

General Specifications
applicable to all practice purposes

- Residue to be retained on the field shall be uniformly distributed. Combines or other harvesting machines shall be equipped with spreaders capable of distributing residue over at least 80 percent of the combine header width.
- Secondary removal of crop residue by baling or grazing shall be limited to retain the amount of residue needed to achieve the intended purpose(s).
- Residue shall not be burned or disturbed by full width tillage operations except for occasional row cultivation for spot treatment of weed escapes or limited use of undercutting operations, such as sweeps or blades used to level ruts or alleviate compaction.
- Planting implements should be equipped with coulters and/or disk openers designed to cut through surface residue.
- No more than 1/3 of the row width shall be disturbed from harvest through planting by nutrient injection, row cleaning, planting, or other operations.
- Row cleaners may be attached to the planters to move residue out of the row area and help warm and dry the seedbed.
- Anhydrous injectors, manure injectors, and similar equipment may need to be modified to operate in high residue situations.
- Weed control techniques must be carefully planned, yet sufficiently flexible, to complement the system.

Additional Specifications
applicable to purposes identified during planning

Reduce erosion from wind and water, and improve water and air quality

- On sloping ground where water erosion is a problem, the row area formed during the planting operation shall be level with or above the row middles unless planting is on the contour. See table 1 notes.
- The required amount, timing, and orientation of residue will be in accordance with site specific data recorded in table 1. Current wind and water erosion technology will be used to establish minimum requirements.

Maintain or increase soil organic matter content

Tillage aerates the soil and increases crop residue decomposition. No-till and strip-till protect the soil from excessive erosion, reduce soil aeration from tillage, allow organic matter to accumulate, and improve the condition of the soil. The required amounts of residue for soil protection are specified in table 1. Tables 2 and 3 can be used to plan and record the crops, field operations, and management necessary to achieve a positive trend in soil organic matter content based on the NRCS Soil Condition Index (SCI) procedure described in the National Agronomy Manual.

Conserve moisture

Residue shall be evenly distributed and maintained on the soil surface to retain soil moisture for crop use by enhancing infiltration and reducing evaporation. A minimum of 50 percent surface cover is required to significantly reduce surface evaporation and meet the intent of this practice purpose.

Manage Snow

Maintain at least 6 inches standing stubble over winter when residue is maintained for snow management purposes.

Provide food and cover for wildlife

The amount of residue, height of stubble, and time requirements to meet the minimum needs of the target wildlife species are specified in table 1. This information is based on a wildlife habitat index procedure.

Record planned practice specifications in table 1. ***Tables 2 and 3 and figures 1 and 2 are for optional use when more detailed planning or design information is needed.***

No-Till/Strip-Till Design and Specification Worksheet

Farm:	Field: 1	No-till ☑	Strip-till ☐

Practice purpose (check one or more that apply)

✓	1	Reduce water erosion		5	Improve wildlife habitat (food and cover)
	2	Conserve soil moisture		6	Manage snow cover for plant available water
✓	3	Improve soil condition		7	Other
	4	Reduce wind erosion			

Table 1 Specifications (and application record)

Tract/ field	Crop to be planted	Previous crop residue	Orientation standing or flat (S or F)	Height in inches	Critical season(s)	Row width inches	Percent row width disturbed	Pounds of residue*		Percent residue cover	
								Planned	Applied	Planned	Applied
1	Corn	Soybeans	F	N/A	After plt.	30	30	N/A	N/A	30%	
	Soybeans	Corn	F	N/A	After plt.	7	30	N/A	N/A	50%	

Notes: If residue is managed for wildlife benefits, describe planned wildlife provisions. Also use this space to describe row direction, grade restrictions, or other site specific requirements.

The critical season for having minimum residue is after planting the crop.

Soil Conditioning Index (SCI) available and used *	(Yes)	No	**Calculated SCI value:** 1.5

Notes concerning soil quality: *The corn/soybean rotation with no-till provide significant long-term improvement in soil quality.*

*SCI provides an indication of the soil condition trend based on planned management. Positive values indicate an upward trend. Negative values indicate a downward trend. The values are based on how crops and management affect soil organic matter content. Refer to tables 2 and 3.

Table 2 Design worksheet for estimating crop residue produced (for planned rotation)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
Crop	**Harvest units**	**lb/unit**	**Yield**	**Residue/yield ratio**	**Est. lb residue/ac**	**Estimated percent ground cover**	**Instructions to estimate values for column 6 & 7**
Corn	bu	56	125	1.0	7,000	95%	Multiply columns 3x4x5 to estimate total pounds of residue available after harvest.
Soybeans	bu	60	40	1.25	2,625	78%	Figure 1 can be used to convert pounds of residue (column 6) to percent ground cover (column 7).
							Use local values for column 5.

Notes:

Information in column 7 is used in table 3 and an estimate of beginning ground cover for each crop in the rotation.

No-Till/Strip-Till Design and Specification Worksheet

Table 3 Design worksheet for residue budget

Crop	Previous crop	Beginning residue	Operation	Date	Percent retained*	Percent residue left
Corn	*Soybeans*	*78%*	*Over winter*	*4/1*	*80%*	*62%*
			Anhydrous	*4/15*	*85%*	*53%*
			No-till plant	*5/1*	*85%*	*45%*
Soybeans	*Corn*	*95%*	*Over winter*	*4/1*	*95%*	*90%*
			No-till drill	*5/1*	*90%*	*81%*

Notes: *The above estimates indicate about 45% ground cover will be present after planting the corn crop and about 81% ground cover will be present after planting the soybeans.*

*Local residue retention values are recorded on figure 2.

Figure 1 Residue lb/percent cover conversion

Percent cover	Corn	Soybeans	Cotton	Grain sorghum	Small grains
10%	250	250	400	300	250
20%	600	400	1,000	650	400
30%	950	600	1,600	1,050	600
40%	1,400	850	2,300	1,550	850
50%	1,850	1,200	3,200	2,100	1,200
60%	2,400	1,600	4,150	2,700	1,550
70%	3,300	2,100	5,300	3,600	2,100
80%	4,400	2,800	6,900	4,800	2,750
90%	6,050	3,900		6,750	3,850

Adapted from table D-4 and Figure 5-4, ARS Ag Handbook 703

Notes:

Figure 2 Machinery table

Implement local values that represent percent of ground cover left after operation	Percent for fragile residue (like peanuts)	Percent for non-fragile residue (like corn)
Over winter	*80%*	*95%*
Anhydrous appl.	*85%*	*90%*
No-till plant	*85%*	*90%*
No-till drill	*80%*	*90%*

Part B Preparing Practice Specifications for Mulch-Till

Background information

The material in part B of chapter 3 will aid users in completing a job sheet for designing and developing specifications for mulch-till on a specific field. The job sheet is based on information in the National Practice Standard. It provides background information, design criteria, and a place to record specifications for the site. State and local specialists are encouraged to modify these instructions or replace them with other instructions or directions based on local practice requirements.

Purposes of mulch-till

Mulch-till has six purposes for which it can be designed and installed. Many of these purposes are instrumental in addressing water quality problems. Mulch-till systems can:

- Reduce sheet and rill erosion.
- Reduce wind erosion.
- Maintain or improve soil organic matter content.
- Conserve soil moisture.
- Manage snow to increase plant available moisture.
- Provide food and escape cover for wildlife.

Completing the specification worksheet

Refer to completed worksheet on page 21.

Step 1. Complete the Practice purpose section— Place an **X** in one or more of the purpose boxes to designate the purposes for which the practice is being planned and installed. More than one purpose may be served. Use the **Other** block for secondary purposes. Additional specifications may be required to accommodate secondary purposes. Enter them in the **Notes** section of table 1 or add supplement pages.

Step 2. Planned residue management specifications—Table 1 contains the specifications for the planned practice. Enter information for each crop in the rotation on a separate line. Fields or tracts sharing a common rotation may be grouped together on the same line. Entries for various residue parameters are to be based on erosion prediction calculations and other technology necessary to determine management needed to accomplish the designated practice purposes.

Residue orientation
Enter whether the residue will be standing or flat during the critical times of the year. Standing residue has proven to be more effective for wind erosion control and flat residue is more effective for water erosion control. For mulch-till systems the residue is generally flat unless stubble mulching implements are used.

Residue height
Enter the height of the stubble if the residue will be left standing during the critical times of the year. Otherwise enter **N/A**.

Row width
Enter the row widths of the crop. This information may be useful for erosion prediction.

Pounds of residue
Planned—Enter the minimum amount of residue, in pounds, needed on the soil surface during the critical times of the year to accomplish the practice purpose(s).

Applied—This column may be useful for documentation purposes. Enter the pounds of residue actually present on the soil surface as determined by field estimation.

Percent residue cover
Planned—Enter the planned amount of residue, in percent ground cover, needed during the critical times of the year to accomplish the practice purpose(s).

Applied—This column may be useful for documentation purposes. Enter the percent ground cover actually present on the soil surface as determined by field estimation.

Step 3. Table 1 Soil conditioning index—The soil conditioning index (SCI) is a procedure contained in the NRCS National Agronomy Manual Part 508C to estimate the trend in soil quality expected to occur under specific crop and management scenarios. Refer to that manual for instructions to calculate SCI for a specific management system. If the trend appears to be negative, a change in crops, tillage or management is recommended for sustained soil condition and productivity. This is an important component of the plan when soil improvement is a concern. SCI is an excellent tool to illustrate the potential for soil improvement with mulch-till systems.

Step 4. Table 2 Worksheet for estimating crop residue produced—This table is optional, but provides valuable information that may be needed to complete table 1. Table 2 is based on residue/yield ratios that indicate approximately how much crop residue is left above the soil surface compared to the crop yield. Local data are recommended for accuracy.

Step 5. Table 3 Design worksheet for residue budget—Table 3 is for optional use to estimate the effects of tillage and other field operations. It is sometimes referred to as a residue budget and is based on the implements used and the amount of residue left after a field operation is performed. Each operation requires another line of data. The final entry in the right hand column is an estimate of residue left on the surface after a planned tillage system is actually applied. Figure 2 is provided to record local implement data.

Residue retention values for various machines are in appendix A of the Conservation Tillage section of this publication and in the National Agronomy Manual. These values represent the reduction in percent ground cover following a single pass of the implement. The percent ground cover, before each operation, multiplied by the retention value provides an estimate of cover remaining after the tillage operation. Ground cover estimates may be calculated any time during the year.

If residue amounts are expressed as pounds rather than percent cover, different retention values are necessary. Sources other than the National Agronomy Manual must be used. Use state or other localized values, if available.

Example field situation

A 40-acre field in southeast Nebraska is comprised of Pawnee clay loam and Wymore silty clay loam soils on slopes ranging from 7 to 9 percent. Slope lengths range from 150 to 200 feet (see fig. 3–1). Several concentrated flow areas are in the field. They drain into larger tributaries that feed into a recreation lake downstream. For this reason, runoff from agriculture land, sedimentation, and soil erosion is a concern. Maintaining soil productivity is also a concern.

Erosion prediction calculations indicate a properly designed mulch-till system that has a corn-soybean rotation will reduce erosion to an acceptable level. After going through the erosion calculations, and discussing crops and yields it was determined that adequate amounts of residue will be available to provide the necessary cover (see tables 2 and 3). The calculations indicate 30 percent ground cover after planting will be sufficient for the corn crop and 50 percent ground cover after planting will be sufficient for the soybean crop (see table 1).

The farmer is familiar with conservation tillage and has the equipment to carry out a mulch-till system.

Information in tables 2 and 3 of the job sheet and the SCI procedure indicate adequate amounts of residue will be left on or near the soil surface to maintain or slightly improve the soil condition.

Buffer practices, such as Grassed Waterways, Field Borders, Filter Strips, and Riparian Forest Buffers, protect the drainage areas and reduce potential water pollution downstream.

Mulch-Till Residue Management

Conservation Practice Job Sheet **329B**

Natural Resources Conservation Service (NRCS) ***August 1998***

Landowner____

What is Mulch-Till?

Mulch-till systems manage the amount, orientation, and distribution of crop and other residue on the soil surface year-round, while growing crops where the entire soil surface is tilled prior to or during the planting operation. Residue is partially incorporated using chisels, sweeps, field cultivators, or similar implements.

Purposes

Mulch-till systems can be designed to accomplish one or more of the following conservation purposes:

- Reduce water erosion
- Reduce wind erosion
- Maintain or increase soil organic matter and soil tilth
- Conserve soil moisture
- Manage snow to increase plant available moisture
- Provide food and escape cover for wildlife

Secondary Benefits

- Water quality improves both onsite and offsite.
- Air quality improves both onsite and offsite.
- Sedimentation is reduced.

Conservation Management Systems

Mulch tillage is normally used as a component of a conservation management system. It should be used in conjunction with Crop Rotation, Nutrient Management, Pest Management, the Buffer Practices, and other practices needed on a site specific basis to address natural resource concerns and the landowner's objectives. Major roles of the mulch-till component of a system include providing soil protection, reducing runoff, and improving soil tilth by allowing the soil to accumulate more organic matter.

Practice Specifications

Practice specifications are provided to assure the mulch-till system meets the resource needs and producer's objectives. The specifications are based on the amount, timing, and orientation of crop residue left on the soil surface. These requirements are recorded in table 1. Supporting information may be included in tables 2 and 3. Residue retention calculations recorded in table 3 are estimates to determine whether the planned number, sequence, and timing of farming operations will leave the specified amounts of residue. (Residue calculations are estimates highly dependent on such variables as operating speed, depth, field conditions, and adjustments.)

General Specifications
applicable to all practice purposes

- Residue to be retained on the field shall be uniformly distributed. Combines or other harvesting machines shall be equipped with spreaders capable of spreading residue over at least 80 percent of the combine header width.
- Secondary removal of crop residue by baling or grazing shall be limited to retain the amount of residue needed to achieve the intended purpose(s).
- Residue shall not be burned.
- Anhydrous injectors, manure injectors, and similar equipment may need to be modified to operate in high residue situations.
- Tillage implements, such as field cultivators, chisels, or similar tools, should be selected and operated to leave a specified amount of residue on the soil surface.
- Planting implements should be equipped with coulters and disk openers designed to cut through surface residue.
- Row cleaners may be attached to the planters to move residue out of the row area and help warm and dry the seedbed.

Additional Specifications
applicable to purposes identified during planning

Reduce erosion from wind and water, and improve water and air quality

The specified amount, timing, and orientation of residue will be in accordance with site specific data recorded in table 1. Current wind and water erosion technology will be used to establish minimum specifications.

Maintain or increase soil organic matter content

Tillage aerates the soil and increases decomposition of organic matter. Mulch-till reduces tillage and leaves the necessary amount of residue on or near the soil surface for soil improvement. The required amounts of residue for soil protection are specified in table 1. Tables 2 and 3 can be used to plan and record the crops, field operations, and management necessary to achieve a positive trend in soil organic matter content based on the NRCS Soil Condition Index (SCI) procedure described in the National Agronomy Manual.

Conserve moisture

Residue shall be evenly distributed and maintained on the soil surface during the growing season or fallow period to retain soil moisture for crop use by enhancing infiltration and reducing evaporation. A minimum of 50 percent surface residue cover is required to significantly reduce surface evaporation.

Manage snow

Maintain 6 inches standing stubble over winter to catch and retain snow cover. Operations that flatten or partly bury residue should be delayed until spring to achieve the stubble requirements for this purpose.

Provide food and cover for wildlife

The amount of residue, height of stubble, and time requirements to meet the minimum needs of the target wildlife species are specified in table 1. This information is based on a wildlife habitat index procedure.

***Record planned practice specifications in table 1.* Tables 2 and 3 and figures 1 and 2 are for optional use when more detailed planning or design information is needed.**

Mulch-Till Design and Specification Worksheet

Farm:	Field: 1

		Practice purpose (check one or more that apply)			
✓	1	Reduce water erosion		5	Improve wildlife habitat (food and cover)
	2	Conserve soil moisture		6	Manage snow cover for plant available water
✓	3	Improve soil condition		7	Other
	4	Reduce wind erosion			

Table 1 Specifications (and application record)

Tract/ field	Crop to be planted	Previous crop residue	Orientation standing or flat (S or F)	Height in inches	Critical season(s)	Row width inches	Pounds of residue*		Percent residue cover	
							Planned	Applied	Planned	Applied
1	Corn	Soybeans	F	N/A	After plt.	30	N/A	N/A	30%	
	Soybeans	Corn	F	N/A	After plt.	7	N/A	N/A	50%	

Notes: If residue is managed for wildlife benefits, describe planned wildlife provisions. Also use this space to describe row direction, grade restrictions, or other site specific requirements.

The critical season for having the minimum amount of residue on the surface is after planting the crop.

Soil Conditioning Index (SCI) available and used * — (Yes) circled / No — **Calculated SCI value:** 1.02

Notes concerning soil quality: *The corn/soybean rotation with mulch-till will maintain the soil organic matter and possibly provide a very slight increase.*

*SCI provides an indication of the soil condition trend based on planned management. Positive values indicate an upward trend. Negative values indicate a downward trend. The values are based on how crops and management affect soil organic matter content. Refer to tables 2 and 3.

Table 2 Inventory of crop residue produced (for planned rotation)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
Crop	**Harvest units**	**lb/unit**	**Yield**	**Residue/yield ratio**	**Est. lb residue/ac**	**Estimated percent ground cover**	**Instructions to estimate values for column 6 and 7**
Corn	bu	56	125	1.0	7,000	95%	Multiply columns 3x4x5 to estimate total lb of residue available after harvest.
Soybeans	bu	60	40	1.25	2,625	78%	
							Figure 1 can be used to convert pounds of residue (column 6) to percent ground cover (column 7).
							Use local values for column 5.

Notes:

Information in column 7 is used in table 3 as an estimate of beginning ground cover for each crop in the rotation.

Mulch-Till Design and Specification Worksheet

Table 3 Design worksheet for residue budget

Crop	Previous crop	Beginning residue	Operation	Date	Percent retained*	Percent residue left
Corn	*Soybeans*	*78%*	*Over winter*	*4/1*	*.80*	*.78 x .80 = 62%*
			Anhydrous	*4/15*	*.85*	*.62 x .85 = 53%*
			Field culti.	*4/25*	*.70*	*.53 x .70 = 37%*
			Planter	*5/1*	*.85*	*.37 x .85 = 32%*
Soybeans	*Corn*	*95%*	*Chisel plow*	*11/1*	*.80*	*.95 x .80 = 76%*
			Over winter	*4/1*	*.95*	*.76 x .95 = 72%*
			Field cultivated	*5/1*	*.75*	*.72 x .75 = 54%*
			Drill-disktype	*5/1*	*.95*	*54 x .95 = 51%*

Notes:

*Local residue retention values are recorded on figure 2.

Figure 1 Residue lb/percent cover conversion

Percent cover	Corn	Soybeans	Cotton	Grain sorghum	Small grains
10%	250	250	400	300	250
20%	600	400	1,000	650	400
30%	950	600	1,600	1,050	600
40%	1,400	850	2,300	1,550	850
50%	1,850	1,200	3,200	2,100	1,200
60%	2,400	1,600	4,150	2,700	1,550
70%	3,300	2,100	5,300	3,600	2,100
80%	4,400	2,800	6,900	4,800	2,750
90%	6,050	3,900		6,750	3,850

Adapted from table D-4 and Figure 5-4, ARS Ag Handbook 703

Notes:

Figure 2 Machinery table

Implement local values that represent percent of ground cover left after operation	Percent for fragile residue (like peanuts)	Percent for non-fragile residue (like corn)
Over winter	*80%*	*95%*
Chisel plow	*50%*	*80%*
Field cultivator	*70%*	*75%*
Double disk planter	*85%*	*95%*
Drill-disk type	*75%*	*95%*
Anhydrous	*85%*	*90%*

Chapter 4 Conservation Tillage Equipment

Harvesting equipment and operation

Grain harvesting equipment has advanced tremendously during the past 50 years. Early machines required harvesting and threshing as separate operations. Small grain crops were harvested, bundled, and hauled to the farmstead or to central points in a field to the threshing machine. Straw and chaff was separated from the grain and piled for later use as livestock bedding. Seldom was straw returned and redistributed over the field. The first combines were called harvester-threshers. They required a team of workers to accomplish what one operator can now handle with a modern combine designed to harvest and thresh all kinds of grain in a variety of crop and field conditions. These machines left the straw and chaff in the field, but typically in windrows rather than evenly redistributed over the field.

Pull-type combines began to be replaced by larger, more efficient self-propelled machines during the 1940s. Progress continues, and the combines available today have headers up to 30 feet wide for small grain or soybeans or up to 12 rows of corn. Special equipment is available for specific crops, but the fundamental design is about the same for all grain-harvesting combines. Uneven distribution of residue can be an even greater problem with these machines unless special attachments are used to redistribute residue over the full harvesting width of the machine.

The two basic types of self-propelled combines are:

- Level-land combines—Used in areas where the terrain is relatively flat or slightly rolling.
- Hillside combines—These models are necessary on steep, sloping hills, such as those of the Pacific Northwest. Hillside combines are equipped with pivoting axles and headers that allow the threshing system to remain level for efficient threshing. They also reduce the risk of accidents.

Combine operation

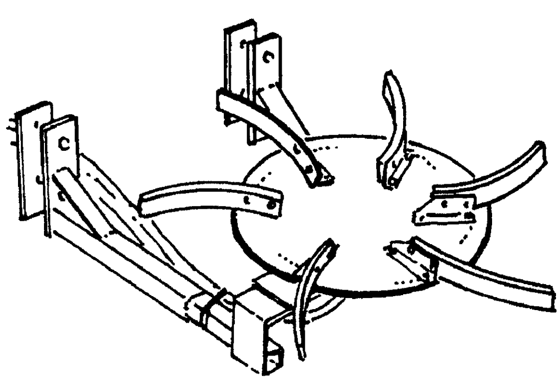
Conservation tillage systems require harvesting techniques that distribute the straw and chaff uniformly and keep as much straw anchored to the soil as possible. Consider the following:

- For no-till systems, leave stubble as high as possible without missing low growing heads.
- Standing stubble attached to the soil causes fewer problems than short cut stubble.
- Loose straw can cause equipment operation trouble as well as problems associated with floating or blowing residue that may accumulate during severe storms.
- Avoid frequent stops for unloading or other reasons.
- Each time the combine stops, it unloads a pile of straw. Accumulations of straw can cause problems.

Straw and chaff management

Large, modern combines handle a tremendous amount of straw and chaff. Therefore, distribution of crop residue during harvest is a significant management consideration. Windrows of the discharged material may occur and cause problems. Chaff is lightweight and easy to spread, but tends to drop out before it is delivered to the spreader. For that reason special attachments (fig. 4–1) are available to supplement the conventional straw spreader and help spread straw and chaff over the entire harvested width.

Figure 4–1 Chaff spreader attachment



Inadequate distribution of straw and chaff cause erratic field conditions and occurrences, such as planting and weed control problems.

Planting problems

- Moisture accumulates under heavy mats of straw and chaff. The resulting wet, cool conditions put extra stress on planting equipment and cause clogging.
- Poor depth control often occurs when residue is not uniformly distributed. Uneven distribution of residue causes erratic field conditions and difficulty in properly adjusting planters as well as other types of equipment.
- Inadequate seed-soil contact may occur because of hair-pinning or punching residue into the seed slot.
- Uneven stands and lack of seeding vigor often occur in the cool, wet spots caused by piles of residue.

Weed control problems

- Weed seeds accumulate in piles of residue. This can result in weedy spots and inadequate stands or poor vigor of the planted crop.
- Herbicide activation may be erratic because of interception of the applied material by the piles of crop residue. If soil applied chemicals fail to reach the soil in the spots occupied by residue piles, weedy spots may develop.
- The wetness caused by residue piles may enhance weed seed germination.

Other residue management considerations

Rodent problems

Rodent problems often increase because of additional food and cover provided by piles of straw and chaff. An increase in rodent population caused by leaving residue on the soil surface is considered a major problem in some areas of the Nation.

Nutrient tie-up

Nutrient tie-up as well as the allelopathic effects of excessive amounts of residue near the planted seed can adversely affect plant growth and vigor. Allelopathy refers to the effects of naturally occurring chemicals produced in some plants that adversely effect germination or growth of plants. These problems are usually associated with small grain, but can be a problem for other crops.

Shredding stubble

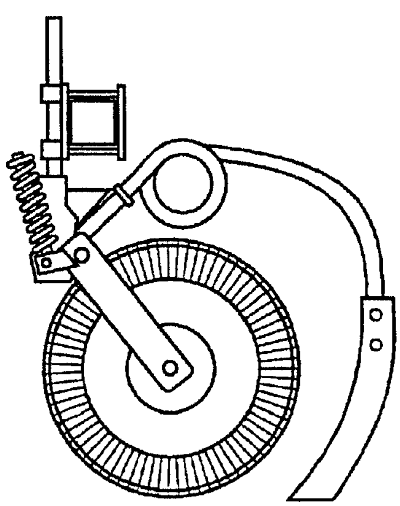
Shredding stubble was a common management technique at one time. However, the problems outweigh the benefits and now few experienced no-tillers shred their stubble. Detached residue may float away during high runoff events and plug culverts and drainage structures or form "drifts" that must be removed. Most farmers have stopped this practice.

Farmers have found by experience that standing stubble causes fewer problems than loose material that can float or blow away and cause problems previously mentioned. Standing stubble generally is less problematic than shredded stubble where large volumes of loose material must be dealt with when anhydrous is injected or at planting time. If there is an advantage to shredding, it is the fact that shredded stubble provides more soil cover and better protection from water erosion. However, for wind erosion purposes, the standing stubble is more effective.

Fertilizer application equipment

Fertilizer application equipment for conservation tillage may require minor changes to accommodate equipment operation in large amounts of surface residue. Application equipment that engages the soil generally requires coulters (fig. 4–2) to cut through the residue and reduce clogging. Closing disks, wheels, or other attachments are often used to close the application slot and redistribute the residue over the cleared strip. Other than that, no changes are necessary.

Figure 4–2 Coulter-knife anhydrous applicator



Equipment for broadcast applied fertilizer does not require change, and modern planting equipment is normally equipped to apply fertilizer simultaneously with planting.

Manure management equipment and operation

Manure applications on no-till and strip-till require some extra planning and equipment specialization. If surface applications are applied, the same equipment can be used for all tillage systems. However, leaving the material on the surface results in loss of plant nutrients from volatilization and surface runoff. The primary environmental concern is the potential risk of polluting the air and water by not incorporating applied manure. Therefore, incorporation of the manure by injection is the recommended method of applying manure in a no-till or strip-till situation.

Mulch-till systems can be planned for tillage incorporation of the manure. For no-till and strip-till, traditional manure injection equipment tills the soil excessively, covers too much of the crop residue, and consequently reduces the benefits of conservation tillage. In addition, the equipment requires extensive power and is expensive to operate and maintain. Equipment is becoming available that uses close spaced, narrow knives that inject the material just below the soil surface. Technology is available for placing the manure on the soil surface underneath the crop residue. The residue slows runoff and allows the dissolved nutrients to enter the soil.

The main point is that manure application on no-till and strip-till poses a few problems, but the problems are being solved by technology improvements.

Planting equipment for no-till

Purposes of the planter or grain drill are to plant seeds evenly and to create favorable conditions for germination and growth. Regardless of the tillage system, surface residue, or method of seedbed preparation, the planter must perform the following functions:

- Open a seed furrow
- Meter the seed
- Place the seed in the furrow
- Cover the seed
- Firm the seedbed

No-till planting equipment performs these same functions, but to perform them properly, coulters and other specialized attachments may be needed to cut through residue, mark rows, and close the seed slot or place fertilizer (fig. 4–3).

Coulters

Coulters are usually needed to cut a path through the surface residue ahead of the disk opener and to slice open the seedbed so the disk openers can deposit the seed. The types of coulters are used on corn planters and drills are wavy or fluted, bubbled, rippled, notched, and smooth. The type of coulters needed depends on the crop being planted, kind of soil, soil conditions, and residue kinds and amounts.

Fluted coulters—Although the ideal width for most conditions is 1 to 1.5 inches, fluted coulters (fig. 4–4) have been manufactured in various widths. Wet soils and clay soils tend to stick to the wide fluted coulters, which pitch large chunks of soil out of the seed row thus making seed coverage difficult. On wet soils fluted coulters may leave a wavy pattern filled with clods, which interferes with uniform seed placement and seed furrow closure. The 1- to 1.5-inch fluted

Figure 4–3 No-till drill with coulter caddy

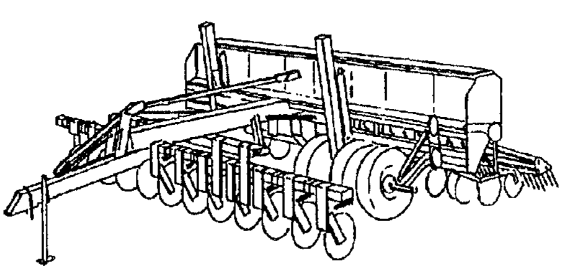
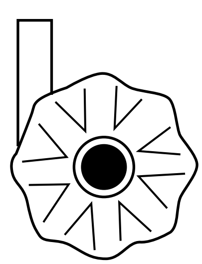


Figure 4–4 Fluted coulter



coulters till a slot wide enough to allow double disk openers to place the seed at optimum depths without creating sidewall compaction. This wider slot permits deeper planting since double disk openers will contact the sidewalls at deeper depths than with narrower coulters.

Bubble and ripple coulters**—**Bubble and ripple coulters (fig. 4–5) till a 0.5- to 0.75-inch slot. Because of this narrow slot, the double disk opener operation depth may be restricted somewhat, which may be a problem if deeper planting is desired. Bubble coulters do not till as much of the seed slot as fluted coulters and may cause sidewall compaction when operated on wet soil and higher organic matter soil. Generally, these coulters are recommended for ground that has been tilled.

Smooth and notched coulters**—**Smooth and notched coulters (fig. 4–6) have the narrowest slot width and do a good job of cutting through sod or heavy residue. They do not till the seed zone to any extent.

In some soil the need to till a wider strip has led to the development of multiple coulter systems that use two or three coulters mounted side by side.

On most corn planters coulters are typically placed as close to the planter unit as possible to ensure uniform cutting depth and seed placement. They are often bolted directly to the front of each planter unit and set to run at a depth of 1 to 2 inches.

In most soil conditions the double disk openers and coulters should be set to operate at about the same depth. When soil is dry, coulters should be set slightly deeper than the seed openers to ensure that loose soil is present at the bottom of the seed slot. This provides good seed-soil contact. When soil is wet, coulters should be set slightly shallower than seed openers to ensure that seed is placed in firm soil in case the seed zone later dries out.

Row cleaners

Row cleaners (fig. 4–7) consisting of a metal spike wheel often are used in addition to coulters to clear residue from the row area. In the case of no-till, little if any tillage is done with these attachments. The metal spike wheels should not be set to till the soil. If this is done, the dryer soil is moved to the side exposing moist soil. This moist soil can be compacted by the planter unit in the row area.

Figure 4–5 Bubble coulter and ripple coulter

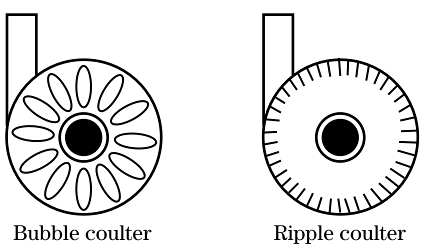


Figure 4–6 Smooth coulter and notched coulter

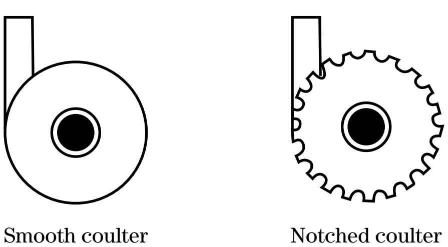
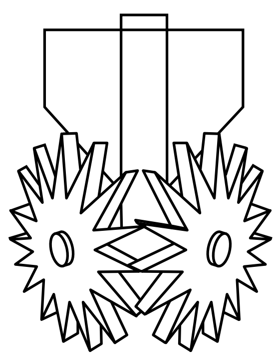


Figure 4–7 Spike wheel row cleaners



Disk or furrow openers

***Double disk openers*—**Double disk openers (fig. 4–8) are necessary in high residue systems such as no-till. These openers are typically mounted parallel and equidistant to each other and form a V-shaped slot into which the seed is dropped as the planter moves along. Potential problems in wet soil may include sidewall compaction, poor seed-slot closure, and poor seedling development.

***Staggered or offset double disk openers*—**These disk openers have a narrower angle because one disk is mounted slightly to the rear of the other. This creates a narrower seed slot; thus, less soil is moved and less sidewall compaction results. The offset double disk also cuts through surface residue better than the normal double disk opener.

Gauge wheels

Gauge wheels are critical in determining uniform planting depth of each row unit. Each planter unit generally has two gauge wheels immediately to the sides and slightly behind the double disk openers.

Press wheels (fig. 4–9) operate directly over the seed furrow and ensure good seed-soil contact by closing the furrow created by the disk opener.

Either one or two press wheels are on each row unit depending on make of planter. They may be 1, 2, or 3 inches wide and are either single or dual V types. Wet or clay soils may cause balling up of 3-inch press wheels. The narrow V press wheels close the seed slot better in dry or shallow planting conditions. They place less pressure on the seed zone and are typically made of hardened nylon or stainless steel. One manufacturer also offers heavy cast-iron press wheels for no-till use. To avoid compaction in the row, care should be taken when using these heavy press wheels under soil texture and moisture situations conducive to compaction.

Seed firmers (fig. 4–10) are small devices, such as plastic wheels or shoes, that run in the bottom of the seed trench to firm it for better seed placement.

Figure 4–8 Planter seed furrow openers

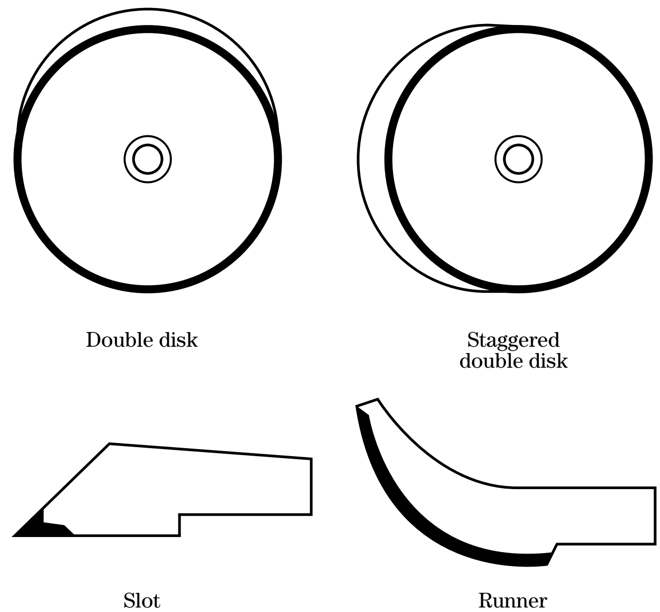


Figure 4–9 Planter press wheels

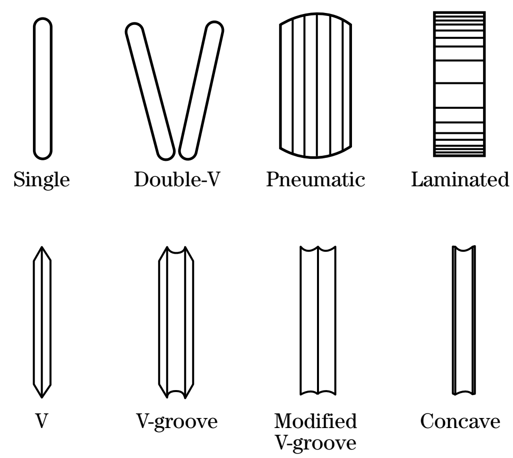
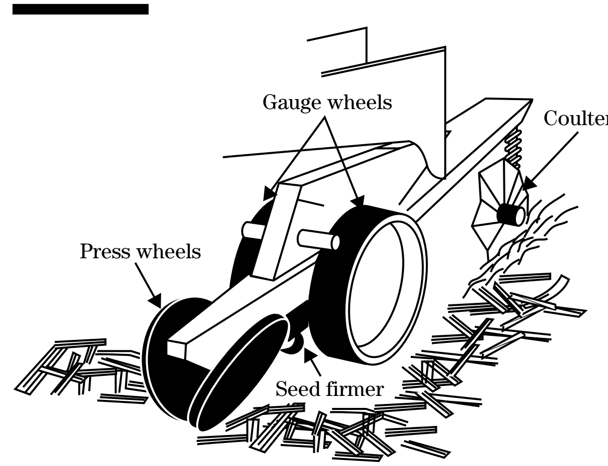


Figure 4–10 Press wheels and seed firmers



Weight and down pressure

Most no-till planters are equipped with adjustable down pressure springs or pneumatic down-force systems on the parallel linkage of each row unit to exert constant force on the coulters and planter units. In some conditions more weight may need to be added to the frame to ensure proper coulter penetration.

Insecticide application

Planter box seed treatment is the most common for pests, such as seed corn maggots, that attack the seed. An insecticide box attachment with an adjustable metering device and delivery tubes is typically used for inseed furrow or on row application of insecticides.

Starter fertilizer

If starter fertilizer is applied with the no-till planting operation, separate coulter and knife opener attachments are available for applying granular or liquid fertilizer. These attachments are set to apply starter fertilizer 2 inches to the side and 2 inches below the seed. Liquid tanks are often mounted on the tractor with pumps and metering devices that deliver starter fertilizer through tubes to the seed furrow. A more thorough description of fertility and equipment is covered under Fertilizer application equipment (p. 32).

Planter marking systems

The presence of high amounts of crop residue in no-till systems can be challenging to marking systems. No-till systems markers generally need to be weighted to cut through heavy residue and cover crops or sod. However, disk markers may cause poor weed control in the marker row if excessive soil is disturbed and herbicides moved or buried.

Drills and air seeders

Coulters

Typically, coulters on no-till drills are the same types as on no-till planters. However, they may be mounted several feet in front of the drill units on coulter caddies in fluff and plant systems. The planting depth is controlled to a large degree by the operating depth of the coulters. Because the coulters are mounted on a separate toolbar from the drill units, weight transfer for down pressure is applied through the tractor's hydraulic system. Not all drills use coulters, however.

Seed openers

Double disk openers, offset disk openers, and single disk openers are typically the same types as on no-till planters except that they are mounted on much closer row spacings. At least two manufacturers use a single large disk opener that runs on a slight angle to function both as a coulter and seed opener. These systems are referred to as *slice and plant systems* and are typical of the Deere 750 and Crustbuster All Plant drills. These disturb the least soil and require the least down pressure. The Case-IH offset disk opener also disturbs very little soil and can be used without a coulter, but is not typically used on drills.

Press wheels

Press wheels are typically the same as on no-till planters. Their primary function is to close the seed slot and ensure good seed soil contact to ensure good germination. Some drills have a second set of closing wheels running on an angle to improve seed furrow closing.

Other closing and covering devices

Most no-till drills have a tine or linked harrow mounted behind the drill to redistribute residue moved by the coulters and openers and to move and level the soil over the seed row. Redistributing residue over the row conserves moisture and improves germination.

Sprayers for burndown herbicides

Pesticide drift is minimized when the sprayer produces droplet sizes larger than 100 microns. The range is 100 to 400 microns for best coverage. Uniform coverage and penetration into the weed canopy are essential when applying burndown herbicides. The two best spray nozzle types for no-till applications are regular flat fan nozzles and flood nozzles. Number 8006 or smaller flat fan nozzles set 18 to 20 inches above the surface or the top of weed or cover crop growth on 20- to 30-inch spacings provide 30 to 50 percent overlap of spray material. The TK-5 or smaller flood nozzles set to provide 100 percent overlap is also suitable. Flood nozzles should be turned down or angled no more than 45 degrees from vertical to direct spray into the canopy or to the soil surface to avoid drift and increase accuracy. To reduce the chance for drift and increase accuracy, flat fans and floods should run at 20 to 30 pounds per square inch at speeds less than 12 miles per hour.

Specialized soil engaging implements for no-till

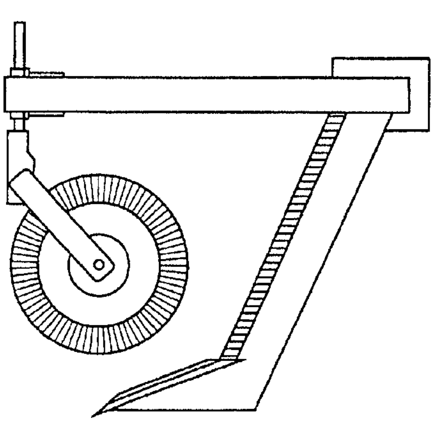
Soil compaction can be a concern when the soil is high in sand or clay. Textural classes in between these extremes do not seem to have the compaction problem.

Surface crusting can also be a problem during the first few years of no-till because it takes time to build up a sufficient amount of organic material in the surface layer to eliminate crusting. The no-till purist opposes the use of tillage implements of any kind. However, if a compaction or crusting problem exists, a few specialized implements are available to help the situation without serious reductions in surface residue.

An implement called an Aerway is a soil aeration tool sometimes used in no-till and strip-till when crusting is a concern. This machine is similar to, but more aggressive than, the implement used on golf courses to punch holes in compacted soil to improve aeration and drainage. The implement buries little residue and if properly operated should be appropriate to use with no-till systems.

Other soil-engaging tools are occasionally used with no-till. They include subsurface tillage tools, such as the Paraplow, BlueJet Subtiller, and Rawson Zone Builder, which shatter and fracture compacted horizons in the soil profile (fig. 4–11). These low disturbance rippers are designed to breakup compacted soil layers with only minimum surface disturbance. The soil should be dry when these machines are used to maximize the shattering effects on the compacted layers. Operating these machines in wet soil can aggravate the compaction problem. Little crop residue is buried, and these implements are effective when compaction is a concern.

Figure 4–11 Subsoil chisel



The use of any of these tillage tools on a regular basis in no-till should be avoided because tillage tends to accelerate the breakdown of organic matter and negates many of the benefits to the soil.

Equipment for mulch-till

Tillage machines

With mulch-till, full width tillage equipment is used to till the entire soil surface while leaving some quantity of residue on the surface. None of the tools used in mulch-till result in complete inversion of the soil, as is the case with the moldboard plow. Mulch tillage tools fall into three primary categories: subsurface, primary, and secondary. Most tools fall into only one of these categories; however, tandem disks and field cultivators may be used either for primary or secondary operations.

Appendix A of the Conservation Tillage section of this document contains a range of residue retention values for various machines based on research and experience that can be used to estimate crop residue amounts left. The variability results in part from:

- Differences in crop varieties and the quantity and quality of residue produced
- Differences in residue distribution and residue orientation following crop harvest
- Differences in tillage equipment adjustments, operating speed, and depth
- Differences in soils including texture, structure, and moisture content

The appendix was developed jointly by Equipment Manufactures Institute's Tillage and Planting Equipment Committee, Agricultural Research Service, and Natural Resources Conservation Service.

Subsurface tillage

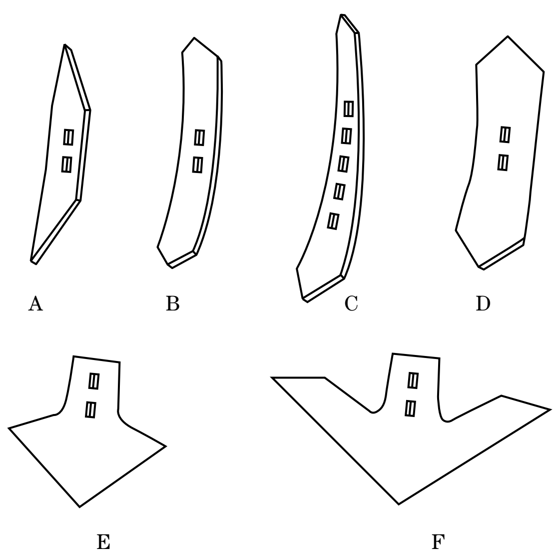
Tools, such as the Paraplow or Paratill, subsoil chisels, deep vee ripper/subsoilers, and disk-subsoiler combinations, are used primarily to fracture tillage pans to improve air and water movement in the root zone. These tools normally are operated as deep as 14 inches so they work beneath the compacted layer and fracture it. Rippers and subsoilers are typically equipped with coulters or disks to cut and mix residue with the soil. Some of the tools may bring big chunks of soil to the surface. If this happens, additional secondary tillage operations are needed to break these clods and level the field.

Primary tillage

Primary tillage operations are performed to loosen and fracture the seedbed; to cut, size, and partly incorporate crop residue; and in some cases to eliminate existing vegetation. If too much of the previous crop residue is buried by the primary tillage operation, it is difficult to bring it back to the surface with secondary operations. The most typical primary tillage machines used in mulch-till systems are chisel plows, disks, field cultivators, and blade plows.

Many plow models available on the market are equipped in various ways to accommodate differing residue and soil conditions. Disk chisels and coulter chisels work well in heavy residue, and most are designed with adequate clearance between ranks of chisel standards or shanks. Selection of the specific primary tillage tool and the type of ground engaging points or blades (fig. 4–12) is critical to the success of mulch-till systems that require moderate to high amounts of residue on the surface. Generally the less inversion action the point or shovel creates, the less residue is buried. Sweeps and spike points bury less residue than do straight points or twisted shovels. Slower speeds and shallower operating depths generally leave more residue.

Figure 4–12 Chisel plow points and sweeps



A 2-inch reversible spike point
B 2-inch reversible chisel plow point
C 3-inch twisted shovel
D 4.5-inch reversible shovel
E 8- or 10-inch shovels
F 12- to 18-inch sweeps

Several types of disk harrows are used including tandem and offset disks. Disks are designed to cut and incorporate residue as they roll across the soil, so they are less likely than chisel plows to become plugged with residue. However, disks tend to compact the soil and to bury more residue, especially under wet soil conditions.

Tandem disk harrows are used as primary and as secondary tillage tools. These harrows consist of four gangs of disk blades mounted in tandem with the front gangs throwing soil out and the rear gangs throwing soil in. Aside from the original choice of the shape, size, and spacing of disk blades, no retrofitting with different blades is normally performed. Most tandem disks do have some provision for adjusting the angle of the disk gangs. The straighter the angle the less aggressive the mixing and incorporation. Cutting depth and front to aft leveling adjustments are also critical to the operation of disks and to surface residue retention. Shallower operating depths tend to retain more residue.

Offset disks are used typically only for primary tillage where aggressive burial and incorporation of vegetation and residue are desired. They are rarely used as secondary or seedbed fitting tools. Offset disks consist of two gangs of concave disks in tandem. The gangs cut and throw soil in opposite directions. The cutting angle of each gang is adjustable as is overall depth and leveling. Offset disks tend to bury large amounts of residue and should be avoided in low residue producing crops and fragile residue.

In some parts of the country, blade plows are used as primary tillage tools. Wide 3- to 5-foot sweeps or blades are set to run at shallow depths to keep residue disturbance to a minimum, yet disrupt the root systems of competing vegetation.

Secondary tillage operations

Tandem disks are often used as secondary tillage tools to level and firm the seedbed and to incorporate surface applied nutrients and chemicals. Because disks are effective at incorporating, they tend to bury more residue than other secondary tillage tools. They are often equipped with harrows and other leveling attachments. The narrower the spacing between blades, the more mixing and incorporation occurs. To maximize residue retention, choose the wider disk blade spacing, operate as shallow and as slowly as possible, and decrease the gang angle.

Field cultivators have become quite popular in mulch-till systems because they bury less residue than disks, are effective in mixing and incorporating chemicals, and can be operated at faster speeds without ridging the soil. Several types of shovels and sweeps are available, as are the types of standards on which they are mounted. Finishing attachments are often added to destroy young weeds, mix chemicals, break clods, and firm and level the soil. Tine-tooth harrows clear more residue, spike-tooth harrows break clods, and rolling baskets also break clods, incorporate chemicals, and firm the seedbed. Chopper reels chop and size residue and mix it with the soil. Incorporator wheels mix chemicals below the residue and kick residue back to the surface. Wider sweeps and wider shank spacing and shallow operating depths increase residue retention.

Combination tools and ***seedbed finishers*** are typically combinations of disks and field cultivators with additional finishing attachments. They are intended for one-pass seedbed preparation and are typically designed with increased frame and fore and aft clearance for good flow of residue. Disk gangs should be operated no deeper than the depth of the sweeps. Shallow operating depths, wider standard spacing, and the choice of wider sweeps tend to retain more residue.

Planting equipment

Planters and drills are the same as previously described under no-till and strip-till. Depending on the amount of residue, some situations may require the use of row cleaners such as the spike wheels or row cleaning disks to move residue out of the row area.

Bubble coulters may be used on planters and drills in mulch-till systems, but when heavy residue is encountered, the same fluted and rippled coulters as described under no-till are often used.

Multiple sweep row cultivators, the same as used in conventional systems, are typically used in mulch-till. In heavy residue a rolling cultivator, rotary ground driven finger wheel, or a large single sweep may be better suited.

Fertilizer application equipment for mulch-till may require minor changes to accommodate equipment operation in large amounts of surface residue. Application equipment that engages the soil generally requires coulters to cut through the residue and reduce clogging. Closing disks, wheels, or other attachments are often used to close the application slot and redistribute the residue over the cleared strip. Other than that, no other changes are necessary.

Equipment for broadcast applied fertilizer does not require change, and modern planting equipment is generally designed to apply fertilizer simultaneously with planting.

Manure management equipment and operation

Manure applications on mulch-till require some extra planning and equipment specialization. Surface applications require the same equipment as conventional tillage. Leaving the material on the surface results in loss of plant nutrients from volatilization and surface runoff. The potential risk of polluting water supplies is a concern. Therefore, incorporation of the manure by light tillage or injection is recommended. Traditional manure injection equipment tills the soil excessively and may cover too much of the crop residue. Equipment is becoming available that uses close-spaced, narrow knives that inject the material just below the soil surface. In addition, new technology is being developed for placing the manure on the soil surface underneath the crop residue.

The residue can then slow runoff and allow the desolved nutrients to enter the soil. Mulch-till allows the option of light tillage to incorporate the manure. This is an advantage over the no-till systems.

Equipment for ridge-till

Harvesting equipment considerations

Ridge-till systems require only slightly different harvesting techniques than no-till systems. However, since next year's crop is planted on this year's ridge, care must be taken to protect the shape and height of the ridge during the harvesting operation. Tire size, alignment, and spacing of wheels on the combine, grain cart, and tractor must be such that the tires do not run on top of the ridges. Combines should be equipped with narrow tires and be spaced apart to not destroy the shape of the ridges. Wide flotation tires should be replaced with narrow duals or triples spaced and aligned to run in the furrows between the ridges. Tire spacing and alignment of tractors and grain carts should match the row spacing and avoid running on top of the ridges. Incidental traffic from grain carts should be avoided, and to the extent possible, restricted to the end rows and to rows where the combine wheels have already run.

Ridge-till planters
These planters are equipped with some type of row cleaning device (fig. 4–13) that skims the top 1 to 2 inches of the ridge and moves a mixture of soil and residue to the furrow between the rows. Row cleaners include horizontal disks, small row cleaning disks, and blades or sweeps.

Guidance systems
Typically, some type of stabilizer disk or ridge tracking gauge wheel system is used to keep the planter units centered on the old ridge. Some ridge-till planters use remote guidance systems that shift the toolbar hydraulically from side to side on the tractor's three-point hitch to keep planter units centered on the ridges.

Sprayers
Because row cultivation to rebuild ridges is an integral part of the ridge-till system, broadcast application of herbicides is not as critical. Banding of herbicides over the row using even flat fan (banding) nozzles mounted on the back of each planter unit makes for a one-pass tilling, planting, and spraying operation.

Specialized soil engaging implements for ridge-till
The most common specialized implement for ridge-till is the ridging cultivator (fig. 4–14). This type of implement is necessary for cultivation between the rows and ridge formation.

Ridge-till is essentially a controlled traffic system with only a few rows receiving the bulk of the wheel traffic from harvesting, fertilizer application, planting, and cultivating operations. Soil compaction can be a concern with ridge-till on these rows. The paratill machine with "legs" mounted on a conventional toolbar is effective at alleviating this compaction if performed when soils are dry. By running this tool in the furrows, little crop residue is buried. As with all field operations in ridge-till, care must be taken to avoid running tractor and implement tires on the ridges.

Fertilizer application equipment
Fertilizer application equipment for ridge-till may require minor changes to accommodate equipment operation in large amounts of surface residue. Application equipment that engages the soil generally requires coulters to cut through the residue and reduce clogging. Closing disks, wheels, or other attachments are often used to close the application slot and redistribute the residue over the cleared strip. Other than that, no other changes are necessary.

Equipment for broadcast applied fertilizer does not require change, and modern planting equipment is generally designed to apply fertilizer simultaneously with planting. However, when applying lime or fertilizer with a floater, the soil should be frozen to avoid compaction and disturbance of the ridges.

Manure management equipment and operation
Manure applications on ridge-till require some extra planning and equipment specialization. Surface applications require the same equipment as conventional tillage, but leaving the material on the surface results in loss of plant nutrients, especially nitrogen, from volatilization and surface runoff. Tillage necessary to incorporate the manure will cover the crop residue. Therefore, incorporation of the manure by injection is recommended. Traditional manure injection equipment tills the soil excessively and may cover too much of the crop residue.

Figure 4–13 Ridge cleaning devises

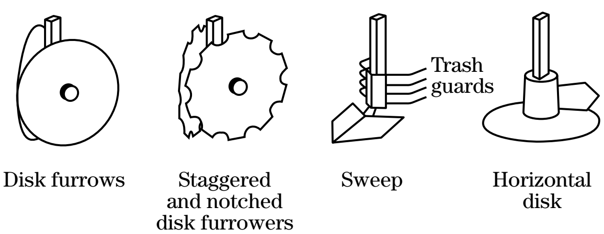
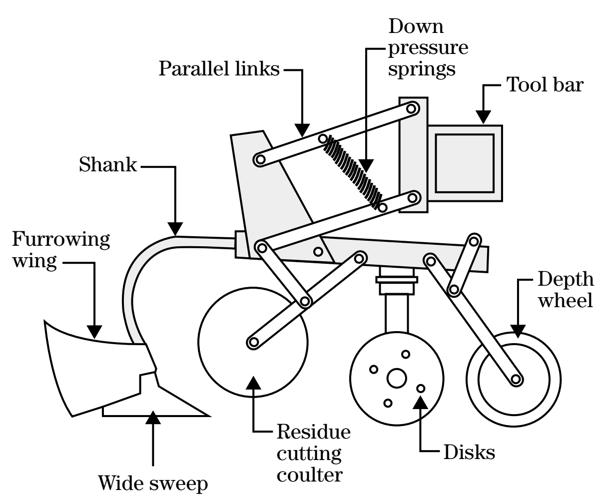


Figure 4–14 Conservation tillage cultivator



Chapter 5 Crop Management

Variety traits

Varieties or hybrid selection are important for conservation tillage systems. Depending on previous crop and latitude, cooler and wetter conditions may exist at planting time. Consequently, varieties should be selected that have the following characteristics:

- Good early growth
- Vigorous root system
- High yields
- Good germination under cool conditions
- Good standability under high populations
- Ample residue for erosion control
- Other agronomic traits (disease, insect resistance)
- Seed treatment for reducing seedling disease

The importance of selecting varieties with these characteristics varies depending on the sensitivity of the crop to the cool, moist conditions that may be experienced at planting time.

Moisture management

Two processes affect moisture management in the surface soil. One is tillage, which decreases the soil density and results in an increase in soil moisture evaporation. Secondly, the residue insulates the soil from the sun's rays reducing moisture evaporation. Depending on soil type, moisture management (too much or not enough) needs to be evaluated both at planting and during crop development.

Planting time

At planting time in sandy soils, no-till may result in improved germination because of the moisture savings associated with the lack of tillage and the insulating effects of large amounts of surface residue. In medium to fine textured soils with excess moisture levels at planting, an additional pass with a horizontal tillage implement (field cultivator, disc, or finishing tool) increases evaporation resulting in improved moisture levels for planting. With excess moisture eliminated, soil temperature ordinarily increases provided the air temperature is sufficient. When this additional pass is performed in no-till systems, the system is no longer a true no-till system because full-width disturbance has occurred. Improvements expected in organic matter and macropore development will be set back. The producer must consider such compromises when making decisions at planting.

No-till planting on poorly drained, clayey soil where the desired soil temperature may be retarded may require patience, and possibly result in delayed planting in some years. However, some type of strip manipulation of the residue may be necessary before planting to accelerate evaporation in the row area.

Compacted zones in the top 14 inches of the soil profile may restrict the movement of water downward as well as upward. These compacted zones may be naturally occurring or may be the result of previous tillage or other field operations. Some type of vertical tillage (ripper) to remove these compacted zones (create uniform soil density) may be needed before no-till is used. If this can be done and horizontal tillage can be eliminated, then a more uniform soil density is created and provides soil conditions that result in vigorous root growth. Vertical tillage may result in a soil that is more "weather proof" because it has uniform density and is better able to tolerate wet or dry periods.

Crop development period

Crop residue retards evaporation from the soil profile and results in additional moisture available for the crop. If compacted layers have been eliminated and macropores have developed, then infiltration may also increase. No-till systems may allow an additional 2 to 4 inches of available moisture being available later in the growing season. This may result in increased yields. Some areas have been able to intensify cropping rotations to take advantage of this additional moisture. In areas of higher rainfall, this increased moisture availability (increased yields) may only make a difference in years when a dry period occurs later in the growing season. Although this additional moisture may buy the grower some time, it is still possible to have inadequate moisture during a prolonged drought. Conversely, years with timely and adequate rainfall may not show any yield advantage related to moisture.

The residue and moisture level of the soil also affects soil temperature. The same factors that resulted in cooler soil temperatures for no-till at planting result in cooler soil temperatures later in the growing season. Overall, soil temperature fluctuates less in systems that are not tilled as compared to bare, intensively tilled soil. Daytime high temperatures are lower and nighttime low temperatures are higher with no-till systems. Consequently, lack of soil temperature fluctuations may result in increased root growth and improved soil biological activity.

Nutrient management

Soil testing

Conservation tillage systems do not mix the soil as much as moldboard plowing. Even chisel plowing with 4-inch twisted points mixes only about 50 percent of the upper 8 inches of the soil profile. This reduction in mixing may result in nutrient stratification. It is recommended that pH, phosphorus, and potassium be at maintenance levels before beginning any conservation tillage program. Obviously, this is even more important in a no-till system because there is little or no soil mixing. Although nutrient stratification may occur, there is not a direct correlation with a decrease in yields. Yet with no-till most of the nutrients are in the top 2 inches and sufficient soil moisture needs to be available in that part of the soil profile for the plants to take up these nutrients.

When taking soil samples, some samples should be taken to monitor the top 2 inches as well as to sampling to the normal state-recommended depth .

Phosphorus and calcium move slowly though the soil profile, and management may need to be adjusted if levels warrant. Phosphorus, potassium, pH, and maybe even micronutrients should be tested frequently, at least every 3 or 4 years. The State Extension Service Office may have other guidelines or suggestions for specific crops.

Pulling soil samples for nitrate levels may involve pulling cores from 1 to 2 feet depending on State Extension guidelines. Nitrate testing needs to be done every year for that particular crop. In humid areas, spring soil nitrate testing is usually recommended.

pH and liming

Before beginning a no-till system, pH must be adjusted to desired levels. The usual recommendation for a no-till system is to apply half as much lime twice as often. High lime application without incorporation can cause an interaction with certain herbicides. This interaction may cause herbicide carryover or crop injury. Lime normally does not move much in the soil profile; however, earthworms may account for some movement.

Nitrogen management

Conservation tillage systems may require additional nitrogen applications. Generally, university recommendations should be followed regarding nitrogen needs based on crop yield, but may not be adequate for a no-till system. Crops like no-till corn may require 10 to 15 percent additional nitrogen during the early transition to no-till. During the first 5 years of no-till, the slower decomposition rate of the residue, caused by lack of tillage, may alter the normal C:N ratio in the soil. In cool climates crops, such as corn, must receive 30 to 40 units of nitrogen as starter with the planter to help overcome the cooler soils and nitrogen tied up in the residue. Tillage results in faster mineralization of the nitrogen from organic matter and decaying residue as compared to no-till systems.

Nitrogen can be incorporated with a mulch-till system, sidedressed with mulch-till or no-till, and can be broadcast in a no-till system. Anhydrous ammonia is less expensive than 28 percent nitrogen, but either can be used as the principal nitrogen source. However, the potential for nitrogen volatilization into the atmosphere with surface-applied 28 percent nitrogen in a no-till system must be understood. Without tillage to incorporate the nitrogen, a rain greater than 0.5 inch needs to occur within 48 hours after application in humid areas or the risk of nitrogen loss is significant. Actual loss varies depending on temperature and humidity. Some producers surface apply 28 percent nitrogen before expected rainfall events to minimize losses. This is somewhat risky if the expected rain does not occur. Another option is to use a nitrification inhibitor with 28 percent nitrogen. This provides as much as an additional 14 days time before a rainfall event is needed to incorporate the nitrogen in the soil profile. Even with a nitrogen inhibitor, there is still some risk of nitrogen volatilization.

Anhydrous ammonia is an option as a principal nitrogen source with mulch-till or no-till systems. Anhydrous, a gas under pressure, must be injected into the soil. A coulter ahead of the knife (5 to 7 inches deep) cuts through the residue and sealing disks behind the knife keep the ammonia from escaping. Anhydrous can be applied fall preplant (where fall soil temperatures reduce nitrification), spring preplant, or sidedressed. In some areas early spring preplant application of ammonia causes compaction problems because of soil wetness. The ridges formed during ammonia application may result in additional planter bounce. Although anhydrous ammonia may be deadly to earthworms, research shows that only those within

4 to 5 inches of the knife are injured and that overall populations rebound within a few weeks.

Fall strip-till is a specialized no-till system where planting occurs in a previously tilled strip (10 inches wide). A common system used in the Northern Corn Belt is to add row markers to an anhydrous ammonia toolbar and apply ammonia in the fall with the same row spacing as the planter. The crop is then planted into these tilled strips the following spring. Usually the soil temperature is 5 to 8 degrees warmer at planting time because of this zone tillage. Toolbar length and row spacing must match the planter. The knife and covering disks should create a mound 3 to 4 inches high. This area will settle and mellow over the winter and result in a slight mound at planting time. Phosphorus and potassium may also be applied with the ammonia using specialized equipment.

Phosphorus management

Phosphorus should be at a maintenance level before beginning a no-till or mulch-till system. Some phosphorus stratification will be evident in the top 2 inches with either tillage system, but more so in no-till. Use of phosphorus in starter fertilizer may help overcome slow early growth. The use of starter fertilizer containing phosphorus is critical in soil testing low in phosphorus.

Starter fertilizer

In row crops the standard starter fertilizer placement configuration is 2 inches to the side and 2 inches below the seed. There are several different dry and liquid fertilizer formulations. Pop-up fertilizer is applied directly into the seed trench, but care should be taken because too much pop-up fertilizer may result in seedling injury. In addition, higher rates of starter and pop-up fertilizer may cause crop injury under dry soil conditions. Liquid fertilizers are easier to handle, but are more expensive than dry fertilizers. Micronutrients may also be added to the starter fertilizer, if needed.

Pest management

Weeds

Weed control for mulch-till and conventional tillage is about the same. The biggest difference is that soil-applied herbicides that require one or two trips of incorporation may significantly reduce surface residue levels. Soil-applied herbicides can be applied on top of the residue (after tillage), but are then dependent on rainfall for incorporation and activation. Post-applied products are another alternative and do not need rain for activation.

Weed shift

With no-till systems a shift in weed species may occur. New weed species may appear because of the lack of tillage and the change in herbicide mode of action being used with no-till. Winter annuals may increase and small-seed weeds, which usually germinate at the soil's surface, may become more dominant. Large-seed weeds, which generally germinate deeper, decrease with no-till systems. Perennial weeds may increase under no-till, including trees and shrubs in some areas. This is particularly true in the warm, humid areas of the South.

Weed control

Usually a burndown is needed in a no-till system to control existing weeds before planting. Careful scouting is needed to help decide on a burndown application since weeds may be small and hidden by the residue. The weather before planting dictates the presence of weeds, and the burndown may be omitted in northern climates if no weeds are present in the field. Cool, cloudy weather may affect the performance of translocated herbicides.

The perception exists that more herbicides are used in a no-till system. However, with the new chemistry available, other than the burndown herbicide, about the same chemicals and application rates are used. With the increased use of weed-specific, post-applied products in no-till, there may be more actual spraying operations. The cost of weed control in no-till was generally somewhat higher, but with the use of bioengineered crops and price reductions of some products, this price difference has changed. Timely scouting and paying attention to weed height (small weeds may be easier to control with some products) may allow growers to use a post emergent product at less than label rates.

The mulch from high residue systems or the use of cover crops has reduced weed pressure and in some cases resulted in less herbicide being used.

Mulch-till and no-till systems may involve one or a combination of early preplant, pre-emergent, and post application products. Regardless of the tillage system, rotating modes of action is a good practice to help prevent herbicide resistant weeds.

Diseases

Four key factors are involved in disease management:

- Presence of susceptible host crop
- A pathogen (disease causing agent)
- Environment that favors the pathogen
- Adequate time for economic damage to occur

Integrated pest management is used as a preventative tool as well as a corrective action. In some areas lack of rotation causes increased disease pressure. Diseases have not been a major factor in the adoption of high residue systems when a good crop rotation is used.

Insects

Insect problems and controls generally are no different for no-till as compared to other tillage systems. The exception is that early weed growth may attract some insects. Appropriate scouting and integrated pest management techniques should be used to reduce the risk of insect damage.

Crop rotation

The importance of crop rotation cannot be overemphasized for successful no-till or mulch-till implementation. Generally rotating a grass with a legume provides the most consistent results. Breaking the green bridge between living roots of older host plants that cause disease problems and the newly planted crops is critical as one rotates from one crop to the next.

Cover crops

Cover crops are particularly important following low residue producing crops. In the South, where overwinter decomposition occurs more rapidly, cover crops are beneficial regardless of the tillage system. However, tilling of the cover crop before planting reduces some of the potential benefits of the cover crop. Cover crops aid in erosion control and also add organic material to the soil. They also may aid in scavenging nitrogen (deep-rooted cover crop) or could be a nitrogen source (legumes). The timing of the burndown application is critical as far as moisture management is concerned. If the cover crop uses too much soil moisture before planting, moisture for crop germination may not be sufficient. In addition, cover crop establishment in northern areas may be difficult because the time between harvest, cover crop seeding, and freeze up is insufficient for this purpose. Cover crops can be used to remove excess soil moisture before planting.

Allelopathic crop effects

Some plants produce toxic material during the breakdown of residue. These chemicals may inhibit the germination or vigor of other plants. This can be detrimental or beneficial. For example, corn planted into corn residue, wheat into wheat residue, or alfalfa into an alfalfa stand, may result in poor stand establishment resulting from autotoxicity, a specific type of allelopathy. Some varieties of these crops are more sensitive than are others. On the other hand, soybeans planted into a rye cover crop may have little weed pressure because of the allelopathic effect produced by decaying rye residue on germinating weed seeds.

Chapter 6 Economic Considerations—Conservation Tillage

Introduction

The overall economics of different tillage/production systems varies among regions, crops, and individual farms and even among fields. Differences in input costs between tillage systems in many cases result in a higher cost in one input area and reduced cost in another (tables 6–1 to 6–5). Although savings in input costs may be significant for some systems, yields can also be a major factor in overall profitability. An overall evaluation of the "bottom line" or actual profit margin needs to be made to compare various tillage systems, especially with no-till. In addition, year-to-year weather variability influences yields.

The two biggest economic factors that may cause producers to consider conservation tillage systems are labor and equipment savings. When conservation tillage systems are applied there are fewer trips made compared to conventional or intensive tillage systems, resulting in fuel savings, less equipment and equipment repairs, and less labor. As tillage is decreased, herbicides are more important for weed control.

Example scenerio

Benchmark condition (future without treatment)
The setting for this evaluation is a 660-acre crop and livestock farm that includes a confined hog production operation of 2,100 pigs per year. The crop rotation is corn, soybeans, and wheat.

The farm is experiencing some soil erosion and resulting sedimentation, old gradient terraces need renovation, the grassed waterways have gullies on each side, and the channels are silted-in. Some trees and shrubs are encroaching into the waterways. The farmer has requested NRCS help in replacing the terrace system with a parallel tile outlet system to eliminate the waterways and brushy draws. The farmer participated in the watershed meetings to discuss sediment and chemical runoff problems in the Peru Lake and is concerned since the farm is served by a rural water system that uses Peru Lake as its source.

Future condition (conservation tillage/no-till)
Based on the stated request of the farmer, the conservation planner decided to investigate at least two other alternatives to reduce the problem.

- a no-till conservation system versus the farmer's conventional till system (tables 6–1 to 6–3)
- a no-till system with nutrient management to the farmer's current conventional till system (tables 6–4 to 6–5)

The enterprise production budgets for conventional tillage and no-till corn, wheat and soybeans used in this evaluation were obtained from the USDA, NRCS staff at the Blackland Research Center in Temple, Texas.

Table 6–1 lists the physical effects that are attributed to the alternatives chosen for evaluation.

Economic evaluation (conventional tillage system versus no-till system)
Tables 6–2 and 6–3 reflect the changes that can be expected to occur in the farmer's production cost if he decides to switch from a conventional tillage system to a no-till system.

For this evaluation, the yields of corn, soybeans, and wheat were held constant. Additional changes were:
Soybeans—two disking and one cultivation eliminated and a no-till drill replaced a row planter.
Wheat—one disking and one plowing eliminated, a grain drill replaced by a no-till drill and two additional sprayings added.
Corn—one disking, one plowing, and one cultivation eliminated and two sprayings added.

Only the changes in the variable production costs were calculated. Labor and fuel costs for all crops decreased; and the cost of herbicides for soybeans and wheat increased; seed cost for soybeans, and herbicide use in corn production all increased.

Table 6–3, which is the partial budget itself, reflects that as a result of the trade-offs that occurred, some costs for the corn will be reduced and added costs for the soybeans and wheat will increase.

Given the conditions and constraints specified for this no-till system, if the farmer decided to switch to this system the overall net change would reflect an additional $1,500 being expended for production costs.

Table 6–1 Summary comparison of effects of alternatives (future condition compared to benchmark condition)

Pluses +	Minuses —
Economic effects	
Increased yields and returns	Increased seed costs
Reduced equipment use and repairing	Increased herbicide costs
Reduced labor and fuel costs	Increased risk
	New equipment purchases
Social effects	
Improved water quality in Peru Lake	Additional chemical use
Increased leisure time	Forced to acquire new managerial skills
Improved air quality	
Overall improved environment	
Resource effects	
Increased soil moisture	New technology and managerial skills required
Increased organic matter	
Improved soil tilth	
Less compaction	
Reduced sheet and rill and gully erosion	
Improved wildlife habitat	

Table 6–2 Conventional tillage system versus no-till system

Crops	Conventional tillage system	No-till system	Increase/ decrease
		Returns	
	($/ac)	($/ac)	($/ac)
Corn	291.00	291.00	N/C
Soybeans	202.00	202.00	N/C
Wheat	192.00	192.00	N/C
Crop/Operations		**Costs**	
Corn			
Operating/machinery costs	17.00	5.00	– 12.00
Material costs	100.00	95.00	– 5.00
Other costs	5.00	5.00	0.00
Total	**122.00**	**105.00**	**– 17.00**
Soybeans			
Operating/machinery costs	14.00	6.00	– 8.00
Material costs	55.00	83.00	28.00
Other costs	3.00	4.00	1.00
Total	**72.00**	**93.00**	**21.00**
Wheat			
Operating/machinery costs	12.00	6.00	– 6.00
Material costs	38.00	49.00	11.00
Other costs	3.00	3.00	0.00
Total	**53.00**	**58.00**	**5.00**

Simply stated, with this alternative the farmer would solve the resource problem, but would have an added $2.36 per acre in out-of-pocket production expense.

Economic evaluation (conventional tillage system versus no-till system with nutrient management)

Tables 6–4 and 6–5 reflect the changes that would occur in the farmer's variable production costs and returns if the decision was made to switch from conventional till to a no-till system complemented with nutrient management. In this alternative the farmer gains with yield increases attributable to balancing nutrient inputs with the needs of the crops during their growth cycle. The waste generated by the confined hog operation would be a source of noncommercial nutrients.

In addition to the previously measured changes in the variable production costs for no-till, the operating and machinery costs for each crop increased $3.00 per acre to include a manure spreader. An $8.00-per-acre, $14.00-per-acre, and $6.00-per-acre fertilizer cost was eliminated from the production budgets for corn, wheat, and soybeans, respectively.

The partial budget in table 6–5 demonstrates that as a result of the trade-offs that occurred, there will be some increased returns and reduced costs for both corn and wheat, plus added costs for soybeans.

If the no-till plus nutrient management alternative is adopted as formulated, the farmer would increase the net returns of the operation by $16,000.00 or $25.00 per acre as well as address the resource problem.

Table 6-3 Partial budget - conventional tillage system versus no-till system

Added returns		-0-
Reduced costs		$4,760
Corn	$17 x 280 = $4,760	
Reduced returns		-0-
Added costs		$6,260
Soybeans	$21 x 280 = $5,880	
Wheat	$5 x 76 = 380	
Net change for operation		**– $1,500**

Presented with the first alternative, everything else being equal, the farmer would normally only consider installing the first alternative if a cost share or other incentive payment was available. However, given the outcome of the evaluation of the second alternative, the farmer may be encouraged to adopt this system because it provides an opportunity to improve the bottom line.

Individual practices often do not solve all soil and water resource conservation problems. Planning flexibility and associated economic analysis can often suggest adding other practices to the system.

Conclusion

Reduced labor cost is a major factor in adopting no-till in some areas. As farms increase in size, producers are looking for ways to farm these acres without adding additional help or equipment. Extra help may not be readily available and is only needed on a seasonal basis. Conservation tillage facilitates expansion or allows operators to use the timesavings for livestock operations, grain marketing, or off-farm employment.

Machinery savings may be substantial in a no-till system as a result of reduced field operations. If a producer is able to convert to a complete no-till system, then most primary and secondary machinery is not needed. Depending on the size of the operation, less horsepower and fewer tractors may be required, which can substantially reduce operation costs. In addition, less maintenance is needed since the machinery is not being operated as many hours each year.

The age and condition of the producer's existing tractor and tillage equipment inventory may be a major consideration in making the transition to no-till. The cost of purchasing no-till equipment makes more economical sense if the existing line of equipment needs replacement because of age.

Generally speaking, no-till systems offer a slight to fairly significant reduction in input costs. If proper management of conservation tillage is used, yields will most likely be maintained and costs will decrease. An overall improvement in the efficiency of a farm operation will result and thus enhance profitability. In areas where moisture retention is improved and soil productivity rises, yield increases can be expected together with improved profits.

Table 6–4 Conventional tillage system versus no-till system with nutrient management

Crops	Conventional tillage system		No-till system plus nutrient management		Increase/decrease	
			Yields	**Returns**		
	(bu/ac)	($/ac)	(bu/ac)	($/ac)	(bu/ac)	($/ac)
Corn	140	291	150	312	10	21
Soybeans	37	202	42	229	5	27
Wheat	58	192	62	205	4	13
Crop/Operations			**Costs**			
Corn						
Operating/machinery costs	17.00		8.00		– 9.00	
Material costs	100.00		87.00		– 13.00	
Other costs	5.00		5.00		0.00	
Total	**122.00**		**100.00**		**– 22.00**	
Soybeans						
Operating/machinery costs	14.00		9.00		– 5.00	
Material costs	55.00		77.00		22.00	
Other costs	3.00		4.00		1.00	
Total	**72.00**		**90.00**		**18.00**	
Wheat						
Operating/machinery costs	12.00		9.00		– 3.00	
Material costs	38.00		35.00		– 3.00	
Other costs	3.00		3.00		0.00	
Total	**53.00**		**47.00**		**– 6.00**	

Table 6–5 Partial budget —Conventional tillage system versus no-till system with nutrient management

Added returns			$14,428
Corn	$21 x 280	= $5,880	
Soybeans	$27 x 280	= 7,560	
Wheat	$13 x 76	= 988	
Reduced costs			$6,616
Corn	$22 x 280	= $6,160	
Wheat	$6 x 76	= 456	
Total			**$21,044**
Reduced returns			-0-
Added costs			$5,040
Soybeans	$18 x 280	= $5,040	
Net change for operation			**$16,004**

Chapter 7 New Technology

Bioengineering (herbicide tolerant crops)

Bioengineering is changing the way crops are grown in a big way. Although the first bioengineered crop was introduced a few years ago, the adoption rate has been anything short of spectacular. Some herbicides kill weeds by inhibiting the plant enzyme acetolactate synthase (ALS). Corn and soybeans were bred to be resistant to certain herbicides, such as Pursuit, Poast, and other ALS inhibiting herbicides. Soybeans, cotton, and corn were bioengineered to be "Roundup Ready®." Roundup will control the weeds, but not harm the crops. Liberty Link™ corn is available, which allows spraying Liberty herbicide that controls the weeds, but will not damage the corn.

Bacillus thuringiensis (Bt) is the bacterial organism that causes fatal diseases in specific insect pests. Bt has been bioengineered into cotton, corn, potatoes, and other crops to control certain insects, such as European corn borer and bollworm. Gene stacking allows placing multiple bioengineered traits into crops, such as Bt and Roundup Ready® corn and Bt and Roundup Ready® cotton. Coming in a few years will be Bt corn, which protects corn from corn rootworm and other traits.

The technology fee associated with some bioengineered crops varies from $38 per acre (Bt and Roundup Ready® cotton), $10 per acre (Bt corn), and $5 to 7 per acre (Roundup Ready® soybeans). Although results vary depending on conditions, the use of bioengineered crops generally results in increased profits for producers because of the increased yield potential from the reduced insect pressure, improved weed control, or both.

Depending on the specific bioengineered trait, if fewer pesticides are applied, then the potential for offsite movement is reduced. The overall result of bioengineered crops is improved yields and less environmental risk.

Precision farming

Precision farming or site-specific farming actually embraces several technologies. Global Positioning System (GPS), Variable Rate Technology (VRT), yield monitors, and injection systems are some of the technologies used under the precision farming umbrella. The concept of precision farming is to place the right inputs in the right location at the right time.

GPS uses satellites to locate your position within a field. By linking your position in the field in real time, controllers can be used to either vary the rates of inputs or monitor yields.

VRT involves variable rate application of one or a combination of the following: fertilizer, herbicide, seed, and insecticide.

Variable rate application of phosphorus and potassium was one of the early precision farming technologies. Grid soil samples are taken using GPS, and a variable rate application map is developed. Although the size of the grid may vary depending on the region of the country, the crop, and additional costs, a 2.5- to 3.3-acre grid size is generally typical. A dry or liquid fertilizer is then applied using GPS and a controller on the application vehicle to vary the actual application rate.

Some areas of the field may receive no fertilizer and some may receive more fertilizer than the past practice of applying the same rate uniformly across the field. Overall change in the amount of fertilizer applied depends on past fertilizer practices. Generally, there has been little correlation associated with variable rate P and K application and yields. This is not surprising because in most cases P and K levels are not the limiting factor. Generally the added expense of variable rate application of phosphorus and potassium has not shown a return on the investment and the environmental benefits have been difficult to quantify.

Variable rate application of lime to adjust pH has, however, shown a positive return. Lime applied only in areas needing lime and at the proper rate increases the possibility of ultimately having uniform pH across the field. The cost of lime and application rates makes variable rate lime application a practice that farmers will adopt from an economic standpoint. Grid soil sampling increases in popularity for variable lime application.

Variable rate nitrogen application is more difficult from an agronomic standpoint. Grid soil sampling to determine nitrogen in the soil and then varying nitrogen rates has been successful from an economic and environmental standpoint with sugar beets. However, it is more difficult with crops like corn. The weather is still a major factor, plus the agronomic research has not been done to scientifically support the “correct” nitrogen application rate for a given point in a field.

Variable rate herbicide application has been used to a limited extent. Label rates for soil applied herbicides vary by clay content and organic matter. By developing a grid map based on clay content and organic matter, a sprayer with GPS and controllers can vary the application rate across the field. Based on the limited use, there was a slight reduction in overall amount of herbicides applied.

Yield monitors

Yield monitors are another aspect of precision farming that holds a lot of potential for integrating resource management. Currently major row crops, such as corn, soybeans, wheat, oats, and rice, are capable of being combined and yield maps developed. A cotton yield monitor is under development. Combines with GPS and yield monitors measure the amount of grain being harvested every 1 to 3 seconds. The data are then downloaded into a personal computer to produce color yield maps. In many cases the field's yield variability has been more than most producers ever expected as yield variability of 50 to 100 percent within a field is not uncommon. Most producers know there is field variability, but it is quantifying the variability that has proved useful.

A Geographic Information System is used in conjunction with the yield maps. Various layers containing maps showing crop boundaries, soil survey, fertility (P, K, and pH), crop history, herbicides, insecticide, crop varieties, streams, tile lines, and topography may be used in conjunction with yield maps to try to make sense of the yield variability.

The other major component is weather data. Crop inputs and soil variation can explain some of the differences in yields, but weather during the growing season probably accounts for 80 to 90 percent of the yield variability. The major component that weather provides is moisture, and most yield variability can be tied back to plant available soil moisture.

Putting all these pieces together can be somewhat overwhelming. The most often asked question is “OK, you have all this information, now, what are you going to change?” At least 5 years of yield data are required for most items to make a confident decision on some change in management. It is even more complicated when the highest yielding areas 1 year are the lowest yielding the next year.

Most experts agree that collecting yield information is the place to begin precision farming. Quantifying the obvious provides some useful information and collecting yield data is important for future years when more is known on how to put these pieces together and software has been developed to help with analysis.

When yield information is translated into profit data, areas that consistently show the producer is losing money are prime candidates for a change in land use.

Appendix A Residue Retention Values

Classifications in the tables 1 and 2 are accepted by the Agricultural Research Service (ARS), Equipment Manufacturers Institute (EMI), and NRCS. Crop residue is generally classified as being either nonfragile or fragile. The classification is subjective, based in part on the ease in which crop residue is decomposed by the elements or buried by tillage operations. Plant characteristics, such as composition and size of leaves and stems, density of the residue, and relative quantities produced, are considered when assigning classifications.

The use of tillage and other types of field equipment is the most important influence on residue burial and the rate of residue decomposition. Field operations that bury crop residue and mix it with the soil reduce the amount of residue left on the soil surface and speed the process of decomposition.

Table 1 Residue types

Nonfragile	Fragile
Corn	Soybeans
Sorghum	Canola/rapeseed
Wheat*	Sugar beets
Alfalfa or legume hay	Peanuts
Cotton	Sweet potatoes
Rice	Corn silage
Flaxseed	Dry peas
Oats*	Dry beans
Rye*	Lentils
Sugarcane	Vegetables
Tobacco	Potatoes
Grass hay	Grapes
Forage silage	Guar
Pasture	Mint
Millet	Flower seed
Tritacale*	Fall seeded cover crops
Forage seed	Safflower
Speltz*	Sorghum silage
Mustard	Sunflowers
Popcorn	
Buckwheat	

* If a combine is used with a straw chopper or otherwise cuts straw into small pieces in harvesting small grain, then the residue should be considered as being fragile.

Planning residue management systems for erosion control or other conservation purposes requires a working knowledge of the degree to which tillage and other field implements bury crop residue. Also needed is knowing how much residue will most likely remain on the soil surface after a single pass of that implement or after the completion of all tillage and planting operations. Each tillage or planting operation leaves a percent of the residue that was present just before that operation. The values in the table represent these remaining percentages. These values are multiplied by the percent ground cover measured or estimated to be present just before the operation to provide an estimate of the percent ground cover following the operation. A series of such calculations is done to estimate the amount of ground cover present after all tillage and planting operations have occurred.

Many factors affect the amount of residue left after a pass with a tractor and tillage machine. Residue levels are sensitive to depth, speed of equipment operation, and to row spacing. Under some conditions field cultivators and other finishing tools that have field cultivator gangs return as much as 20 percent of residue incorporated at shallow depths by recent previous operations.

The following rules-of-thumb should be used when selecting values from table 2:

1. Select values from the higher end of the range when equipment is operated at shallower depths because at shallower operating depths, greater amounts of residue are left on the surface. At deeper operating depths, more residue is buried, and values should be selected from the lower end of the range.
2. Select values from the higher end of the range in situations where equipment is operated at slower operating speeds because slower speeds tend to leave more residue on the surface. At faster speeds more residue is buried, and values should be selected from the lower end of the range.

The values in table 2 may be used as a guide in selecting the types of equipment and types of blades, points, or sweeps to be used in the residue management system. Field measurements of the actual amount of residue being left by the operation should be made, and adjustments made accordingly.

Table 2 Residue retention values

Equipment	Percent residue remaining nonfragile (%)	fragile (%)	Depth of operation (in)
Plows			
Moldboard plow	0 – 10	0 – 5	4 – 8
Moldboard plow – uphill furrow (Pacific Northwest region only)	- - -	30 – 40	4 – 8
Disk plow	10 – 20	5 – 15	4 – 8
Machines that fracture soil			
Paratill/paraplow	80 – 90	75 – 85	8 – 12
V ripper/subsoiler			
12- to 14-inch deep, 20-inch spacing	60 – 70	50 – 60	10 – 16
Combination tools			
Subsoil chisel	50 – 70	40 – 50	10 – 16
Disk subsoiler	30 – 50	10 – 20	8 – 16
Chisel plows with			
Sweeps	70 – 85	50 – 60	4 – 8
Straight chisel points	40 – 80	30 – 60	4 – 8
Twisted points or shovels	35 – 70	20 – 40	4 – 8
Combination chisel plows			
Coulter chisel plows with:			
Sweeps	60 – 80	40 – 50	4 – 8
Straight chisel points	30 – 60	25 – 40	4 – 8
Twisted points or shovels	25 – 60	10 – 30	4 – 8
Disk chisel plows with:			
Sweeps	60 – 70	30 – 50	4 – 8
Straight chisel points	30 – 60	25 – 40	4 – 8
Twisted points or shovels	20 – 50	10 – 30	4 – 8
Undercutters			
Stubble-mulch sweep blade plows with:			
V blades or sweeps, 30-inch and wider	75 – 95	60 – 80	3 – 6
Sweeps 20 to 30 inches wide	70 – 90	50 – 75	3 – 6
Disks harrows			
Offset			
Heavy plowing >10-inch spacing	25 – 50	10 – 25	4 – 8
Primary cutting >9-inch spacing	30 – 60	20 – 40	4 – 8
Finishing 7- to 9-inch spacing	40 – 70	25 – 40	2 – 6
Tandem			
Heavy plowing >10-inch spacing	25 – 50	10 – 25	4 – 8
Primary cutting>9-inch spacing	40 – 70	25 – 40	4 – 8
Finishing 7- to 9-inch spacing	30 – 60	20 – 40	2 – 6
Light tandem disk after harvest, before other tillage	70 – 80	40 – 50	2 – 4
Oneway disk with:			
12- to 16-inch blades	40 – 50	20 – 40	4 – 8
18- to 30-inch blades	20 – 40	10 – 30	4 – 8
Single gang disk	50 – 70	40 – 60	2 – 6

Table 2 Residue retention values—Continued

Equipment	Percent residue remaining nonfragile (%)	fragile (%)	Depth of operation (in)
Field cultivators (including leveling attachments)			
Field cultivators as primarary tillage operation			
Sweeps 12 to 20 inch	60 – 80	55 – 75	4 – 6
Sweeps or shovels 6 to 12 inch	35 – 75	50 – 70	4 – 6
Duckfoot points	35 – 60	30 – 55	2 – 4
Field cultivators as secondary operation following chisel or disk			
Sweeps 12 to 20 inch	80 – 90	60 – 75	2 – 4
Sweeps or shovels 6 to 12 inch	70 – 80	50 – 60	2 – 4
Duckfoot points	60 – 70	35 – 50	2 – 4
Finishing tools			
Combination secondary tillage tools with:			
Disks, shanks and leveling attachments	50 – 70	30 – 50	2 – 4
Spring teeth and rolling basket	70 – 90	50 – 70	2 – 4
Harrow			
Springtooth (coil tine)	60 – 80	50 – 70	2 – 4
Spike tooth	70 – 90	60 – 80	2 – 4
Flex-tine tooth	75 – 95	70 – 85	2 – 4
Roller harrow (cultipacker)	85 – 95	85 – 95	1 – 2
Packer roller	90 – 95	90 – 95	1 – 2
Rotary tiller			
Secondary operation 3 inches deep	40 – 60	20 – 40	3
Primary operation 6 inches deep	15 – 35	5 – 15	6
Rodweeders			
Plain rotary rod	80 – 90	50 – 60	2 – 4
Rotary rod with semichisels or shovels	70 – 80	60 – 70	2 – 4
Strip tillage machines			
Rotary tiller, 12 inches tilled on 40-inch rows	60 – 75	50 – 60	4 – 6
Row cultivators			
Single sweep per row	75 – 90	55 – 70	1 – 3
Multiple sweeps per row	75 – 85	55 – 65	1 – 3
Finger wheel cultivator	65 – 75	50 – 60	1
Rolling disk cultivator	45 – 55	40 – 50	1 – 3
Ridge till cultivator	20 – 40	5 – 25	1 – 3
Drills			
Hoe opener drills	50 – 80	40 – 60	1 – 2
Semi deep furrow drill or press drill (7- to 12-inch spacing)	70 – 90	50 – 80	1 – 2
Deep furrow drill with >12-inch spacing	60 – 80	50 – 80	1 – 2
Single disk opener drills	85 – 100	75 – 85	1 – 2
Double disk opener drills (conventional)	80 – 100	60 – 80	1 – 2

Table 2 Residue retention values—Continued

Equipment	Percent residue remaining nonfragile (%)	fragile (%)	Depth of operation (in)
No-till drills and drills with attachments			
In standing stubble			
Smooth no-till coulters	85 – 95	70 – 85	1 – 2
Ripple or bubble coulters	80 – 85	65 – 85	1 – 2
Fluted coulters	75 – 80	60 – 80	1 – 2
No-till drills and drills with attachments			
In flat residue			
Smooth no-till coulters	65 – 85	50 – 70	1 – 2
Ripple or bubble coulters	60 – 75	45 – 65	1 – 2
Fluted coulters	55 – 70	40 – 60	1 – 2
Air seeders	(Refer to appropriate field cultivator or chisel plow depending on the type of ground engaging device used.)		
Air drills	(Refer to corresponding type of drill opener.)		
Row planters			
Conventional planters with:			
Runner openers	85 – 95	80 – 90	1 – 2
Staggered double disk openers	90 – 95	85 – 95	1 – 2
Double disk openers	85 – 95	75 – 85	1 – 2
No-till planters with:			
Smooth coulters	85 – 95	75 – 90	1 – 2
Ripple coulters	75 – 90	70 – 85	1 – 2
Fluted coulters	65 – 85	55 – 80	1 – 2
Strip-till planters with			
2 or 3 fluted coulters	60 – 80	50 – 75	1 – 2
Row cleaning devices (8- to 14-inch wide bare strip using brushes, spikes, furrowing disks, or sweeps)	60 – 80	50 – 60‘	1 – 2
Ridge-till planter	40 – 60	20 – 40	1 – 2
Unclassified machines			
Anhydrous applicator	75 – 85	45 – 70	4 – 8
Anhydrous applicator with closing disks	60 – 75	30 – 50	4 – 8
Subsurface manure applicator	60 – 80	40 – 60	4 – 8
Rotary hoe	85 – 90	80 – 90	1
Bedders, listers, and hippers	15 – 30	5 – 20	2 – 6
Furrow diker	85 – 95	75 – 85	2 – 6
Mulch treader	70 – 85	60 – 75	2 – 4
Climatic effects			
Over winter weathering*			
Following summer harvest	70 – 90	65 – 85	1 – 2
Following fall harvest	80 – 95	70 – 80	1 – 2

* In northern climates with long periods of snow cover and frozen conditions, weathering may reduce residue levels only slightly, while in warmer climates, weathering losses may reduce residue levels significantly.

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Glossary

Cation exchange capacity (CEC)
The sum total of exchangeable cations that a soil can adsorb, expressed in milliequivalents per 100 grams of soil. A milliequivalent is one thousandth of an equivalent of a chemical element.

Full width tillage
Tillage operation that cultivates the entire soil surface of the field as opposed to implements that till in a strip pattern.

pH
The degree of acidity or alkalinity of a soil. It is the negative logarithm of the hydrogen-ion activity of a soil. A pH of 7.0 is neutral, <7.0 is acid, and >7.0 is alkaline.

Plant available water
The portion of water in a soil that can be readily absorbed by plant roots. Generally considered to be that water held in the soil between field capacity and the wilting point.

Soil aggregate
Many soil particles held in a single mass or cluster, such as a clod, crumb, block, or prism.

Soil aggregate stability
Ability of soil aggregates to resist breakdown. Organic compounds of various kinds are known to process binding agents that help hold soil particles together. Aggregates of soil high in organic matter are much more stable than are those low in this constituent. Low organic matter soil aggregates fall apart when they are wetted while those high in organic matter maintain their stability.

Soil organic matter
That fraction of the soil composed of anything that once lived, including plant and animal remains in various stages of decomposition. Well-decomposed organic matter forms humus, a dark brown, porous, spongy material that has a pleasant, earthy smell. In most soils the organic matter accounts for less than about 5 percent of the volume.

CORE4 Key Conservation Practices

Part 2 Nutrient Management

Chapter 1 Nutrient Management Planning — Overview

Introduction

Nutrients are essential to all plant and animal life. They are present in soil, air, water, and organic materials. Agricultural crops generally obtain their nutrients through roots or leaves, from the soil, water, and atmosphere.

The 16 elements essential to plant growth are:

carbon (C)	sulfur (S)	manganese (Mn)
hydrogen (H)	calcium (Ca)	molybdenum (Mo)
oxygen (O)	magnesium (Mg)	chlorine (Cl)
nitrogen (N)	iron (Fe)	boron (B)
phosphorus (P)	copper (Cu)	
potassium (K)	zinc (Zn)	

Carbon, hydrogen, and oxygen are not mineral nutrients, but are the products of photosynthesis. N, P, K, S, Ca, and Mg, are considered macronutrients, because they are needed in relatively large amounts and must often be added to the soil for optimum crop production. The others, Fe, Cu, Zn, Mn, Mo, Cl, and B, are considered micronutrients because they are needed only in much smaller amounts and are usually (though not always) present in the soil in ample quantities for crop production.

The practice of nutrient management serves four major functions:

1. Supplies essential nutrients to soils and plants so that adequate food, forage, and fiber can be produced.
2. Provides for efficient and effective use of scarce nutrient resources so that these resources are not wasted.
3. Minimizes environmental degradation caused by excess nutrients in the environment.
4. Helps maintain or improve the physical, chemical, and biological condition of the soil.

Proper nutrient management economizes the natural process of nutrient cycling to optimize crop growth and minimize environmental losses. Additional information on nutrient management planning is in the Natural Resources Conservation Service (NRCS) training course, "Nutrient and Pest Management Considerations in a Conservation Management System."

Nutrient cycling

All plant nutrients are cycled through the environment. Cycles of the three nutrients most often limiting to crops—nitrogen, phosphorus, and potassium—are illustrated in figures 1–1, 1–2, and 1–3. Nutrients in the soil are absorbed by plants and incorporated into the phytomass. When these plants die, the nutrients in their phytomass are decomposed by soil organisms, especially micro-organisms, and returned to the soil where the cycle begins again. Nutrient cycles are leaky, however. If nutrients are present in the soil in greater quantities than they are needed or at times when they cannot be used by crops or soil microbes, they may be lost to the environment through runoff, erosion, leaching, or volatilization. Nutrient availability to crops also depends on the chemical form in which nutrients are present. Nutrients present in an unavailable form will not be taken up by plants although they may be needed, and may be lost from the cycle. Nitrogen in particular undergoes a number of transformations as it is cycled. These transformations occur under different environmental conditions. Understanding when these transformations will most likely occur can improve nutrient management planning. Detailed descriptions of the primary nutrient cycles are in any soil fertility textbook.

Nitrogen

The nitrogen cycle (fig. 1–1) is very much tied to the carbon cycle. Soil micro-organisms (bacteria, fungi, and microinvertebrates) decompose carbon material to obtain the energy contained in the sugars and carbohydrates. They also acquire other nutrients from the organic material. Where organic material has a high carbon content (carbon-to-nitrogen ratio of more than 30), micro-organisms require additional nitrogen to complete their metabolism. They obtain this nitrogen from the soil and the plant residue recently returned to the soil. Micro-organisms can outcompete plants for available nitrogen in the soil. Sufficient nitrogen is available from the organic material to satisfy micro-organism metabolism only if the C:N ratio is less than 30, as it is in most manure products. Soil organic matter has a C:N ratio between 10 and 15. Most crop residue has a C:N ratio of more than 30. A C:N ratio as high as 100 can occur in small grain straw.

Additional N from the soil or added fertilizer is required for the micro-organisms to break down and decompose crop residue.

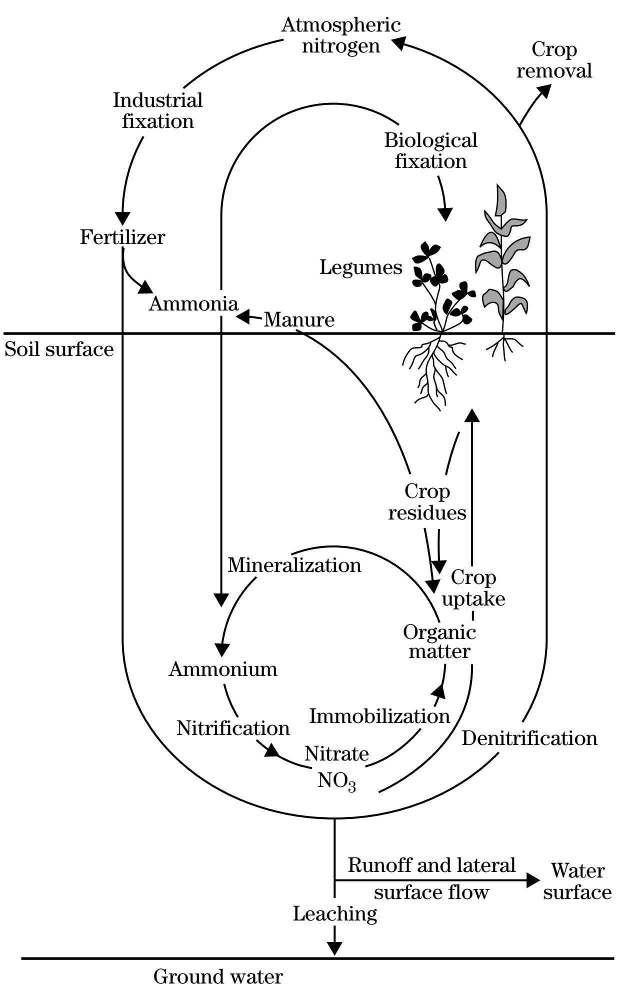
To increase soil organic matter (SOM), which has a C:N ratio of 10 to 15, additional nitrogen needs to be added to the soil not only to satisfy the decomposing micro-organisms, but also to increase the soil organic matter. Soil organic matter contains about 5 percent nitrogen. As an example, soil with 1 percent SOM has 20,000 pounds of SOM in a 6 2/3 inch furrow slice. This slice weighs 2,000,000 pounds. If the SOM is 5 percent nitrogen, then 1 percent SOM contains 1,000 pounds N. Because micro-organism are not completely efficient in converting soil N to SOM nitrogen, it takes more than a 1,000 pounds additional N to build up each 1 percent of SOM. Precise guidance is not available on how much additional nitrogen is required to build up soil organic matter. Many soil, crop, and climate variables control the process. As a general guidance for improving SOM content and nitrogen cycling in reduced tillage systems, soil nitrogen is available for mineralizing about 3,000 pounds of crop residue material. About 0.5 pound of additional N (above the agronomic crop rate) is required for each 100 pounds of crop residue above this threshold level of 3,000 pounds.

Example

A 100-bushel wheat crop produces 8,000 pounds of crop residue. This is 5,000 pounds above the residue threshold level of 3,000 (8,000 –3,000 = 5,000). If it takes 0.5 pounds of additional nitrogen for each 100 pounds of crop residue above the threshold, then 25 pounds of N will be needed to increase SOM:

$$\frac{5{,}000}{100} = 50 \times 0.5 = 25 \text{ lb. N}$$

Figure 1–1 Nitrogen cycle



Nitrogen is generally the most limiting nutrient in crop production systems and is added to the soil environment in the greatest amount of any of the plant nutrients. Increases in nitrogen content of the soil and plant uptake generally lead to higher nitrogen and protein content of the plant as well as yield. Ammonium nitrogen (NH_4^+) is a cation and is held to the soil on the cation exchange sites. It is also wedged in place (fixed) between clay layers, becoming available for plant uptake only when the soil bonds are broken. Nitrogen in the soil system can present an environmental risk to the atmosphere, ground water, and surface water.

Significant amounts of surface-applied ammonium can be lost to the atmosphere as ammonia gas (NH_3) through volatilization. Under specific soil environmental conditions, nitrogen may be lost to the atmosphere as gaseous nitrogen (N_2) and nitrous oxide (N_2O). These additions of nitrogen to the atmosphere can contribute to environmental problems. Nitrous oxide is a gas that contributes to the greenhouse effect. Ammonia volatilized to the atmosphere is a component of nitrogen-enriched rain.

Excess movement of nitrogen into surface water can lead to degradation of water quality. Soil nitrogen in the form of organic matter or soluble ammonium and nitrate can be carried off the land surface through runoff and erosion. Movement of high-nitrate ground water into surface water can also increase surface water nitrogen levels. Ammonia is soluble in water and is used as a source of nitrogen by aquatic plants including algae. When ammonia dissolves in water, a portion reacts to form ammonium ions (NH_4^+) with the balance remaining as ammonia. The concentration of ammonia increases with increasing pH and temperature. Total ammonium nitrogen can also exert a significant oxygen demand on the water. Oxygen is required by bacteria to nitrify ammonium nitrogen to nitrate nitrogen. This is called nitrification.

Nitrate-nitrogen (NO_3^- – N) is an important plant nutrient, but it is not essential for animal nutrition. Nitrogen in the form of nitrate in the soil is very mobile and, therefore, subject to leaching. Leaching occurs when precipitation or irrigation supplies water in excess of soil storage capacity. Once the nitrate is transported below the root zone, there is less opportunity for chemical/biological transformation. Continued leaching can move the nitrate to the ground water.

Table 1–1 Recommendations for use of water with known nitrate content

Nitrate content (ppm) nitrate-nitrogen	nitrate	Interpretation
0 – 10	0 – 44	Safe for all animals and humans
10 – 20	44 – 88	Safe for livestock unless feed has high nitrate levels.
20 – 40	88 – 176	Might cause problems for livestock. If feed contains more than 1,000 ppm, total nitrate will most likely exceed safe levels.
40 – 100	176 – 440	Risky for livestock. Feed should be low in nitrates, well-balanced, and fortified with vitamin A.
100 – 200	440 – 880	Should not be used. General symptoms, such as poor appetite, are most likely when provided free choice to ruminants on a good ration.
> 200	> 880	Should not be used. Acute poisoning and some deaths likely in swine. Probably too much total intake for ruminants on usual feeds.

Conservation buffer practices may help reduce runoff or leaching losses of nitrogen and other nutrients. Properly functioning buffers can filter out nutrient-rich sediment, enhance infiltration (which can reduce soluble losses from runoff), and take up nitrogen and other nutrients before they reach waterbodies. Deep-rooted buffer plants can actually take up NO_3^- that has already leached below the crop rooting-zone.

Nitrate-nitrogen is a nutrient source to aquatic plants and micro-organisms. It is soluble in water. Human and animal health risks have been documented. Specifically, a drinking water standard of 10 mg/L nitrate nitrogen has been set for human consumption. Table 1–1 gives nitrate-nitrogen guidelines for livestock consumption.

Phosphorus

Figure 1–2 shows the phosphorus cycle. Phosphorus is an essential nutrient for plant growth. It occurs in the soil as inorganic orthophosphate and organic compounds. Plants take up phosphorus in the orthophosphate form. Although the total amount of phosphorus in the soil is large, the quantity of plant-available phosphorus in the soil solution is small, ranging from 0.25 to 3.00 pounds per acre. A dynamic equilibrium exists in the soil between the adsorbed phosphorus of mineral and organic components and the soil solution. Plants require approximately 0.5 to 1.0 pounds of phosphorus per acre per day. To achieve this amount of uptake the soil solution must be replenished continually by the equilibrium. Also new soil territory must be explored by the roots.

The major loss of phosphorus from the land surface is through the process of surface runoff and erosion. In tilled cropland about 80 to 90 percent of the phosphorus load is carried in the sediment. The remaining 10 to 20 percent of the P is carried in solution. On untilled land, such as pastures, hayland, and no-till, only 10 to 20 percent of the P loss occurs as sediment, while the remaining 80 to 90 percent is in solution. Generally, phosphorus lost in runoff amounts to less than 5 percent of that applied to agricultural land. From a crop production standpoint, this amount is considered insignificant. From a water quality standpoint, this small amount can lead to a significant reduction in surface water quality. Most of the phosphorus is lost in only one or two storms or runoff events. Phosphorus applied to the surface, as either manure or commercial fertilizer, is subject to loss/ transport in runoff. However, soluble phosphorus, though only 10 percent of the total runoff load, is highly bioavailable and can contribute significantly to eutrophication even at these low levels.

Some soils remain relatively low in phosphorus and need to be supplemented by phosphorus additions. However, many regions of the United States, especially those with a high concentration of confined animal operations, are experiencing levels of soil test phosphorus far above those required for optimum crop production. These elevated soil test levels increase the risk of phosphorus transport to surface water and accelerated eutrophication.

Potassium

Figure 1–3 shows the potassium cycle. Potassium (K) is used in relative large quantities by plants. Tissue concentrations range from 1 to 2 percent. Potassium plays an important role in plant hardiness and disease tolerance. Most directly, the potassium ion (K^+) regulates the water status in plants. It also works in the ion transport system across cell membranes and activates many plant enzymes. Potassium is a cation (K^+), which is held on the soil cation exchange sites.

High levels of potassium in the soil can contribute to problems with grass tetany, a serious problem in lactating ruminant animals. Grass tetany occurs when these animals do not get enough magnesium in their diet. If a soil is high in potassium, forage crops will take up potassium at the expense of magnesium, causing an imbalance in the plant. Cattle grazing this forage will not get enough magnesium, causing grass tetany. The problem is more common when manure and other organic materials high in nitrogen and potassium are applied early in the growing season to forage crops. This can result in an imbalance of potassium to magnesium in the plant tissue that leads to grass tetany problem. Legume crops have a more favorable potassium-to-magnesium ratio, but legumes

Figure 1–3 Potassium cycle

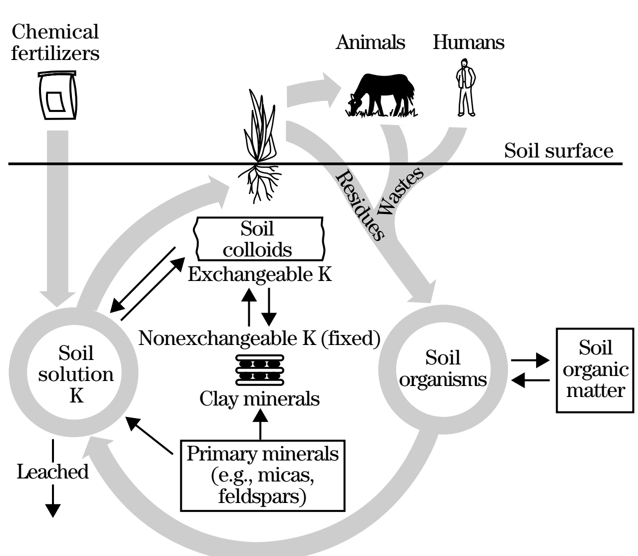
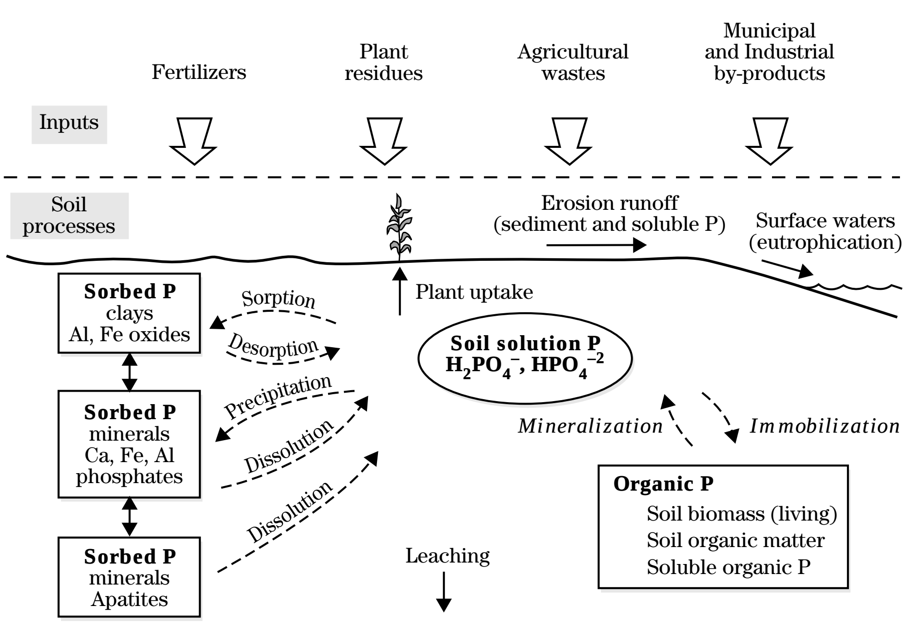


Figure 1–2 Phosphorus cycle



regrowth is slower early in the growing season, especially if the grasses have an excess of nitrogen nutrition. Early season application of organic material to forages should be avoided until the slower growing legumes have an opportunity to flourish. Grazing can be delayed until the legumes provide a good balance in the pasture with the grasses.

The same problem can occur when forages that are grown on soil that has a high K level are harvested and fed to lactating cattle. Again, the imbalance of K to other nutrients, namely calcium and magnesium, is the problem.

The only known deleterious effect of K in fresh or saline water is an increase in the salt content and electric conductivity.

Nutrient impacts on the environment

Modern agriculture depends on an adequate supply of nutrients available to the crops for high levels of production. A major part of the yield increases during the last 50 years can be attributed to high levels of crop nutrition that support high yielding crop varieties. An abundant supply of nutrients, particularly nitrogen and phosphorus, is credited with an abundant food, fiber, and forage supply. Plants depend on nutrients for growth, but in turn supply nutrients back into the environment. Plants also provide ground cover for erosion protection and wildlife habitat. Carbon supplied to the plants from carbon dioxide is cycled through plants along with water and oxygen. The energy of the sun is converted into chemical energy forms that can be used by living organisms including humans. Without plants and the nutrients associated with their growth, there would be no livable environment.

Excess nutrients impact on the environment

When nutrients are used to help assure adequate production of food, fiber, and forages, the benefits are considered positive. When nutrients produce unwanted vegetation or vegetation out of place, such as weeds, aquatic vegetation, and algae, which are not considered to be economically nor environmentally beneficial, the consequence is considered negative. Nutrients are essential for life, but excess nutrients become a burden on the environment and often create an imbalance in the ecosystem. Some examples of nutrients out of balance with the environment follow.

Excess growth of aquatic plants, including algae and submerged weeds, that can impair the desired use of waterbodies. Concentrations of nitrogen in fresh water higher that 0.5 to 1.0 mg/L are considered threshold levels for eutrophication. Estuaries and marine environments have even lower threshold concentrations, less than 0.6 mg/L. Phosphorus threshold concentration levels in both fresh and saline water range from 0.02 to 0.05 mg/L. Phosphorus tends to be the limiting nutrient in freshwater while nitrogen is often limiting in saltwater. This in not always the case, however.

Excess nitrate ($NO_3^- - N$) and nitrite ($NO_2^- - N$) nitrogen can become health risks to humans as well as other animals. Water concentrations of nitrate nitrogen greater than 10 mg/L are considered unsafe for human consumption, in particular for small babies. Livestock water with up to 100 mg/L nitrate nitrogen can be used if other sources of feed are low in nitrate nitrogen (see table 1–1).

Ammonia produced in animal manure and other organic nutrient sources can become toxic to aquatic life. The concentration of ammonia in water increases with increasing pH and temperature. Levels greater than 0.02 mg/L (20 parts per billion) are considered toxic to fresh water aquatic life.

Nutrition of forages becomes out of balance when levels of potassium exceed the proper ratio with magnesium. Such nutrient imbalances cause poor livestock health and can even lead to serious illness (grass tetany). High levels of nitrogen in forage or plant stress that greatly reduces the utilization of nitrogen can produce toxic plant residue that affects livestock that eat it.

Deficiency of potassium or chlorine in plants reduces disease resistance. Potassium is used in many plant metabolic processes that transfer energy and nutrients throughout the plant.

Luxury consumption of nitrogen by plants can lead to weak, succulent tissue that is susceptible to lodging disease and insect attack. Lodging occurs when the aboveground growth of a crop becomes too heavy and the crop falls over. Lodging was once a serious problem. Today's crop varieties are less susceptible to lodging than they were, however. Plants generally store excess nitrogen as nitrates, rather than as amino acids or protein. During periods of low soil moisture or cool, cloudy conditions, nitrates accumulate in forages and can cause serious illness or death in cattle feeding on the forage.

Nutrient salts, like sodium, can adversely affect plant water relations and cause soil structural changes. Soils with high salt content potentially can have lower yields and poor utilization of other nutrients.

Managing the source and transport of nutrients

The objective of nutrient management is to supply adequate chemical elements to the soil and plants without creating an imbalance in the ecosystem. This is not an easy task. Nutrients are part of the biological system that is part of the bigger environment. All the things that affect the environment (climate, soils, air, water, human activities) affect the fate and transport of nutrients. Managing nutrients becomes an attempt to manipulate the environment to the greatest extent possible. Certain parts of the environment are difficult, if not impossible, to control. Precipitation events and temperature influence nutrient transformation, transport, and even additions to the soil-water-air-plant-animal system, yet they are difficult to manage.

Nutrient sources, such as the application of fertilizer, irrigation water, and organic materials, are the easiest to regulate. Once the nutrient is a part of the soil-water-air-plant-animal environment it is harder to manage. Monitoring nutrients in the environment through soil, water, air, plant, and animal testing is the most direct way of knowing what levels exist. Adjusting the inputs based on the current levels of nutrients available and amount required for crop production is the best way to maintain crop production and avoid excess accumulations. Soil testing measures the current levels of nutrients in the soil. Testing irrigation water and manure and other organic material tells the producer the nutrient content of these sources. Adding atmospheric deposition and nitrogen credits from previous legume crops gives the total nutrients available.

Once the source has been determined and adjusted to meet the production needs, the nutrients must be retained where they can be most efficiently used by the plant. This is generally in the soil where roots are or will soon grow. Environment influences, such as rainfall, wind, and gravity, tend to move nutrients away from the root zone. The forces of wind and water erosion should be managed to minimize the movement of nutrient-enriched soil particles from the field.

Runoff water has high potential for dissolving and carrying nutrients from the site. While not as destructive to the soil as erosion, runoff can carry soluble material and is more difficult to control. Improving soil surface structure and promoting greater infiltration reduce runoff. Higher infiltration and percolation of water through the soil profile can increase nutrient movement by leaching and deep percolation. Perennial crops and reduced tillage systems may actually increase nutrient movement toward the ground water because they are both effective at reducing erosion and runoff.

Leaching of nutrients may be the most difficult to manage because much of it occurs during the times when plant transpiration demands are low, precipitation is high, or both. Management of irrigation water and continuation of plant growth during the high rainfall/low evapotranspiration periods will modify the amount of soil moisture capable of carrying nutrients below the root zone. Soil type affects leaching potential, so managing nutrients by soil type is important.

Another form of transport involves movement of nitrogen as ammonia gas directly from the soil to the atmosphere. Ammonia forms readily under warm, dry conditions and at high (greater than 6.8) soil pH. Ammonia in the atmosphere is very reactive with water and can return to the soil with rainfall. This offsite transport and return does not always redistribute the nitrogen back to soil, but can lead to enrichment of adjacent waterbodies. Ammonia losses to the atmosphere can be prevented by soil incorporation with tillage, injection, or irrigation.

A second form of gaseous nitrogen loss is by denitrification of nitrate (NO_3^-) nitrogen in the soil. Nitrate nitrogen is converted to gases of molecular nitrogen (N_2) and nitrous oxide (N_2O). Three components are essential for denitrification:

- A source of nitrate nitrogen
- Carbon to provide energy for bacterial metabolism of the nitrate ion
- Low oxygen conditions in the soil for the denitrifying bacteria to remove the oxygen from the nitrate

Minimizing the amount of nitrate nitrogen in the soil and maintaining a well drained, aerated soil reduces the amount of denitrification.

In summary, nutrients are essential for production of plant biomass and harvestable crops. Excess nutrients are detrimental to many systems of the environment, including water, plants, and animals. To protect the environment from excess nutrients, both the source of nutrients and their transport must be managed.

Assessment tools

A variety of assessment tools is available to nutrient managers. These tools generally fall into one of two categories:

- Tools to assess the agronomic needs of a crop.
- Tools that assess environmental risk associated with nutrient applications.

Some tools may fall into both categories. Properly using available tools can significantly improve nutrient management decisions.

Agronomic needs assessment tools

These tools provide information on the current nutrient status of crops, soils, and soil amendments. They help the nutrient management planner develop a more accurate nutrient budget to determine the amount and type of nutrients actually required by the soil-plant system. Agronomic needs assessment tools include several tests. Sampling techniques for these tests should follow Extension Service or Land Grant University guidelines.

Traditional soil tests

Traditional soil tests include tests for pH, nitrogen, phosphorus, potassium, soil organic matter, and electrical conductivity (EC). These tests generally are performed on the soil plow layer, but may also be performed on the top few centimeters of the soil if the soil is not regularly tilled. Other soil tests, such as tests for sulfur or zinc, may also be performed in cases where special needs are suspected. Soil tests give the nutrient management planner a sense of the nutrient supply in the soil. If soil test levels of individual nutrients are **high**, there may be no need to apply these nutrients to the crop. If they are **low** or **medium**, fertilization is probably advisable. If soil pH is low, liming may be warranted to allow for adequate uptake of nutrients applied. If it is high, an acidifying amendment may be necessary to optimize crop nutrient uptake. Soil organic matter generally indicates overall soil nutrient status. Electrical conductivity indicates the level of salts in the soil. Salts may be a concern if EC is extremely high. Traditional soil tests provide an important baseline of information and should be performed regularly every 3 to 5 years, or more often if conditions change.

Nitrate testing

Pre-plant nitrate test, pre-sidedress nitrate test and deep nitrate test

In certain parts of the country, the pre-plant nitrate test (PPNT) and pre-sidedress nitrate (PSNT) test are used to determine whether additional nitrogen is necessary. The nitrate concentration in the soil solution of the crop root zone at a given point in the growing season may indicate the amount of nitrogen available in the root zone for crop uptake. If the available nitrogen is sufficient, a sidedress application is not warranted. See appendix E for a procedure to use this information.

The deep nitrate test is another tool sometimes performed to determine how much nitrogen has already leached below the crop root zone. If this test shows significant amounts of nitrate leaching, it may be advisable to include a deep-rooted crop in the rotation and look for other ways (including water management where applicable) to ensure that the appropriate amount of nitrogen is provided to the crop when it is needed.

Traditional plant tests

A variety of plant tests is available and being developed to provide information on the current nutrient status of the crop. Petiole tests and other plant tissue tests are performed during the growing season to help make decisions about the need to sidedress apply nitrogen or micronutrients. The chlorophyll meter has recently been used to quickly determine the nitrogen status of the crop without destroying any plant tissue. The chlorophyll meter works by analyzing the absorption of light of certain wave lengths characteristic of chlorophyll absorption. The late season chlorophyll meter test and certain tissue tests are also being developed to analyze the nitrogen status of crops just before harvest. These tests can help determine how successful the current nutrient management plan was in supplying the nitrogen needs of the crop so that the nutrient management plan can be refined for the next year. Use of remote sensing, particularly infrared photography, is also increasing as a quick means of assessing crop nitrogen status during the growing season.

Organic material analysis

Organic material, such as manure, municipal wastewater sludge, or other organic products, is often applied to cropland as nutrient sources. Unlike commercial fertilizers, the nutrient content of these amendments varies. The nutrient content of the organic material must be known to develop an accurate nutrient planning budget. Therefore, a series of nutrient tests have been devised for organic material analysis. These tests are chemically similar to soil tests, but generally also include moisture content. Moisture contents of organic material can vary dramatically. The moisture content is needed to calculate the quantity of nutrients in a gallon or ton of organic material applied to the land.

Irrigation water test

Because the salt status and pH of irrigation water can often affect crop uptake of both water and nutrients, water that is to be applied to cropland may be tested for electrical conductivity and pH. Surface irrigation water may also be tested for nitrate, since a high level of nitrate in the water may indicate a reduced need for nitrogen fertilization. Well water may also be tested for boron and chloride. These plant nutrients are beneficial in low concentrations, but toxic at higher concentrations. Irrigation water should be tested at least annually or more often if the water chemistry is expected to change significantly over the growing season.

Environmental risk assessment tools

These tools provide information on the potential environmental risk associated with nutrient applications. Environmental risk assessments tools may be used to identify sensitive areas in which careful nutrient management is critical to protect a water resource or where nutrient applications should be strictly limited. Risk assessment tools may involve simple analyses or elaborate models. A few of the less complex risk assessment tools available for your use are listed below:

Leaching index

The leaching index (LI) is a simple index of potential leaching based on average annual percolation and seasonal rainfall distribution. The LI considers the saturated hydraulic conductivity and storage capacity of individual soils, the average annual rainfall, and the seasonal distribution of that rainfall. It does not look at the leaching potential of specific nutrients, but rather the intrinsic probability of leaching occurring if nutrients are present and available to leach. The LI is in section II of the Field Office Technical Guide (FOTG). See appendix B for more information.

Phosphorus index

The phosphorus index (PI) is a simple assessment tool that examines the potential risk of P movement to waterbodies based on various landforms and management practices. The PI identifies sites where the risk of P movement may be relatively higher or lower than other sites. It considers soil erosion rates, runoff, available P soil test levels, fertilizer and organic P application rates, and methods to assess the degree of vulnerability of P movement from the site. A weighting procedure includes the various contributions each site characteristic may have. The PI is in the NRCS FOTG, state supplements to the National Agronomy Manual, or state technical notes.

Water Quality Indicators Guide

The Water Quality Indicators Guide (WQIG) is a qualitative tool for assessing surface water quality. It considers five major sources of agriculturally related nonpoint source pollution: sediment, nutrients, animal waste, pesticides, and salts. The WQIG contains a series of field sheets that are completed using onsite observations of physical and biological resources rather than chemical measurements. Two types of field sheets are provided: one for receiving water and the other for agricultural lands draining into the receiving water. The guide can help the user assess the risk of nutrient impairment to waterbodies in a given area. The WQIG is referenced in section I of the FOTG.

Nitrate Leaching and Economic Analysis Package

The Nitrate Leaching and Economic Analysis Package (NLEAP) is a moderately complex, field scale model that assesses the potential for nitrate leaching under agricultural fields. It is one of several water quality models that can be used to assess potential nutrient pollution under different scenarios. NLEAP can be used to compare nitrate leaching potential under different soils and climates, different cropping systems, and different management scenarios. When calibrated to local conditions, this model can be a powerful tool to assess nutrient management planning decisions. NLEAP is referenced in section I of the FOTG.

Revised Universal Soil Loss Equation and the Wind Erosion Equation

The Revised Universal Soil Loss Equation (RUSLE) and the Wind Erosion Equation (WEQ) assess the potential for soil loss through water and wind erosion. As nutrient losses are often associated with eroded sediment, these tools can help determine the potential risk of nutrient transport toward waterbodies when combined with estimates of nutrient concentrations in surface soils. RUSLE and WEQ are in section I of the FOTG.

EPA 303(d)

The EPA 303(d) report for your state can often be used to help assess the potential environmental risk associated with a particular land area. This report lists the waterbodies, including stream segments, within each state that have been designated as impaired for one or more uses. A copy of this report may be obtained from your state water quality agency.

Special designations

Certain areas have been designated for special protection: sole source aquifers (aquifers that provide the sole source of drinking water for an area), wellhead protection areas, and hydrologic unit areas. These special designation areas will most likely be at greater risk for environmental contamination.

Sensitive areas

Some areas or regions may have conflicting goals relating to nutrient application. Nutrients are needed for adequate production, but special environmental concerns may also be in these areas. The nutrient management planner must use the results of an agronomic needs assessment and environmental risk assessment to balance these conflicting goals.

Most planning and assessment are done at the field level as opposed to a group of fields or a watershed. This field area is called the agricultural management zone (AMZ) which is defined as the edge of the field, bottom of the root zone, and top of the plant canopy. Sensitive areas for nutrient application can include fields where soils or landscape position would allow nutrients to leach or run off the application site. While the amount of nutrients leaving the AMZ is difficult to predict, methods are available to predict the relative risk that losses will occur.

Sensitive areas may fall into one of three types. The first includes areas that have already been identified or exist by virtue of a state or local designation. A previously identified sensitive area could be listed on the state's 303(d) list of impaired waterbodies, be a designated trout stream, or be listed as a sole source aquifer. These designated sensitive areas are listed because of sensitivity to excess nutrients either in the surface or ground water.

Sensitive areas may also be identified by use of one of the assessment tools mentioned in this section. For example, analysis of the application area with RUSLE may reveal that the field has a high rate of erosion. Erosion and runoff would move nutrients, especially surface applied nutrients, thus making this application site sensitive. Another example would be soils that have high soil test levels of nitrogen or phosphorus. The leaching potential of the soil may point out a sensitive field.

The third type of sensitive area may be identified by intuitive observation. If the area has high concentrations of livestock or density of feedlot generating large volumes of animal manure, that area could be considered sensitive. Growing continuous potatoes or corn with high application rates of fertilizer or production of specialty crops, such as strawberries or tomatoes, could also be thought of as sensitive.

Sensitive areas should be identified on the conservation plan map, and the reason for the sensitivity noted. Special management practices and conservation measures are required to mitigate sensitive areas.

Analytical water quality monitoring

Analytical water quality monitoring is another tool that can be used to assess the potential impairment of waterbodies and associated environmental risk. Long-term monitoring, such as monitoring performed by the U.S. Geological Survey and state environmental agencies, can show quantitative trends in water quality over time, although trends are often slow and difficult to predict with short term monitoring.

Soil testing

Soil testing for environmental risk assessment includes tests for soil nitrates in the root zone and phosphorus in the surface soil. Soil nitrate tests were described previously. The surface soil phosphorus test indicates the buildup of available phosphorus at the soil surface, which can be correlated with risk of phosphorus losses through runoff or erosion.

Others

The tools described in this document are only a small fraction of the tools that may be available for use by conservationists and nutrient management specialists to help them develop nutrient management plans that are appropriate, needed, and effective. A variety of water quality models, including EPIC, GLEAMS, AGNPS, ANAGNPS, SWRRB, and SWAT, may be used to look at the influence of different management scenarios and environmental conditions on the potential environmental risk of nutrient contamination to waterbodies. A variety of physical, chemical, and biological tests are also available to assess water quality in designated areas. Most states have already designated many environmentally sensitive areas. For further assistance in this area, consult your NRCS state office or state environmental agency .

National policy

NRCS policy on nutrient management is in the General Manual, Title 190, Part 402, and Title 450, Part 401. An excerpt from the General Manual highlighting pertinent sections of the policy is shown as exhibit 1–1. These policy statements will be highlighted in the National Agronomy Manual (NAM).

State and/or local standards

The national nutrient management standard is the basis for the state nutrient management standard developed for the FOTG. States should review the national standard and compare their existing nutrient management standard with the national standard and the national nutrient management policy. If the differences are significant, states should begin the process of revising their standard. As with all standards, the state standard may be more restrictive than the national standard, but not less restrictive. States may add additional purposes to their standard if they feel it is necessary. If new purposes are added, additional criteria to meet these purposes must be added.

A copy of the national nutrient management standard is at the end of this section.

Exhibit 1–1 Nutrient management policy excerpt

NUTRIENT MANAGEMENT POLICY

(Content in capital letters and bold print highlight important policy changes.)

GENERAL MANUAL – Title 450, Part 401

401.03(b)(3)(iv)(B)(2) Water Quality

WHEN NUTRIENTS AND PEST MANAGEMENT NEGATIVELY IMPACT surface or ground water or potential problems exist, nutrient and/or pest management practices, including timing, forms, and rate and method of application; shall be recommended to reduce adverse effects. The use of pesticides and nutrients with high potential for polluting water are avoided where site limitations, such as slope, **PROXIMITY TO A SURFACE WATER BODY**, depth to ground water, soil, and materials in the vadose zone or aquifer could **CAUSE CONTAMINATION**. The **SOIL PESTICIDE SCREENING TOOL, LEACHING INDEX (LI), PHOSPHORUS INDEX (PI), AND OTHER APPROVED ASSESSMENT PROCEDURES ARE USED ACCORDING TO FIELD OFFICE TECHNICAL GUIDE (FOTG) GUIDELINES** to identify potential problem situations from surface runoff and/or leaching. **ALTERNATIVE PRACTICES** for pest management (e.g. chemical, mechanical, cultural, or biological) or **NUTRIENT MANAGEMENT (E.G. PHOSPHORUS BASED MANURE MANAGEMENT, LEGUME COVER CROPS, SPLIT NITROGEN APPLICATIONS)** or integrated methods are recommended where site limitations exist that increase the probability of degrading water supplies.

401.03(b)(3)(iv)(D) Plants

Nutrient applications and **APPLICATION METHODS** for any land use are based on plant nutrient requirements, **ENVIRONMENTAL CONSIDERATIONS**, production requirements, soil test recommendations, soil fertility, soil potential limitations **INCLUDING SOIL PHOSPHORUS THRESHOLD VALUES**, and the types of practices planned. Nutrients from all sources (i.e. animal manure, crop residue, soil residual, **NITROGEN CREDITS FROM LEGUMES**, commercial fertilizer, nutrient credits from animal manures) are considered when calculating the amount of nutrients to apply. **TIMING, METHOD, AND RATE OF APPLICATION**, and chemical forms of nutrients to be applied are considered in planning practices. **NUTRIENT APPLICATION RATES ARE DETERMINED USING THE CONSERVATION PRACTICE STANDARD "NUTRIENT MANAGEMENT" (CODE 590) IN THE FOTG. RECOMMENDED PROCEDURES FOR DEVELOPING AND DOCUMENTING PLANS FOR NUTRIENT MANAGEMENT ARE FOUND IN THE GENERAL MANUAL, TITLE 190, SECTION 403, AND THE NATIONAL AGRONOMY MANUAL, SECTION 503, SUBPART B**.

Chapter 2 Nutrient Management Planning

Components of a nutrient management plan

The management of nutrients becomes a component part of the overall conservation plan. A few basic elements need to be a part of the nutrient management component of a complete conservation plan. These elements guide the producer in making decisions on the placement, rate, timing, form, and method of nutrient application. They help producers become fully aware of the steps that need to be taken to successfully manage their nutrients and protect the natural resources of the community. The plan must be implemented to meet these goals. These nine elements are not intended to be all-inclusive, but are the minimum requirements for the nutrient management plan component of a conservation plan.

The implementation of the nutrient management component of the overall conservation plan, including modifications, requires frequent review of the plan, periodic monitoring of progress, and continual maintenance. Planning sets the framework for results that are accomplished by on the land implementation.

Site aerial photographs or maps

Site aerial photographs or maps, including a soil map, are generally part of the overall conservation plan; however, additional site information may be needed for the fields where nutrients will be applied. This information may include proximity to sensitive resource areas, areas with some type of restriction on nutrient applications, and soil interpretations for nutrient application.

Location of nutrient application restrictions within or near sensitive areas or resources

If present, sensitive resource areas will be delineated on the maps. Any restrictions on nutrient application will also be delineated. This may include setbacks required for application of animal manure, reduced application rates, soil conditions that require reduced application rates or restrictions on time and method of application, or areas with special resource concerns. The producer will remain aware of these areas and modify management accordingly.

Soil, plant, water, and organic material sample analysis results

Since nutrient management is based on crop needs and sources of nutrients, an analysis of these factors is essential to know the supplying power of the nutrients and the crop response. These are basic factors to determine the nutrient budget. Soil tests (fig. 2–1) tell the producer the nutrient status of the soil. Plant tissue testing, done at various times during the growing season, shows if the plant is getting adequate nutrients. Testing irrigation water and any organic material added to the field tell the producer the amount of nutrients supplied by these sources.

Current or planned plant production sequence or crop rotation

Nutrient application is based on crop requirements. The sequence of crops determines nutrient needs as well as nutrients carried over from one crop to another.

Figure 2–1 Soil test results are an important part of a nutrient management plan

Expected yield

The expected crop yield is the basis for determining the nutrient requirement for that particular yield level. Generally, the higher the yield expectation, the higher the nutrient requirement to reach that yield. Several methods are available to calculate expected yield goals. Use the method developed by the State Land Grant University or Extension Service.

Quantification of important nutrient sources

Nutrient sources may include, but are not limited to, commercial fertilizer, animal manure and other organic by-products, irrigation water, atmospheric deposition, and legume credits. This information is needed for planners to know what nutrients are available for crop production, when the nutrient will be available, and the type of equipment or management that is required for application. The estimates used to determine the amount of nutrient supplied is based on the soil, plant, water, and organic analysis mentioned previously (fig. 2–2).

Nutrient budget for complete plant production system

A nutrient budget determines the amount of nutrients available from all the sources and compares this to the amount of nutrients required to meet the realistic yield goal. When yield requirements of nutrients exceed the available source then additional nutrients must be brought in to satisfy the crop's requirement. On the other hand, if nutrient supply exceeds crop needs, management measures must be taken to ensure that the excess nutrients are either reduced as inputs or that their application will not cause detrimental effects to the plants, soil, or surrounding environment. An example nutrient budget is in the Nutrient Management job sheet at the end of chapter 6 of this section.

Figure 2–2 Amount of fertilizer needed for a healthy crop depends on the crop and other available nutrients

Recommended rates, timing, and methods of application

These specifications are given to the producer. The specifications are for individual fields or for groups of fields depending on the soil and crop rotation. The specifications for rates are based on the nutrient requirement of the crop (usually taken from soil test recommendations or university publications). Timing is determined by crop growth stage and nutrient needs and by the climatic conditions that can affect the transformation and transport of nutrients. How the nutrient is applied is based on the form and consistency of the nutrient, soil conditions, and potential for movement and loss to the environment.

Operation and maintenance of the nutrient management plan

Several items of the nutrient management plan need to be reviewed on a regular basis. They include

- Calibration of application equipment
- Maintenance of a safe working environment
- Review and update of plan elements
- Periodic soil, water, plant, and organic waste analysis
- Monitoring of the resources
- Keeping records of management activities

This element reminds the producer to continually keep the nutrient management component plan up to date.

Developing a nutrient budget

A nutrient budget is the comparison between the total nutrients available to the producer and the nutrients required to meet the crop and soil needs. The available nutrients can come from on the farm, such as livestock manure or credits from legumes, or from off the farm, such as purchased fertilizer, irrigation water, or atmospheric deposition. The total nutrient requirement is the amount needed by the crop to obtain the expected yields.

Most values for nutrients available from different sources (credits) and crop nutrient requirements are calculated from many years of field research. No "real time" method is available for calculating exactly the crop's nutrient requirement or the nutrients available at any one time. More closely, both the nutrient requirements and availability are based on past performance for that climate and soil condition. These values are given with some surety that the crop grown will be supplied with adequate nutrients during the growing season and the crop will not be limited in its growth. All incidental environmental losses, such as runoff and leaching, have been accounted for. Climate conditions, particularly temperature and soil moisture, greatly influence both the crop performance and the soil's capacity to provide nutrients to the plant. During any growing season, changes in the climate conditions affect the crop growth and soil delivery of nutrients to the crop.

Although a nutrient budget is not an exact formula for supplying nutrients, it is one method for matching the nutrient needs of the crop with the nutrients available on the farm. A nutrient budget can easily determine if there is a gross imbalance between the nutrients that are available and the amount required. It is one of the best methods to see the overall supply of crop nutrients available compared to the estimated crop needs as given by historic records and field research. Continued use of soil testing, plant and water analyses, and yield monitoring is essential to maintain a good nutrient balance.

Two methods for calculating a nutrient budget are available. The first is based on a soil test analysis and crop nutrient recommendation as given by the land grant university. As its basis, the nutrient requirement of the crop has been determined from historical field research for that soil and climate. The nutrient credits for nutrients supplied are taken from analysis of soil, water, plants, and organic material that provide nutrients to the crop. Some of these values have been modified, again by research data, to reflect the estimated supplying power of these individual sources. This is the method used in the Nutrient Management job sheet that is at the end of chapter 6 of this section.

The second method is based on the balance between nutrients supplied to the field and the nutrients removed each year in the harvested crop. A worksheet for this method is shown in figure 2–3. The instructions for its use follow.

Nutrient balance worksheet based on crop removal

Planned crop or crop rotation

List the crop that will receive nutrient application. In the case of rotation, list the crops in sequence. Nutrient budgets can be calculated for a single crop or over the entire crop rotation.

Yield expectation

Describe the expected crop yield based on realistic soil, climate, and management parameters. Yield expectations can be determined from producer or county yield records, soil productivity tables, or local research.

Nutrients removed by crop

When a crop is harvested and removed from the field, the nutrients in that crop are also removed. These removed nutrients represent a net loss to the soil and plant system of that field. Other losses, such as erosion and runoff, leaching, denitrification, and volatilization, can occur and must be estimated if the objective is to maintain a constant level of the nutrients in the field. The USDA NRCS Agricultural Waste Management Field Handbook (AWMFH), table 6–6, can be used to estimate nutrient content in harvested crops. Chapter 11 of that handbook also gives some guidance on how to estimate nitrogen nutrient losses from the field system. Note that crop utilization, the amount of nutrients needed to produce a crop, is not the same as the crop removal, the amount that is taken from the field. Crop utilization includes nutrients required for growing roots, stems, and leaves that may not be harvested and removed from the field, but returned to the soil.

Nitrogen credits

Nitrogen is a mobile nutrient and occurs in the soil and plants in many forms. It can be stored in the soil's organic matter and released as the organic matter decomposes.

Legume nitrogen credits—Nitrogen is taken from the air by legume plants and brought into the soil. Amounts of nitrogen added by legume production vary by plant species and growing conditions. Refer to local university information for the legume nitrogen credits.

Nitrogen residual—Not all the nitrogen applied in previous manure applications is available to the crop the year of application. A percentage of last year's manure application and an even smaller percentage of previous applications become plant available during this crop season. Refer to local mineralization rates to

Figure 2–3 Nutrient budget based on nutrients removed by planned crops

A. Planned crop or crop rotation ______________________________

B. Yield expectation (goal) ______________________________

C. Nutrients removed by crop

C 1. Yield (units of measure) * Unit weight (lb) = pounds crop material harvested

____________ * _________ = ____________ lb/acre

C 2. Nutrient content of harvested material (refer to table 6–6 Agricultural Waste Management Field Handbook)

% N = _______ % P = _______ % K = _______

C 3. Crop nutrient content

N = [(C 1) (C 2 %N)] = _______ P = [(C 1) (C 2 %P)] = _______ K = [(C 1) (C 2 %K)] = _______

C 4. Convert to fertilizer equivalent units

C 3 N = C 3. N = _______ C 3. P * 2.29 = ______ P_2O_5 C 3. K * 1.2 = ______ K_2O

D. Nitrogen credits

D 1. Legumes credits from previous crop _______ lb/acre

D 2. Residual from previous manure applications _______ lb/acre

D 3. Irrigation water nitrate nitrogen _______ lb/acre

D 4. Others (atmospheric deposition, mulch) _______ lb/acre

D 5. Total N credits ($D_1 + D_2 + D_3 + D_4$) _______ lb/acre

E. Sources of nutrients available to the field	N	P_2O_5	K_2O
E 1. Manure and organic material applied	_______	_______	_______
E 2. Nitrogen credits (D 5)	_______		
E 3. Starter fertilizer	_______	_______	_______
E 4. Others	_______	_______	_______
E 5. Total nutrient sources	_______	_______	_______

F. Show nutrient balance	N	P_2O_5	K_2O
F 1. Nutrients removed by harvested crop (C 4)	_______	_______	_______
F 2. Total nutrient sources (E 5)	_______	_______	_______
F 3. Nutrient balance (F 1 – F 2)	_______	_______	_______

If F 3 is a positive number: This is the amount of additional nutrients required. Supply with fertilizers or other forms of nutrients.

If F 3 is a negative number: This is the amount of nutrients that are in excess. Reallocate the sources of nutrients available.

determine the residual release of nitrogen. Phosphorus and potassium are considered 100 percent plant available the year of application; therefore, no residual amounts are calculated.

Irrigation water nitrate nitrogen—Irrigation water, especially from shallow aquifers, contain some nitrogen in the form of nitrate nitrogen. This nitrogen is available for crop use. To calculate the amount of nitrogen applied with irrigation water, determine the concentration of nitrate nitrogen in the water (in ppm or mg/L). The application amount will equal the nitrate nitrogen concentration (in ppm) multiplied by the volume (in acre-inches) times 0.23. The factor 0.23 converts ppm or mg/L and acre-inches into pounds per acres.

Other nitrogen credits—Other nitrogen credits come from atmospheric deposition from dust and ammonia in rainwater. This value is recorded by a number of weather stations throughout the USA and can be obtained from National Atmospheric Deposition, Fort Collins, Colorado. Atmospheric deposition may range from a few pounds per acre per year to over 30 pounds per acre per year.

The nutrient content of any other material that is brought onto the site, such as mulch or compost, can be determined by estimating the mass weight and percent concentration of nitrogen in the material.

Sources of nutrients available to the field

The producer has the capability to bring various sources of nutrients onto the field to supply the requirements of the crop. The nutrient budget is designed to allocate the sources of nutrients available and adjust the amounts based on the calculations to match the crop's needs.

Manure and other organic material can be produced either on the farm or transported to the farm with the expressed purpose of utilizing the nutrients. Manure application rates should be based on crop nutrient requirements, but can also be applied to distribute organic material and micronutrients over a broader number of fields.

Nitrogen credits are summed and carried to the calculation here.

If *starter fertilizers* are required, as in cases of cool, wet soils or reduced tillage systems, the amount of starter nutrients is entered here.

Other nutrient additions can be entered here.

Show nutrient balance

The required amount of crop nutrients, either determined from the land grant university recommendations or from the crop removal, is subtracted from the total nutrients available to the field. A deficiency of nutrients in the balance means that additional nutrients need to be applied to the field to meet the crop requirement. This can be done with additions of fertilizer or higher rates of animal manure. There is no opportunity to increase the manure residual mineralization rate or amount of atmospheric deposition, and only a slight increase with additional irrigation water. Fertilizer is considered the easiest because the exact nutrient ratio can be derived by using any of a number of fertilizer blends.

When the balance shows excess, more of one or more nutrients is available in the field than required by the crop. This excess of nutrients can become an environmental liability when subject to runoff and leaching. The field inputs, most likely the manure additions, must be adjusted to balance with the crop requirements.

Chapter 3 Animal Manure and Nutrient Management

Animal manure and other organic material contain valuable crop and soil nutrients. The nutrients are in waste feed material, manure, bedding, and animal parts, such as feathers and hair. These by-products of animal operations have nitrogen, phosphorus, and potassium levels high enough to be utilized as soil amendments and nutrient supply for crops (fig. 3–1). Waste products are also a source of organic material and micronutrients to support soil organic matter and crop nutrient needs. Animal manure contains from 0.1 to 4.0 percent of the major plant available nutrients, N, P, and K. A wide range of nutrient content values is in agricultural waste products. Onsite sampling and laboratory analysis of waste products immediately before land application and utilization are the assured ways of determining nutrient content. Many universities and Extension Service offices have published book values for the nutrient contents of various agricultural by-products. These book values have been compiled from research and field inventories. Chapter 4 of the Agricultural Waste Management Field Handbook also has a procedure for estimating nutrient content of waste products.

Nutrients contained in the waste by-product may or may not be plant available during the year of land application. Nitrogen is only partly plant available during the first crop season. Most of the ammonium nitrogen (NH_4^+–N) is plant available. The organic portion of nitrogen becomes gradually available during decomposition of the waste product and mineralization of the nitrogen. The decomposition and mineralization rates vary by region of the country and carbon content of the waste. Figure 3–2 gives a general estimate of nitrogen availability from animal manure.

Figure 3–1 Animal production systems can supply valuable nutrients for crops

Ratios of nitrogen, phosphorus, and potassium found in animal manure vary with animal species, feed content, and storage method. Generally, manure ratios of plant available N-P_2O_5-K_2O are between 3-2-3 and 2-1-2. This is in contrast to the plant's required nutrient ratios for growth, which is between 8-1-3 and 3-1-2. Thus, there is an imbalance between the nutrient requirements of the crop and the nutrient supply in the agricultural waste product. A decision must be made as to which nutrient should be selected to supply adequate material to the soil and crop and what other nutrient material will be brought in to complete the crop's nutrient needs. Overapplication of nutrients to the soil and crop system is not an acceptable resource management practice. Levels of nutrients in the soil greater than the crop requirements have potential for offsite movement and contamination of soil, air, and water resources.

A difficult management aspect occurs in handling and using animal manure and other agricultural products. The growth and concentration of the livestock industry have created large supplies of animal nutrients in small land areas.

Dealing with animal manure production for land application and nutrient utilization is an issue in many parts of the country. A balance must be made between the crop nutrient requirement of a region and the livestock manure produced in the same area. While crops use nutrients mainly during the growing season, animal manure and other agricultural by-products are produced year-round. This creates an accumulation of nutrients until the next opportunity for field application and crop growth. Because application of these products requires special equipment and usually full access to the crop field, there is some limitation to when the material can be applied. Timing of the nutrient release from this field-applied organic material may or may not coincide with the crop requirements. While the maturing and harvest of crops will in most cases end the crop's nutrient uptake and utilization, it does not stop the soil processes that continue to decompose organic forms and mineralize nutrients. Continued availability of nutrients within the soil after crop harvest may lead to contamination of the air, water, and soil resources. Careful management of the rate, timing, and method of application of organic materials is essential to optimize the utilization of the nutrients and minimize to the extent possible any excesses that could find a way to enter resource sensitive areas.

When manure or other organic material is used as a nutrient source, odors can be a problem. Under certain atmospheric conditions (warm temperatures, high humidity, light winds), strong odors can be released from surface-applied material. Avoid application under these conditions if possible. Incorporating the manure soon after application can reduce odors. Use an injector applicator instead of spreading on the surface. Applying this material when the wind is blowing enough to disperse the odor also helps.

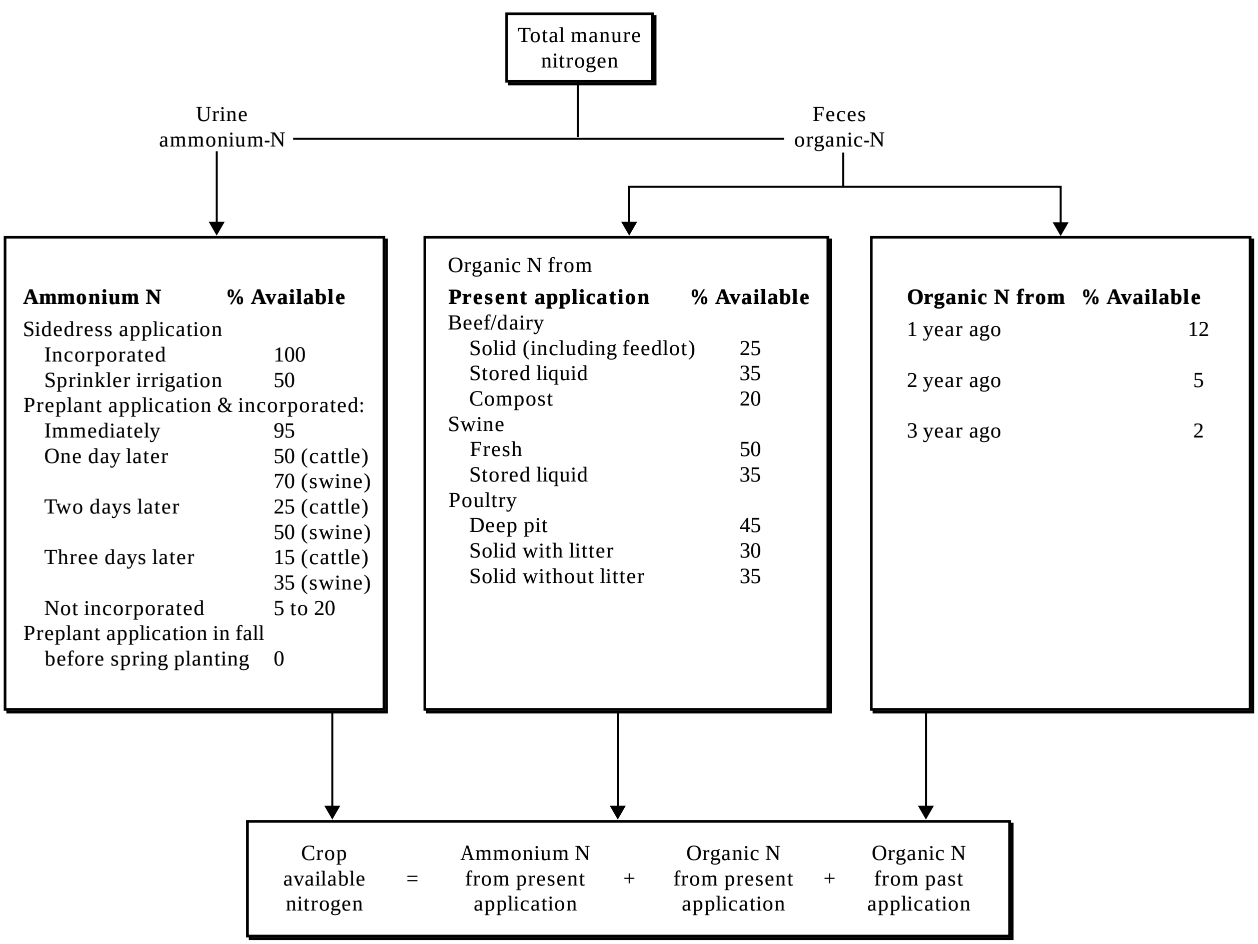
A drawback to incorporation of organic nutrient sources is that it not only buries manure, it also buries crop residue. This may conflict with an existing residue management system on the farm. Chisel plows with twisted points can bury up to 55 percent of residue on the surface. A one-way disk can bury up to 70 percent of crop residue, and a tandem disk up to 50 percent of residue on the surface. These conflicts should be resolved in the planning process, if possible. Some options that could be used are:

- Plan manure application for the fields that have the least potential for sheet and rill erosion and, therefore, have less need for residue management.
- Develop the erosion control system using other conservation practices, such as contour farming or buffers, that do not rely on crop residue.

If the quantity of manure exceeds the farm's capacity to use all the manure nutrients in an efficient and environmentally safe manner, an alternative method or methods of utilization must be found. Some possible alternatives include:

- Acquiring more land for application.
- Reallocating land to the existing lands.
- Trading or selling to neighbors.
- Reducing livestock numbers.
- Producing a value-added product, such as compost, feedstuff, or combustible material.

Figure 3–2 Estimate of nitrogen availability from animal manure



Chapter 4 Water Management and Nutrient Management

The control and management of the water resources required for crop production are essential for controlling and managing the environmental effects that water has on our natural resources. In areas where rainfall provides the majority of soil moisture for crop production, incoming precipitation is impossible to control. The overland flow of excess precipitation or the water status in the soil profile is often necessary to control. In arid areas where irrigation water supplies the majority of the soil moisture, the water additions to the soil and any excess soil profile moisture that may occur must be controlled.

Water management practices have been developed by NRCS for three major areas.

- Irrigation
- Drainage
- Water level management

NRCS has developed a number of conservation practice standards that give guidance for water management. These practice standards are in the Field Office Technical Guide and the National Handbook of Conservation Practices.

Irrigation water management involves controlling the rate, timing, amount, and rate of application of irrigation water so that crop moisture requirements are met while minimizing water losses and soil erosion. Matching irrigation water application to crop needs and soil infiltration rates reduces surface runoff during irrigation. This helps to prevent erosion and loss of nutrients. Irrigation water can be applied so the timing maximizes the benefits from pesticide and yet reduces the chance of loss from leaching or runoff. Properly designed and managed irrigation and drainage systems remove runoff and leachate efficiently, control deep percolation, and minimize erosion from applied water. This reduces adverse impacts on surface and ground water.

Irrigation volume and frequency should be determined by crop needs and soil characteristics. Soil moisture should be monitored to determine when application is needed to prevent crop stress and limit deep percolation. When soil is irrigated, the volume applied should be planned to meet the water-holding capacity of the soil in the root zone of the crop. The rate should not greatly exceed the absorption or infiltration rate. When fertigation or chemigation is used, wells must be equipped with check values and antisiphon devices to prevent well contamination, which can lead to contamination of the aquifer.

Pollution process

Pollution is the result of a series of processes. These can be categorized as availability, detachment, and transport. A water pollution hazard exists only when a pollutant is available in some form at the field site, becomes detached, and is transported beyond the edge of the field, below the root zone, or above the crop canopy toward a receiving waterbody. An existing or potential pollution problem from irrigation activities may result if the irrigation decisionmaker uses an unsuitable irrigation system, poor operation techniques, and poor irrigation water management decisions when matching irrigation application to pesticide and nutrient application. A potential pollution opportunity still exists even if the best of water management practices is used because all the chemical compounds are vulnerable to the pollution process.

Availability

A potentially polluting substance is available in some amount and in some place. The potential pollutant could be sediment from a highly erosive soil since soil is always available. Chemical compounds vary not only in quantity, but also in the degree of their availability for movement. The amount available at the time of runoff or deep percolation is important. Nutrients from fertilizer in or on the soil or from mineralized crop residue, pesticides applied to the field, bacteria carried with an application of animal manure, or some other potentially harmful material all have different forms and timing of availability for movement.

Detachment

The potential pollutant or its environment is modified so that the substance can be moved from where it is supposed to be to where it should not be. The detachment process is either physical or chemical. Chemical pollutants can be grouped into three categories based on their adsorption characteristics: (1) strongly adsorbed, (2) moderately adsorbed, and (3) nonadsorbed.

Detachment is dependent on:
- The type of compound and concentration
- Bonding strength to the soil particles
- Quality and quantity of irrigation water
- The chemical, physical, and biological characteristics of the soil (pH, soil organic matter, porosity, and electrical conductivity)
- Climatic conditions (wind, temperature, and water movement)
- The properties of the chemical compound

Highly soluble compounds are easily detached by dissolving into both surface runoff and percolating water. Strongly adsorbed compounds are sometimes not detached, but are carried by soil particles that have been separated by water drop splash or surface runoff sheer.

Transport

Transport is the movement of a material from its natural or applied position. A contaminant is transported to a place where it may become harmful to human or environmental health. Agricultural pollutants are typically transported in water as surface runoff or deep percolation, or can be moved through wind drift and volatilization. The particular pathway by which a pollutant leaves the field depends on soil type, hydrology of the field, type of irrigation system and its operation techniques, timing and rates of nutrients and pesticides applied, and the interaction of the compounds with the water and soil as affected by management practices.

Pollutants are generally transported to receiving water by surface runoff and/or deep percolation. Excess irrigation water application because of either poor distribution uniformity or poor management decisions provides the opportunity. Runoff from sprinkler irrigation systems typically results from inadequate design, poor operation techniques, soil compaction, or letting the system run too long on one set. Some runoff from graded furrow and border irrigation systems is necessary to provide adequate irrigation water to all parts of the field.

Deep percolation and lateral flow can occur with most irrigation methods and types of systems. With poor operation and management, excess deep percolation and runoff probably have the greatest opportunity to occur with surface irrigation methods. However, it should be strongly emphasized that when adequately designed, operated, maintained, and managed, surface irrigation systems can provide adequate uniformity with minimal pollution potential. A poorly designed and managed sprinkler system can have high potential for providing excess deep percolation and runoff. Deep percolation carries dissolved substances, such as nitrates, salts, and pesticides, in original form or in a metabolized form downward in the soil profile. The metabolized form may have different chemical properties (half-life, toxicity, solubility) than the original form and may present a greater or lesser risk to the environment.

To summarize, contamination of water occurs through availability, detachment, and transport. For contamination to occur, contaminants must be available at the source of supply. Mechanisms with strong forces separate (detach) contaminants from the source and move (transport) them to where they may degrade a water resource. The potential for pollution can be reduced by:
- Minimizing availability of the pollutant in the environment
- Minimizing the detachment of the contaminant compound
- Minimizing the transport of the contaminant substance

Conservation practices for pollution control and reduction

Source reduction

A nutrient management plan helps reduce the pollution source. Generally, fewer nutrients are applied to a field when a producer follows a nutrient management plan. This may not be true the first years of the plan implementation because soil fertility may need to be adjusted to meet the nutrient needs of the cropping system. Nutrients, especially fertilizers, should be applied so that their availability matches the plant's uptake needs as closely as possible. Matching application to plant requirements can reduce the amount available for detachment and transport.

Maintain soil surface cover to prevent erosion and entrap potential pollutants. Provide the necessary conservation tillage, vegetative cover, and water management practices to reduce irrigation induced soil erosion and runoff, which can reduce the contact time of water with the potential contaminant.

Reduction of availability

The producer can optimize nutrient availability by managing the rate, timing, source, and method of application. Soil and plant testing to monitor the buildup of available nutrients in the crop root zone is a basic management practice. Incorporation of chemicals reduces contact time with irrigation water for surface loss. The amount of chemical compounds susceptible to leaching losses can be minimized by growing deeper-rooted crops that will scavenge these materials that have percolated below normal rooting depths. Improving the soil's chemical, physical, and biological condition can help retain and degrade many of the chemical compounds in the plant root zone.

Reduction in detachment

For those nutrients that are strongly adsorbed to soil particles, detachment and transport off the field are major avenues of loss. Phosphorus is tightly bound to soil particles by aluminum, iron, and calcium minerals. It is, therefore, not readily transported except when soil becomes detached. Phosphorus becomes part of the surface water pollution mainly because of soil erosion and deposition of sediment in surface water. Some phosphorus moves when runoff water desorbs the nutrient from the soil particle. Increased organic matter and other organic residue on the soil surface decrease detachment of nutrients if soil structure and other physical conditions are improved.

Reduction in transport

Because many nutrients and salts are strongly adsorbed to soil particles, the amount of these materials lost from the field is directly related to the amount of sediment carried from the field. Chemicals that dissolve readily are easily transported with excess irrigation water either from the edge of the field or the bottom of the root zone. Proper water application amounts and timing are essential to reducing transport potential. Decreasing deep percolation losses caused by excess and nonuniform irrigation can decrease nitrate nitrogen movement. The inorganic form of nitrogen, ammonium (NH_4^+), is moderately held on the soil particles and, therefore, not readily transported by soil water, while nitrate nitrogen (NO_3^-) is soluble and readily moves with the water solution.

Infield soil erosion with furrow irrigation systems can be controlled by:
- Using proper inflow streams
- Reducing irrigation grades
- Maintaining crop residue on the soil surface
- Using a soil stabilizing compound, such as polyacrylamide (PAM)
- Promoting crop rotation

Off-field sediment movement can be reduced by:
- Using vegetative filters at lower edge of the field
- Controlling runoff to reduce velocities
- Installing sediment detention basins
- Collecting and redistributing tailwater

Salt

All irrigation water contains dissolved salts. Every irrigation event adds some salts to the soil. Fertilizer and animal manure also contain salts. These salts may stay in solution and move below the root zone, or they may precipitate within the root zone. The total level of salts in water is described in terms of electrical conductivity (EC) or in total dissolved salts in parts per million (TDS ppm). Water that has 300 ppm total dissolved salts contains 300 pounds of salt per million pounds (120,048 gallons) water. Electrical conductivity is measured in millimhos per centimeter or deciSiemens per meter. It is a measure of how easily an electrical current passes through water. Pure water without salts does not conduct electricity. The more salt in the water, the easier it is to conduct electricity through it. An approximate relationship between EC and TDS is that 650 ppm total dissolved salts is equal to 1 millimhos per centimeter electrical conductivity, or 1 deciSiemens per meter.

Excessive or imbalanced dissolved salts can cause four types of production problems for irrigated agriculture:
- General yield declines
- Structure problems
- Toxicity
- Corrosion

General yield declines

Dissolved salts create an osmotic force that holds water back from plant uptake. Excessive dissolved salts reduce the amount of plant available water in the soil. This can create an additional stress on the crop.

Structure problems

The total amount of dissolved salts in the soil may not be as important as the relative ratio of the different salts. If salt types are out of proportion, soil structure problems can result. The most significant salt imbalance occurs if there is too much sodium in relation to magnesium and calcium in the soil water. This structure problem usually leads to low water permeability of the soil. As infiltration is reduced, the soil becomes hard, making it difficult for root penetration. The type and amount of clay in the soil determines the extent of the infiltration problem.

Toxicity

Some nutrient salts, while essential for plant growth in small amounts, are toxic in excessive amounts. Boron is an example. Boron is toxic to plants and starts to affect plant growth when irrigation water exceeds 1 ppm boron.

Corrosion

Salts can cause corrosion of irrigation equipment. Water must be handled and treated carefully to prevent disruption of water distribution, especially with drip irrigation systems.

Drainage and runoff

The removal of excess soil water by drainage has greatly increased agricultural production. Drainage not only removes the gravitational water from the soil, it allows for freer exchange of soil air with atmospheric air. Changing the water and air status of the soil impacts the fate and transport of agrochemical compounds. Foremost, drainage water carries with it any dissolved materials from the soil. Soluble carbon, nitrates, potassium, phosphorus, and pesticides move with drainage water. This water is transported to subsurface drain outlets, seeps and springs, open channels, and fissures in the bedrock and can become part of the surface water. A portion of the drainage water moves vertically down, does not resurface, and becomes part of the ground water.

Some irrigation water must pass through the root zone of the crop to maintain soil salinity at a desirable level. Deep percolation is required to remove salts from the root zone. The key questions are: *How much deep percolation is required?* and *Where does it go?* The timing in the rotation is also important to avoid periods when nutrients or pesticides would be moved by the leaching and transported from the root zone by the drainage water. Leaching should be done when residual soil nitrate levels are at the lowest.

Internal drainage must be sufficient in the soil to allow the pore spaces to become free of water and the soil-air to be exchanged with the atmosphere. Plant roots require air to carry on respiration. Drainage of the large soil pores is a natural process of gravity. Percolation water moves downward or laterally out of the plant root zone. The concern is about the quality of water carried by drainage moving toward the ground water. The drainage water is carrying dissolved nutrients, pesticides, and salts.

If insufficient drainage occurs, as is the case when impermeable rock or clay is relatively near the soil surface, percolating water backs up and creates a saturated zone in the soil. Under these conditions natural drainage cannot remove the excess water fast enough and plant roots suffer from lack of oxygen in the soil. Artificial drainage systems need to be installed to carry away the excess soil water. These systems are generally perforated, polyethylene tubes buried at various depths and spacing at or near the bottom of the crop root zone. Soil water enters the perforations and is carried by gravity to a surface outlet or is pumped to the surface for disposal. The drainage water, which contains nutrients, pesticides, and salts resulting from deep percolation in the soil, has a potential to contaminate surface water where it is being disposed.

Water level control

Water level control is the manipulation of soil moisture to create suitable soil and plant environment for control of vegetative growth, reduction of such compounds as nitrate nitrogen, or promotion of soil micro and mesa fauna. This is accomplished by changing the aeration or water status of the soil pores. Such crops as rice respond favorably to saturated soil conditions and can out-compete other vegetation. Plants classified as obligate wetland species grow in these same conditions.

Water level control practices, such as subsurface irrigation, flooding, and water control structures, saturate the soil profile and change the reduction-oxidation (redox) status of the soil. This change in redox impacts the minerals and organic compounds in the soil. A change in redox potential alters the chemical form of the compound, thereby affecting the plant availability and mobility. The conversion of highly adsorbed ferric phosphate to soluble ferrous phosphate occurs when soils become saturated with water.

The change in the soil moisture status also affects the biology of the soil and plant ecosystem. Different species of soil flora and fauna are present with different soil moisture regimes. Associated soil fauna become transitory to the changing soil conditions. Nitrogen responds to varying soil moisture conditions. When sufficient oxygen is present in the soil, nitrogen transforms to the nitrate nitrogen (NO_3^-) form. If oxygen is limited, the soil microbes use the oxygen in the nitrate and convert the compound to atmospheric nitrogen (N_2). Soil carbon also transforms in different pathways depending on the redox potential of the soil. If oxygen is available in the soil, carbon is released to the atmosphere as carbon dioxide (CO_2). Limited oxygen produces methane (CH_4).

Water management planning accounts

Two types of water management planning accounts are used by planners depending on the purpose and need. A water budget is a projected accounting of the water supply in the soil for a general area for a general period of time. Simply, where does the water come from and where does it go? A water balance is the daily accounting of the water supply for a specific field (soil and crop type) during a specific time. The difference in the two methods can be compared to a family expense account. The budget is the money that is known to come in (income) and be spent (expenses) each month. A balance is the daily running account of what is deposited (precipitation and irrigation) and what is spent (runoff, evapotranspiration, and deep percolation). Budgets are estimates based on past habits and historic conditions. The balance is the actual ledger of money (soil moisture) on hand in the account at any one time.

Water budgets are used for water management planning or broad assessment of the field or farm conditions. For nutrient management, they can be used to show periods throughout the year when excess water may be available to leach nutrients out of the root zone. Other uses are general irrigation design, seasonal crop water requirements, and farm operation scheduling.

The difference in a water balance and a water budget is in the detail and the accuracy used. Water budgets generally are based on average monthly values from historic weather records. They may use averages of rainfall or precipitation over a 10- or 15-day period. The inputs are precipitation plus irrigation, and the debits are evapotranspiration, runoff, and deep percolation plus changes in the soil water storage. Average monthly values are used to calculate average monthly budgets. Budgets vary according to crop, soil, and location. They can be developed as a general scenario for each climatic zone, county, or watershed, either for 1 year or for the crop rotation. Water budgets are more useful when they are customized to local conditions.

Water balances are site specific soil water accounts and can be used as information about the soil water holding capacity, daily climate data, and crop water requirements. Daily crop evapotranspiration values are calculated at real time every day, and a daily accounting of soil moisture content is made based on inputs and debits. Any water added to the soil surface is added to the soil moisture profile as a net gain after evaporation, runoff, and deep percolation are subtracted. Water balances are used for scheduling irrigations, evaluating effects of management on water quality and quantity, and measuring changes in the soil water content, rainfall, irrigation application, crop evapotranspiration, deep percolation, and runoff. All this is measured on a daily basis.

Chapter 5 Integration of Nutrient Management with Other Practices

Many conservation practices are used together to make up a resource management system. Resource management systems consist of the proper combination of conservation practices needed to solve indentified resource problems. The CORE4 practices described in this document are considered key conservation practices specifically selected to address resource concerns. How these practices interact is important to the overall effectiveness of the system. The planner must be aware of these interactions so that the functioning of the system is not jeopardized. Examples of situations in which nutrient management interacts with one or more other conservation practices are given in this chapter.

Residue immobilization and slow release of nutrients in residue management systems

The nutrient management plan must take into account the amount and type of crop residue on or immediately below the soil surface. The bacteria in the soil that decompose crop residue may use some of the fertilizer nitrogen as an energy source. This reduces the amount of nitrogen available for the crop. If surface-applied nitrogen is used, the amount of nitrogen applied may need to be increased to account for this. Another option is to change the form and/or placement of the fertilizer. Injecting the fertilizer below the surface zone of high biological activity reduces the amount of nitrogen used by bacteria.

Pest management through nutrient management

Providing adequate plant nutrition promotes healthy, vigorous plants. Healthy plants can resist pest pressure. Pest management through nutrient management; i.e., succulent growth, can be associated with leaf hopper damage and foliar diseases. In some crops an excess of nitrogen can result in a flush of new leaves. This lush, tender new growth is more easily attacked by leafhoppers and similar insects. These insects may carry viruses or cause physical crop damage that allows the entry of fungi or bacteria.

Buffers in nutrient removal

Buffers can trap nutrients that are in runoff, preventing them from causing offsite water quality problems. The effectiveness of buffers in nutrient removal depends on nutrient levels in runoff. Buffers have a finite capacity to trap and sequester nutrients in runoff and sediment. They are designed to function effectively under average conditions. If excess nutrients are applied to the fields above buffers, the nutrient level in the runoff may exceed the ability of the buffer to take it up.

Nutrient balance

Nutrient balance associated with healthy plants can reduce pest damage. A healthy, vigorously-growing crop is a strong defense against insect and disease damage. A good nutrient management program ensures that all needed nutrients are available in the proper amounts. This minimizes excess vegetative growth that may attract leaf-feeding insects that may carry diseases to the crop. It may also reduce the severity of some plant diseases.

Water management

Good water management makes good nutrient management; e.g., leaching nutrients below crop root zone. Nutrient losses are minimized when proper water management is coupled with good nutrient management. In irrigated crops, leaching and runoff losses are minimized when good irrigation water management is practiced.

Cropping rotation/sequence

Cropping rotation/sequence can aid nutrient management. A cropping sequence with a variety of crop types (grasses, legumes, summer annuals, winter annuals, perennials) and rooting characteristics (shallow roots, deep roots, fibrous root system, tap root) better utilize the available nutrients in the soil.

Following a shallow-rooted crop with a deep-rooted crop helps scavenge nutrients that may have moved below the root zone of the first crop.

Nitrogen-fixing crops can supply some of the nutrient needs for the following crop.

Cover crops can scavenge nutrients left after harvest of the primary crop. These nutrients become available to subsequent crops as the organic material decomposes and the nutrients are mineralized.

Conservation tillage system

Erosion and runoff can remove nutrients from the soil surface. Erosion can cause significant nutrient losses from a field because nutrients are attached to the soil particles that are carried away by the wind or water. A conservation tillage system can reduce both wind and water erosion, keeping the nutrients on the field.

Nutrient management as component of overall conservation plan

Plan nutrient management to complement the overall conservation planning objectives. Nutrient management is a component of the overall conservation plan. When planning nutrient management, implementation practices and management activities should be coordinated with other objectives of the producer and the conservation plan. For example, if the soil is shallow and stony, the use of sidedress application of anhydrous ammonia may not be feasible and may conflict with the planned objective of minimum tillage. Also, planning of organic waste incorporation to conserve nutrients and reduce odor may conflict with crop residue requirements of the tillage and cropping system. Soil erosion or runoff control may outweigh the desire to control ammonia losses or odor. Confer with the overall conservation plan to make sure the resource concerns have satisfied to the extent possible the desired conditions for the management system.

Modification of nutrient management components

When the conservation plan is successfully implemented, a resource management system is considered applied to the producer's operation. The nutrient component of the overall conservation plan must be successfully implemented before this happens. Sometimes unforeseen circumstances require a change in the nutrient management components. The climate, producer's health, or the economics of the livestock and commodity markets can disrupt the planned components of nutrient management and require some modification for the nutrient components. For example, wet weather and saturated soil conditions may prevent application of animal manure before planting of the planned crop. Alternative nutrient sources must be found as well as additional land area to apply the manure later. Large rainfall events or severe drought change the nutrient (especially nitrogen) dynamics in the crop and soil. Additional soil testing and nutrient application may be required.

Adjustments and modifications of the nutrient plan components must be made when changes are made in the cropping system or nutrient sources. The changes should be made in a timely manner and based on the overall plan objectives.

Chapter 6 Economic Considerations—Nutrient Management

Introduction

Nutrient management systems provide a means for safely disposing of onfarm produced waste products and reduce the need for commercial fertilizer. As an integral part of farming operations, nutrient management systems contribute significantly to the reduction of nonpoint source pollution while often improving the producer's bottom-line. Specific elements of nutrient management differ among regions and states because of weather and climate conditions, soils, waste storage requirements, and crop growth requirements. Costs may be incurred by equipment changes, structural measures required, and labor or time costs.

In the example that follows, cost savings are produced by reductions in amounts of commercial fertilizer applied and improved yields from fully meeting crop needs. Offsite benefits are reduction of potential for nitrate leaching and reduction of nitrate runoff.

Table 6–1 is a listing of potential effects, pluses, and minuses of implementing a nutrient management system. It is not an all-inclusive list nor is it meant to be limited to any one particular set of circumstances.

Example case scenario

This example unit is a 500-acre farm with a confinement hog operation that has recently purchased a 160-acre unit. The farm raises 2,100 hogs at 130 pounds annually, or a total of 273,000 pounds (273 animal units). For purposes of this analysis, it is assumed that:

- The original 500 acres could not effectively utilize all the nutrients in the manure generated by the hog operation. The 636 acres of cropland are calculated to absorb all the nutrients produced by the hog operation.
- The producer has no plans to increase animal units.
- No additional equipment is needed because the operator already applies manure to his cropland.
- 24 acres are set aside for a conservation buffer (see example), reducing total cropping to 636 acres.
- The producer will not be spreading manure in the buffer area.
- The 160 acres acquired were cropped previously.
- The implementation of nutrient management produces higher yields. The producer plans to maintain 24 acres in the conservation buffer and to rotate 636 acres in cropland as follows:
  - 280 acres in corn
  - 280 acres in soybeans
  - 76 acres in wheat

Table 6–1 Summary comparison of the effects of implementing nutrient management

Pluses +	Minuses —
Economic effects	
Increased yields	Increased management consulting costs
Potential reduction in production costs by avoiding application of purchased fertilizer	Potential increase in machinery time and costs
Social effects	
Decreased risk of water contamination	Increase in perceived risk associated with adopting a new technology
Decreased health risks to family and neighbors	
Resource effects	
Improve water quality (reduced nutrient runoff or leaching)	

- The typical rotation is corn-wheat-soybeans; wheat follows a portion of the corn annually.
- A total of 21,412 pounds of N and 16,314 pounds of P is available each year in the hog manure, and 40 pounds residual N is available from soybean production. Potassium needs can be fully met by the manure.
- The fee for the nutrient management consultant is $5.00 per acre. Consultant fees for nutrient management includes soil testing, manure testing, and plant tissue testing. However, applying multiple practices simultaneously can increase efficiency. For example, the services of a pest management consultant cost $6.00 per acre. Combined consultant services for both nutrient management and pest management can be obtained for $7.50 per acre.

There is an offsite water quality concern in the reservoir downstream. Neighbors are sensitive to any increase in manure or other use on cropland that may affect it. After attending a public meeting on the lake's water quality, the producer became concerned about the effects of residual nutrients on the family's water supply.

The producer obtained average per-acre yields of 140 bushels corn, 37 bushels soybeans, and 58 bushels wheat before implementing nutrient management. It is assumed that with the implementation of nutrient management corn yields would increase by 10 bushels, soybean yields by 5 bushels, and wheat yields by 4 bushels. Analysis of manure content and crop nutrient indicate that manure will provide all the needed phosphorus for the crop. (Phosphorus is the limiting nutrient in the sense that any further application of phosphorus in excess of that provided by manure from the hog operation might contribute to phosphorus runoff to surface water or leaching to ground water.)

Added returns
Added returns include those items that will increase income to the landowner, such as increased crop yields. In this scenario nutrient management would increase per acre crop yields by 10 bushels for corn, 5 bushels for soybeans, and 4 bushels for wheat.

Reduced costs
Reduced costs typically include variable production costs for crop production. Variable costs change as production is changed. In this scenario purchases of fertilizer were less after crediting manuress nutrient content and the residual nitrogen following the soybean crop the decrease was an average of 26 pounds per acre of phosphorus and 41 pounds of N per acre of cropland.

Reduced returns
Reduced returns include those items that will decrease the landowner's revenue. They normally consist of any reduced yields that may occur through a change in a cropping practice or revenue reduction because of land removed from production. In this scenario there are no discernible reduced returns.

Added costs
Added costs are those items that increase the landowner's cost and consist of the nutrient management consultant's fees.

Conclusion

This analysis indicates nutrient management will reduce onfarm nutrient loading, increase yields, alleviate drinking water concerns, and address offsite water quality concerns. This can be accomplished for an added cost of about $3,200. Revenues would increase by $14,500, and costs would be reduced by $10,000. This represents a net increase of $21,300, or $33/acre for the 636 acres in production. See table 6-2.

Table 6–2 Data for economic evaluation of installation of nutrient management

Added returns (+)	**Unit**	**$/Unit**	**Amount**	**Total Revenue**
Increase corn yield with Nutr. Mgt	acre	$20.80	280	$5,824.00
Increase soybean yield with Nutr. Mgt.	acre	$27.25	280	$7,630.00
Increase wheat yield with Nutr. Mgt.	acre	$13.24	76	$1,006.24
			Subtotal	**$14,460.24**
Reduced costs (+)				**Total cost**
Decreased purchased fertilizer - corn				$7,167.74
Decreased purchased fertilizer - wheat				$459.94
Decreased purchased fertilizer - soybeans				$2,394.65
			Subtotal	**$10,022.33**
Reduced returns (-)	**Unit**	**$/Unit**	**Amount**	**Total revenue**
-none-	—	—	—	—
Added costs (-)	**Unit**	**$/Unit**	**Amount**	**Total cost**
Nutrient consultant management fee:	acre	$5.00	636	$3,180.00

Partial budget summary	
Added returns	$14,460.24
Reduced costs	$10,022.33
Reduced returns	0.00
Added costs	$3,180.00
Net change to operation	$21,302.57

Chapter 7 Nutrient Management Job Sheet Instructions

The Nutrient Management Conservation Practice Job Sheet at the end of this chapter shows example specifications. The following instructions can be used to fill out the job sheet. (Throughout this chapter the term *nutrient management plan* means the nutrient management component of a conservation management system.)

Step 1. General Information
Enter the landowner's name, field(s), who assisted with the planning, and the date.

Step 2. Purpose
Check all purposes for which the practice will be applied.

Step 3. Job sketch
Sketch the field or fields covered by this plan on the back page of the job sheet. Include the field location(s), field identification, any sensitive areas within or adjacent to the field, and required setback areas. Within the boundaries of each field, record the total acreage of the field and the acreage to which nutrients can be applied (considering required setbacks). Other relevant information, such as complementary practices or adjacent field or tract conditions, may be included.

The sketch should be prepared early in the planning process. A visual image of the fields with respect to surrounding areas is needed before developing the rest of the nutrient management plan. A completed nutrient management plan includes aerial photographs or maps (including a soil map) and soil interpretation that may be a part of the overall conservation plan. These maps and/or photos can help in preparing the sketch in the specification sheet.

Table 1
Table 1 of the specifications sheet shows field conditions and nutrient application recommendations.

Step 4. Crop sequence/rotation
The crop sequence/rotation should describe the sequence of crops for 5 years. Start with last year's crop and project the crop rotation for the next 4 years. Crop rotation is important to calculate the total nutrient needs over the period of the rotation, nutrient buildup, and nutrient removal by way of harvest. The previous crop will indicate any nutrient credits, especially legume credits when present in the rotation. Circle the current crop.

In the example job sheet, the crop rotation is soybeans-corn-grain sorghum-soybeans-corn. The current crop is the first corn.

Step 5. Expected yield
Enter the expected yield for the current crop. The expected yield is the basis for determining the nutrient requirement for the current crop. An unrealistic estimate of expected yield can result in either too much or too little nutrients being applied. Overapplying too many nutrients creates the potential for environmental contamination and inefficient use of the resource. Too few nutrients applied can cause crop stress and limit potential yield.

The expected yield should be based on realistic soil, climate, and management parameters including crop variety. Yield may be determined from producer records or county yield averages, soil productivity tables, or local research. Because climate can dramatically affect yields, expected yield should be based on data from at least the last 5 years. Extreme climate years should not be included in the analysis as they may bias the results. Expected yields may be calculated in a variety of ways.

In the example, the corn yields obtained on the field over the past 5 crop years were 157, 142, 128, 80, and 129 bushels per acre. To estimate expected yield, the extreme low and high yields are eliminated and the average of the three remaining yields is used. Adding 5 percent to the overall average compensates for prospective favorable weather conditions. The estimated yield was thus:

$$\frac{(129 + 142 + 128)}{3} = 133 \text{ bu} + 5\% = 140 \text{ bu / ac}$$

Step 6. Current soil test levels
The nutrient status of the soil is an important component of a nutrient management plan. This information is used to make recommendations for nutrient application. In this section enter the soil test values for N, P, K, and other soil constituents as given in the report from the soil testing laboratory. Indicate whether the values are in parts per million (ppm) or pounds per acre (lb/acre).

In the example, the soil test levels are:

10 ppm NO_3^-N
70 ppm P
150 ppm K
pH 6.2
SOM 2.2%
No test taken for EC

Step 7. Recommended nutrients/amendments to meet expected yield

Using the soil test results and considering the expected yield, record the estimated amounts of nutrients and other soil amendments needed to produce the expected yield. The land grant university or other approved soil test laboratories base nutrient requirements for the crop on the soil test results, crop yields from field research, and local climatic conditions. Consult the Extension agronomy guide or other publications from the land grant university. Extensive research results from similar soils and climatic conditions are used to develop recommended nutrient rates. Recommendations for micronutrients or other amendments may be entered in the blank columns.

In this example, recommendations of nutrients given by the land grant university based on soil test are:

150 pounds N
No P_2O_5
100 pounds K_2O
No limestone
10 pounds Zn

Table 2

In table 2 of the specifications sheet, steps 7, 8, and 9 are the completion of the nutrient budget. A nutrient budget is the comparison between the quantity of all the sources of nutrients available to the producer and the requirement of nutrients to meet the crop and soil needs. The source can be from on the farm, such as livestock manure or credits from legumes, or from off the farm, such as purchased fertilizer or irrigation water. The requirement is the amount of nutrients needed by the crop to obtain the expected yields.

Although a nutrient budget is not an exact formula for supplying nutrients, it is one method to compare the nutrient needs of the crop with the nutrients available on the farm. Nutrient budgets can easily determine if there is a gross imbalance between the nutrients that are available and the amount required. Nutrient budgets are one of the best methods to see the overall supply of crop nutrients available compared to the estimated crop needs as given by historic records and field research. Continued use of soil testing, plant and water analyses, and yield monitoring are essential to maintain a good nutrient balance with desired results.

Step 8. Nutrient sources - credits

A number of nutrient sources for crop production are available before the crop is planted. One source is the inherent nutrients in the soil determined by soil test levels of nitrogen, phosphorus, and potassium. Others become available to the crop through a process of recycling through animals, plants, air, water, and organic matter. Nitrogen from legumes and organic waste mineralization are examples.

Nitrogen credits—Nitrogen is a mobile nutrient and occurs in the soil and plants in many forms. It can be stored in the soil's organic matter and released as the organic matter decomposes.

Line 1 Credits from previous legume crops

Atmospheric nitrogen is fixed by legume plants and brought into the soil. Amounts of nitrogen added by legume production vary by plant species and growing conditions. Refer to local university Extension information for the most appropriate legume nitrogen credits.

This corn crop follows a 40+ bushel soybean crop. The nitrogen credit for the previous legume crop is 40 pounds per acre.

Line 2 Residual from long-term manure applications

Not all of the nitrogen applied in previous manure applications is available to the crop during the year of application. Some of the nutrients are tied up in organic complexes that require organic material decomposition before the nutrients are made available for plants. A percentage of last year's manure application and an even smaller percentage of previous applications will become plant available during this crop season. Use local manure mineralization rates to determine the amount of nitrogen released from previous manure application. Phosphorus and potassium are considered almost 100 percent plant available the year of application; therefore, little or no residual amounts are calculated for these nutrients.

Twenty tons of beef manure that contained 6 pounds of organic nitrogen per ton was applied 2 years before the current corn crop. The nitrogen available to this corn crop is 5 percent of the total organic N in the manure applied 2 years ago. Then 0.05 x 20 x 6 = 6 pounds per acre of N that can be credited to this year's corn crop.

Line 3 Irrigation water

Irrigation water, especially from shallow aquifers, contains some nitrogen in the form of nitrate nitrogen. This nitrogen is available for crop use. To calculate the amount of nitrogen applied with irrigation water, determine the concentration of nitrate nitrogen in the water (in ppm or mg/L). This requires a water analysis. The amount of nitrogen added in irrigation water equals the nitrate nitrogen concentration (in ppm or mg/L) multiplied by the irrigation water volume (in acre-inches) times 0.23. The factor 0.23 converts ppm or mg/L and acre-inches into pounds per acre.

In the example, 8 acre-inches of irrigation water is applied having a nitrate nitrogen concentration of 10 ppm:

N (lb/acre) = Concentration of NO_3^- –N (ppm or mg/L) x volume of irrigation (acre-inches) x 0.23

N = 8 x 10 x 0.23 = 18 lb/acre

Line 4 Other

Other nitrogen credits come from atmospheric deposition from dust and ammonia in rainwater. This value is recorded by a number of weather stations throughout the United States and can be obtained from National Atmospheric Deposition Program, Fort Collins, Colorado. Atmospheric deposition may range from a few pounds nitrogen per acre per year to over 30 pounds.

The nutrient content of any other material that is brought onto the site, such as mulch or compost, can be determined by estimating the mass weight and percent concentration of nitrogen of the material.

Consider atmospheric nitrogen contribution of 8 pounds per acre.

Step 9. Plant available nutrients applied to the field

The producer has the capability to bring various sources of nutrients onto the field to supply the requirements of the crop. The nutrient budget is designed to allocate the sources of nutrients available and adjust the amounts based on the calculations to match the crop's needs. Use the column **Trial A** for calculating the first budget trial.

Line 6 Credits

Total nutrient credits are summed in line 5 and entered here.

40 from legume + 6 residual manure + 18 irrigation water + 8 atmosphere = 72 lb N

Line 7 Fertilizer

If additional fertilizer is required (such as starter fertilizer to overcome the effects of cool, wet soils or sidedressed anhydrous ammonia), enter those amounts on the appropriate line. Note how and when these fertilizers will be applied in the **Nutrient Management Specifications** box at the bottom of the page.

In this location for corn, the University recommendation is 5 pounds N, 10 pounds P_2O_5, and 5 pounds K_2O as starter fertilizer.

Line 8 Manure and organic material

Manure and other organic sources can be produced either on the farm or transported to the farm with the expressed purpose of utilizing the nutrients. Manure application rates should be based on crop nutrient requirements, but can also be applied in lesser rates to distribute organic material and micronutrients over a broader number of fields.

Manure application rates in line 8 are based on plant available nutrients delivered to the crop. Manure nutrient content is calculated from information gathered from the moisture content and nutrient analysis of the manure. In lieu of nutrient analysis, a published estimate of plant available nutrients from specific sources of manure can be used. These book values are based on state university research and inventory data, and offer guidance for land application. A historic average of the farm or storage manure consistency can be used if the history is based on laboratory analyses over a period of years,

The losses resulting from field application, namely nitrogen volatilization in the form of ammonia, have been considered in the calculation. The values for nutrients placed on line 8 are plant available nutrients, so the total quantities applied may be higher depending on the field application losses. The Waste Utilization Job Sheet (633) should be used to calculate the storage volume of manure, the nutrient analysis of the manure, and the potential for field losses depending on the application timing and methods. States should provide appropriate field loss estimates, such as ammonia volatilization with surface application.

20 tons of beef cattle manure is applied with a plant available content of 8 pounds N, 4 pounds P_2O_5, and 10 pounds K_2O per ton, based on manure analysis. Total nutrients applied are 160 pounds N, 80 pounds P_2O_5, and 200 pounds K_2O.

Step 10. Nutrient status

The nutrient sources available for field application are subtotaled on line 9.

N = 72 + 5 + 160 = 237
P_2O_5 = 10 + 80 = 90
K_2O = 5 + 200 = 205

Next, the nutrient recommendations to meet expected yield are taken from table 1 and put on line 10. Subtracting the nutrient requirements (line 10) from the nutrients available (line 9) gives a nutrient status (line 11).

N = 237 – 150 = +87 lb/ac
P_2O_5 = 90 – 0 = +90 lb/ac
K_2O = 205 – 100 = +105 lb/ac

If line 11 is a negative number, the amount shown on this line represents a deficiency of nutrients for the crop based on obtaining the expected yield. This amount of nutrients must be supplied to the field to supplement the nutrient credits, fertilizer, and manure already applied. This supplement is generally provided by commercial fertilizer, but can be added by additional rates of manure or even irrigation water. Enter the method and timing of the application in the appropriate place on the specification sheet.

If line 11 is negative (e.g., additional nutrients are required to meet crop needs) then add nutrients by adjusting inputs including fertilizer.

If line 11 is a positive number, the amount shown on this line represents an excess of nutrients needed for the crop, again based on obtaining the expected yield. There is no reason for nitrogen nutrition to be applied in quantities greater than crop requirements. Phosphorus and potassium are overapplied when animal manure or organic material is applied at rates to meet the nitrogen needs of the crop.

*If line 11 is positive, (e.g., nutrients are applied in excess of crop needs), return to lines 7 and 8 to adjust nutrient additions on the field. Use column **Trial B** to adjust the nutrient budget.*

The nitrogen credits in lines 1 through 4 cannot be controlled by management. They are a result of previous management activities and the local environment. All adjustments to the nutrient budget must occur in the amount of fertilizer and manure applied in the current year.

In the example, all three major nutrients are in excess. A decision must be made on which nutrient will be used to balance the budget, knowing that excesses or deficiencies in the other two may occur. Nitrogen is chosen for this example.

The nitrogen credits are 72 pounds per acre. The decision is made to still use starter fertilizer, so the total nitrogen input to this point is 77 pounds per acre. From line 10, 150 pounds per acre of N is required, leaving a need for 73 pounds per acre N. If the manure application rate is adjusted to 10 tons per acre, that would apply 80 pounds of N, for a total of 157 pounds per acre N. This results in only a slight excess of N being applied, which is within the acceptable variability of estimating nitrogen requirements.

When the manure application is reduced to balance N, the amount of P and K applied is also reduced. The amount of P_2O_5 applied in the manure was reduced to 40 pounds per acre, and K_2O to 100 pounds per acre. This produces a surplus of 50 pounds per acre P_2O_5 and only 5 pounds per acre of K_2O.

Step 11. Nutrient management specifications

Record the amount of each nutrient to be applied (from step 10) and the planned method, form, and time of application. The efficiency of nutrient use by plants is significantly affected by the timing and method of nutrient application. Nitrogen should be applied as near as possible to the time of maximum plant uptake to minimize potential losses from leaching or volatilization. Both nitrogen and phosphorus fertilizers should be injected or incorporated to reduce the risk of loss in runoff water or by attachment to sediment.

Broadcast apply 10 tons per acre of beef cattle manure 2 weeks before planting. Do not apply the manure within 50 feet of the perennial stream that forms the boundary between fields 144 and 142. Incorporate the manure applied within a 100-foot radius of the sinkhole in field 142. Apply 100 pounds per acre of 5-10-5 as a starter fertilizer at planting time.

Step 12. Operation and maintenance

On the second page of the job sheet in the box **Perform the following operations and maintenance** enter the information requested. Nutrient management plans should normally be reviewed annually by the producer, and a more thorough review performed at least every 5 years unless there are significant changes in the operation.

Field records should be maintained for at least 5 years. State regulations may require a longer period of record retention. Some producers may wish to maintain records indefinitely.

Application equipment should be calibrated so that it will apply nutrients to within 10 percent of the expected rate. Uniform application across the field is vital. Generally, no more than 10 to 15 percent variance in the required application rate from the actual amount applied is allowed. Commercial fertilizer applicators are easier to calibrate than manure spreaders. An added complication with manure spreaders is the uncertainty of available nutrient content in the manure.

All nutrient material should be handled with caution. Ammonium-containing materials, especially anhydrous ammonia, may be caustic. Protective clothing should be worn when handling these materials. Goggles are appropriate when handling any fertilizer material including organic material.

Fertilizer materials remaining when fertilizer application is complete should be washed from application equipment and disposed of in a safe manner. Fertilizer materials left in application equipment may corrode or otherwise damage the equipment.

Observe all state and local setback requirements for applications adjacent to waterbodies and watercourses.

Perform periodic soil, water, plant, and organic material analyses based on state guidelines.

Fertilizer and manure storage facilities shall be protected from weather and accidental leakage or spillage that may adversely affect the environment.

Step 13. Additional specifications and notes

Write any additional specifications and notes in the box provided. Additional notes may include any constraints not previously noted, special nutrient requirements of the crop, equipment constraints, constraints because of pest pressures, residue limitations, conservation buffer requirements, local regulations, and any other information of interest to the producer. Additional notes may also refer to sources of information used to calculate available nutrients and nutrient requirements.

Nutrient Management

Conservation Practice Job Sheet **590**

Natural Resources Conservation Service (NRCS) ***March 1999***

Landowner____

Definition

Nutrient management is managing the source, rate, form, timing, and placement of nutrients.

Purpose

Nutrient management effectively and efficiently uses scarce nutrient resources to adequately supply soils and plants to produce food, forage, fiber, and cover while minimizing environmental degradation.

Where Used

Nutrient management is applicable to all lands where plant nutrients and soil amendments are applied.

Conservation Management Systems

Nutrient management may be a component of a conservation management system. It is used in conjunction with Crop Rotation, Residue Management, Pest Management, conservation buffer practices, and/or other practices needed on a site-specific basis to address natural resource concerns and the landowner's objectives. The major role of nutrient management is to minimize nutrient losses from fields, thus helping protect surface and ground water supplies.

Nutrient Management Planning

Nutrient management components of the conservation plan will include the following information:

- field map and soil map
- crop rotation or sequence
- results of soil, water, plant, and organic material samples analyses
- expected yield
- sources of nutrients to be applied
- nutrient budget, including credits of nutrients available
- recommended nutrient rates, form, timing, and method of application
- location of designated sensitive areas
- guidelines for operation and maintenance

Nutrient management is most effective when used with other agronomic practices, such as cover and green manure crops, residue management, conservation buffers, water management, pest management, and crop rotation.

General Nutrient Management Considerations

- Test soil, plants, water and organic material for nutrient content.
- Set realistic yield goals.
- Apply nutrients according to soil test recommendations.
- Account for nutrient credits from all sources.
- Consider effects of drought or excess moisture on quantities of available nutrients.
- Use a water budget to guide timing of nutrient applications.
- Use cover and green manure crops where possible to recover and retain residual nitrogen and other nutrients between cropping periods.
- Use split applications of nitrogen fertilizer for greater nutrient efficiency.

Guidelines for Operation and Maintenance

- Review nutrient management component of the conservation plan annually and make adjustments when needed.
- Calibrate application equipment to ensure uniform distribution and accurate application rates.
- Protect nutrient storage areas from weather to minimize runoff and leakage.
- Avoid unnecessary exposure to fertilizer and organic waste, and wear protective clothing when necessary.
- Observe setbacks required for nutrient applications adjacent to waterbodies, drainageways, and other sensitive areas.
- Maintain records of nutrient application as required by state and local regulations.
- Clean up residual material from equipment and dispose of properly.

Nutrient Management Assessment

Make a site-specific environmental assessment of the potential risk of nutrient management. The boundary of the nutrient management assessment is the agricultural management zone (AMZ), which is defined as the edge of field, bottom of root zone, and top of crop canopy. Environmental risk is difficult to assess beyond the AMZ.

Within an area designated as having impaired or protected natural resources (soil, water, air, plants, and animals), the nutrient management plan should include an assessment of the potential risk for nitrogen and phosphorus to contribute to water quality impairment.

The Leaching Index (LI), Nitrogen Leaching and Economic Analysis Package (NLEAP), the Phosphorus Index (PI), erosion prediction models, water quality monitoring, or any other acceptable assessment tools may be used to make risk assessments.

Evaluate other areas that might have high levels of nutrients, produced or applied, that may contribute to environmental degradation. For example, areas with high livestock concentrations or large areas of high-intensity cropping, such as continuous potatoes, corn, or specialty crops, may be contributing heavy nutrient loads to surface or ground water.

Conservation practices and management techniques will be implemented with nutrient management to mitigate any unacceptable risks.

Nutrient Management – Design and Specifications Sheet

Landowner Alexandria J. Simmons Field number 142 south quarter

Assisted by John Doe Date 4-27-99

Purpose (check all that apply)	
☑ Budget and supply nutrients for plant production	☑ Utilize manure/organic material as a nutrient source
☑ Minimize agricultural nonpoint source pollution (water quality)	☐ Maintain or improve soil condition

Table 1 Field Conditions and Recommendations

Crop sequence/rotation (circle current crop)						Expected yield
1998 soybeans	1999 corn	2000 sorghum	2001 soybeans	2002 corn	2003 soybeans	Corn 140

Current soil test levels (ppm or lb/ac)					
N	P	K	pH	S.O.M.%	EC
10 ppm	70 ppm	150 ppm	6.2	2.2	N/A

Recommended nutrients/amendments to meet expected yield (lb/ac)					
N	P_2O_5	K_2O	Lime	Other Zinc	Other
150	0	100	0	10	10

Table 2 Nutrient Sources

Credits	N	P_2O_5	K_2O
		Pounds per acre	
1. Nitrogen credits from previous legume crop	40		
2. Residual from long-term manure application	6		
3. Irrigation water	18		
4. Other (e.g., atmospheric deposition)	8		
5. **Total credits**	72		

Plant-available nutrients applied to field		N		P_2O_5		K_2O	
(Circle column that is landowner's decision)		Trial A	Trial B	Trial A	Trial B	Trial A	Trial B
6. Credits (from row 5, above)		72	72	0	0	0	0
7. Fertilizer	Starter	5	5	10	10	5	5
	Other	0	0	0	0	0	0
8. Manure/organic material		160	80	80	40	200	100
9. **Subtotal (sum of lines 6, 7, and 8)**		237	157	90	50	205	105
10. **Nutrients recommended (from table 1)**		150	150	0	0	100	100
11. **Nutrient status (subtract line 10 from line 9)**		+87	+7	+90	+50	+105	+5

If line 11 is a negative number, this the amount of additional nutrients needed to meet the crop recommendation.

If line 11 is a positive number, this is the amount by which the available nutrients exceed the crop requirements.

Nutrient Management Specifications

Amount to be applied (lb/ac)	N	85	P_2O_5	50	K_2O	105

Method, form, and timing of application:

Applied nutrients will come from manure and starter fertilizer.

Broadcast apply 10 ton/acre beef cattle manure two weeks prior to planting.

Do not apply manure within 50 feet of the perennial stream which forms the boundary between fields 142 and 144.

Incorporated the manure applied within a 100 foot radius of the sinkhole in field 142.

Apply 100 lb/ac of 5-10-5 as a starter fertilizer at planting time.

Nutrient Management – Job Sketch

Draw of sketch the field, showing any sensitive areas and required setback zones. Inside each sketched field, enter total field acres and net application acres. Other relevant information, such as complementary practices or adjacent field or tract conditions may be included.

Scale 1"=________ ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")

Perform the following operations and maintenance:
Review this nutrient management plan every _______ years.
Maintain field records for 5 years.
Calibrate application equipment to apply within ± _______ % of the recommended rate.
Handle all nutrient material with caution. Wear appropriate protective clothing.
Clean up residual material from equipment and dispose of properly.
Additional specifications and notes:

Landowner ______________________ **Assisted by** ______________________ **Date** ______________________

Year			
Field number/crop	**N**	**P_2O_5**	**K_2O**

Information on form, rate, and timing of application:

Year			
Field number/crop	**N**	**P_2O_5**	**K_2O**

Information on form, rate, and timing of application:

Year			
Field number/crop	**N**	**P_2O_5**	**K_2O**

Information on form, rate, and timing of application:

Year			
Field number/crop	**N**	**P_2O_5**	**K_2O**

Information on form, rate, and timing of application:

Appendix A—Phosphorus Buildup Calculation

The use of livestock manure and organic material as nutrient sources presents one particular problem for developing a nutrient budget. Nutrients contained in manure are not balanced in the same proportion as crop requirements. While most animal manure has an N-P_2O_5-K_2O ratio of 3-2-3 or 2-1-2, crops require nutrients in a ratio of 8-1-3 or 3-1-2. Balancing nutrients on any one of the major crop elements (N, P, or K) creates either a deficiency or excess in nutrients for the other two.

When phosphorus accumulates in the soil and begins to leak, it is an environmental concern for the soil and plant system. Monitoring the levels of phosphorus in the soil is important to avoid situations of excess P nutrients building up on the landscape and causing future environmental impacts. Excess potassium can cause nutrient imbalance in forage feed rations.

The process used to calculate the phosphorous and soil thresholds is described in the following paragraphs (see Phosphorus Considerations worksheet).

Line A
Enter the excess amount of P_2O_5 over agronomic crop requirements that will be applied if the nutrient budget is followed. If no excess is being applied, stop the analysis.

In the example in chapter 3, trial B had an excess of 50 pounds per acre P_2O_5.

Phosphorus Considerations Worksheet

A. From your nutrient budget, enter the amount by which applied P_2O_5 exceeds crop requirements.
__________ lb/ac/yr (if zero, stop analysis)
Example: 50 lb excess P_2O_5 being applied this year.

B. Determine the P buildup factor. This is the inverse of the pounds of P_2O_5 necessary to raise the soil test level 1 ppm
Example: As an average, 20 lb P_2O_5 is needed to raise the soil test P 1 ppm. The inverse of 20 is 0.05.

C. Multiply amount in line B by the soil test buildup factor and enter here __________.
Example: 50 lb P_2O_5 x 0.05 = 2.5

D. Enter soil test P threshold value __________. If threshold level has not been determined, use 5 times the lowest value in the high soil test P range.
Example: High range is 50 to 80 ppm. Threshold level is 50 x 5 = 250 ppm.

E. Using the current soil test P level, calculate how long it would take to reach the soil threshold level.
__________ years.
Example: Threshold level (line D) = 250 ppm. Current soil test P level [table 1 on job sheet] = 70 ppm. Amount of available soil test P that can be applied before the threshold P level is reached is 250 – 70 = 180 ppm. Annual excess P_2O_5 application rate = 50 lb/acre.

Using 20 pounds P_2O_5 per unit increase in ppm soil test P, the annual increase in soil test P [from line B] is:

250 – 70 = 180

$$\frac{180}{2.5} = 72 \text{ years}$$

Line B

Excess levels of phosphorus application above the amount required for crop production will build up in the soil and be expressed by higher soil test levels. The rate of buildup depends on the soil type, soil test method, and excess level of P application. As a general guidance rule, it takes somewhere between 8 to 16 pounds of excess P_2O_5 to raise the soil test P level 1 pound. This is the same as saying it takes 16 to 32 pounds of P_2O_5 to raise the soil test P level 1 ppm.

Using a value of 20 pounds of excess P_2O_5 as an estimate to raise the soil test level 1 ppm, then multiplying the excess phosphorus amount in pounds by 0.05, the P buildup factor (the inverse of 20) would give the increase in soil test P level in ppm. If your state uses a different rate of soil test buildup, use that amount in your calculations. (P buildup factor equals the inverse of the pounds of P_2O_5 required to raise the soil test P level by 1 ppm.)

> *The example showed an excess of 50 pounds per acre P_2O_5. 50 x 0.05 = 2.5 gives the increase in soil test level P (in ppm) for each year that an excess of 50 pounds P_2O_5 is applied.*

Line C

Many states have developed the relationship between soil test levels of P and potential for significant P movement on the landscape. Some states have set threshold soil test levels of phosphorus at which either nutrient management should change or management practices should be put in place to control runoff and erosion. Above some soil test P level, there may even be a total restriction of additional P application to the site.

If the threshold soil test value has been developed, enter it here. If no threshold soil test level has been developed, a surrogate value can be determined using the agronomic soil test levels suggested for the crop being grown. The basis for using agronomic soil test levels relates to the producer's understanding of a **high** soil test level at which no expected crop yield increase will occur. As a surrogate, five times the soil test P value for the minimum level of the **high** category can be considered the threshold level. The minimum level of the **high** soil test category is the breakpoint between a **medium** and **high** soil test level.

> *As an example, when the soil test level category of **high** for corn starts at 50 ppm P, a surrogate threshold level would be 5 x 50 ppm, or 250 ppm.*

Line D

The calculation for time required to raise the current soil test P level to the threshold level follows.

Multiply the excess phosphorus application in pounds per acre by the P buildup factor. The soil test P level will raise this amount per year. Next, subtract the current soil test P level from the P threshold value. This is the amount of soil test value remaining until the threshold is reached. Divide the remaining soil test value by the annual rate of increase in soil test P. This is the number of years that it will take for that field with the current cropping and nutrient budget to reach the threshold level.

> *If the excess amount of phosphorus being applied each year is 50 pounds per acre and the P buildup factor is 0.05, then the annual increase in soil test P is*
> *50 pounds x 0.05 = 2.5 ppm*

> *If the current soil test level is 70 ppm and the threshold soil test P level is 250 ppm, then the amount of remaining soil test value is*
> *250 – 70 = 180 ppm*

> *The buildup of soil test P to reach the threshold level will take 72 years (180 ÷ 2.5).*

Appendix B—Leaching Index

The amount of water that percolates through the soil and below the crop's root zone is important in determining the amount of nitrate nitrogen leached. Various crop, soil, and climate factors interact to affect the amount of deep percolation. A leaching index (LI) for each soil hydrologic group has been developed for various regions of the country. The LI uses soil hydrologic groups (A, B, C, and D), annual precipitation, and seasonal rainfall when no crops are growing to create plant transpiration. The LI for local areas is in the Field Office Technical Guide, section II-3, or may be calculated using the following equations.

$$LI = PI \times SI$$

where:

$$(PI) = \frac{(P - 0.4s)^2}{P + 0.6s}$$

where:

P = annual precipitation

$$s = \left(\frac{1,000}{CN}\right) - 10$$

where:

CN = curve number

$$SI = \left(\frac{2PW}{P}\right)^{\frac{1}{3}}$$

where:

PW = Fall and winter precipitation when crop growth is minimal, usually the sum of precipitation during October, November, December, January, and February.

Guidelines for leaching assessment

An LI below 2 inches would probably not contribute to soluble nitrogen leaching below the root zone; however, an LI between 2 and 10 inches may contribute to soluble nitrogen leaching below that zone. Nutrient management practices and techniques, such as split nitrogen application rates, pre-sidedress nitrate nitrogen testing, and use of a nitrification inhibitor, should be considered.

An LI larger than 10 inches contributes to soluble nitrogen leaching below the root zone. An intense nitrogen management must be employed to minimize nitrate nitrogen movement. This would include careful management of applied nitrogen, precise timing to match crop utilization, conservation practices that restrict water percolation and leaching, and cover crops that capture and retain nutrients in the upper soil profile.

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Williams, J.R., and D.E. Kissel. 1991. Water percolation: An indicator of nitrate nitrogen leaching potential. In R.F. Follett, D. R. Keeny, and R. M. Cruse (eds.), Managing Nitrogen for Groundwater Quality and Farm Profitability. Soil Science Society of America. Madison, WI.

Appendix C—Runoff class index

A set of relative indices has been developed to assess environmental risk of runoff from a landscape position. Transport of solutes in runoff can be an important source of contaminants. Estimating the runoff potential from a given site is necessary to assess the over-all potential for contaminant transport. Planners can use this information to identify areas on the landscape from which runoff could have detrimental impacts on adjacent areas.

Method 1, shown in table 1, is taken from the USDA-NRCS Soil Survey Manual. It relates the slope of the landscape, as a percent, to the saturated hydraulic conductivity class (very low to very high) for the soil, taken from the soil survey. The index values are a function of slope and the saturated hydraulic conductivity of the soil.

Method 2, shown in table 2, uses the NRCS Runoff Curve Number, a family of curves formulated from runoff data from a large number of watersheds. Either procedure can be used in assessing runoff risk.

If quantitative values of runoff are desired, planners should use hydrologic models that balance precipitation between infiltration and runoff, and use a correction for soil storage. These types of models use climate data and soil physical properties to estimate infiltration, evaporation, and deep percolation.

Table 1 Index of surface runoff classes based on slope and saturated hydraulic conductivity (Method 1)

Slope (%)	----- Saturated hydraulic conductivity class 1/ -----					
	very high	high	moderately high	moderately low	low	very low
Concave	N 2/	N	N	N	N	N
< 1	N	N	N	L	M	H
1 – 5	N	VL	L	M	H	VH
5 – 10	VL	L	M	H	VH	VH
10 – 20	VL	L	M	H	VH	VH
> 20	L	M	H	VH	VH	VH

1/ Saturated hydraulic conductivity classes:

Class	K_{sat} (mm/s)
Very high	> 100
High	10 – 100
Moderately high	1 – 10
Moderately low	0.1 – 1.0
Low	0.01 – 0.1
Very low	< 0.01

2/ N = negligible, VL = very low, L = low, M = medium, H = high, VH = very high.

Table 2 Surface runoff class site characteristic determination from the relationship of the NRCS curve number and the field slope 1/

Slope (%)	------------ Runoff class 2/ ------------				
	Runoff curve number: < 50	50 – 60	60 – 70	70 – 80	> 80
< 1	N	N	N	N	M
1 – 2	N	N	LV	L	M
2 – 4	N	N	L	M	H
4 – 8	N	LV	M	H	HV
8 – 16	LV	L	M	HV	HV
> 16	LV	L	H	HV	HV

1/ Refer to National Engineering Handbook, section 4, 1985, (Method 2).

2/ N = negligible, LV = very low, L = low, M = medium, H = high, HV = very high.

Appendix D—Developing Crop Nutrient Recommendations from Soil Test Analysis

Soil test recommendations are derived from two sources of information:

- soil samples that have been analyzed in a laboratory for nutrient content
- relationship of the soil test results compared to crop yield, derived from field research

First, a representative soil sample must be collected from the area to be fertilized. Generally, samples are taken from 10 to 20 areas within the field, and then combined into one sample. This one or two pound sample attempts to represent the millions of pounds of soil in that area. Samples from tilled fields should be taken to the tillage depth. Samples from undisturbed fields, such as hayland, pasture, or no-till, should be taken from the top 2 to 4 inches of the soil profile.

Once collected, samples are prepared, sent to an acceptable laboratory, and analyzed for nutrient content. The land grant university has standardized the chemical extraction and testing procedure used by the laboratory for the crop, climate, and soils of the area. Many types of soil sample extractants and forms of analysis exist, but whichever method is used must relate to the university's procedure for developing crop nutrient recommendations. In other words, the analytical results must be related to plant growth and yield response for that soil in that climate.

Extensive soil sampling, sample analysis and field crop research have calibrated the soil, soil analysis, and crop growth. This calibration identifies the soil test level above which growers would not expect a significant or economic yield increase. Figure 1 shows the yield repsonse to soil test phosphorus levels.

We are now trying to determine at what level of soil nutrients there will be a significant increase in movement of these nutrients from the soil and the landscape. For this calibration, soil test levels are partitioned into different ratings for each nutrient and crop. A general description of soil test levels follows.

Very Low (VL)—Soil test level at which crops will yield less than 50 percent of its potential. Large applications of nutrients for crop yield and soil buildup are generally recommended.

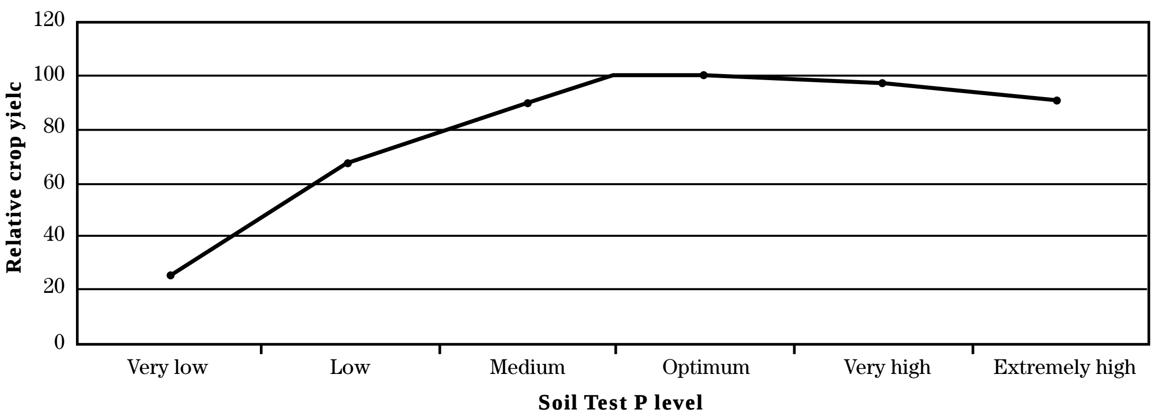
Low (L)—Soil will yield 50 to 75 percent of its potential. Application of nutrients is required to obtain an expected yield and buildup of soil test levels.

Medium (M)—Soil will yield 75 to 100 percent of its yield potential. Application of nutrients is needed to obtain expected yield and maintain soil test levels.

Optimum (O)—The supply of soil nutrients is adequate to obtain crop yields. No additional amount of crop nutrients is required to increase yield.

Very High (VH)—The supply of nutrients in the soil is more than double the amount considered adequate to meet any realistic crop yield. No yield increase from additional nutrients can be expected. Some leakage of nutrients from the soil can be expected.

Figure 1 Yield response to soil test phosphorus levels



Extremely High (EH)—The supply of nutrients in the soil is more than four times the amount considered adequate to achieve the expected crop yield. This level is excessive for crop growth and may be detrimental to the plant growth or cause a nutrient imbalance and may contribute to pollution of ground and surface water.

Field crop research coupled with soil test results is the basis for setting crop nutrient recommendations. Soil types are grouped into categories based on physical, chemical, or soil mineral classes. Classes may be yield potential, cation exchange capacity, soil texture, parent material, or any combination thereof. For example, soils are commonly grouped by their yield potential and cation exchange capacity.

Each group of soils has been researched in the field for yield response at different soil test nutrient levels. This relationship between yield and soil test levels has been documented by a response curve (fig. 2).

The nutrient recommendation is read directly from the response curve or can be calculated from an equation of the response curve function. Keep in mind that each crop for each soil group has its own response curve. Likewise, a specific equation exists for each crop within each soil group.

As an example, sorghum is grown on a Group 2 soil (silt loam with CEC = 10 to 15 meq/100 grams). The soil test P level is 29 pounds per acre. The response curve equation to recommend phosphorus fertilization is:

$$Y = 170 - 2.07\ X$$

where

Y = pounds of phosphorus fertilizer equivalents (as P_2O_5) needed to be added to obtain the expected yield at that soil test level

X = soil test P level in pounds per acre

Solving for Y:

$Y = 170 - 2.07\ X$

$Y = 170 - (2.07)\ (29)$

$Y = 170 - 60$

$Y = 110$ pounds P_2O_5

Using the previous information buildup capability from applying nutrients to the soil was estimated. The estimate was 10 pounds of P_2O_5 fertilizer is needed to raise the soil test phosphorus level 1 pound.

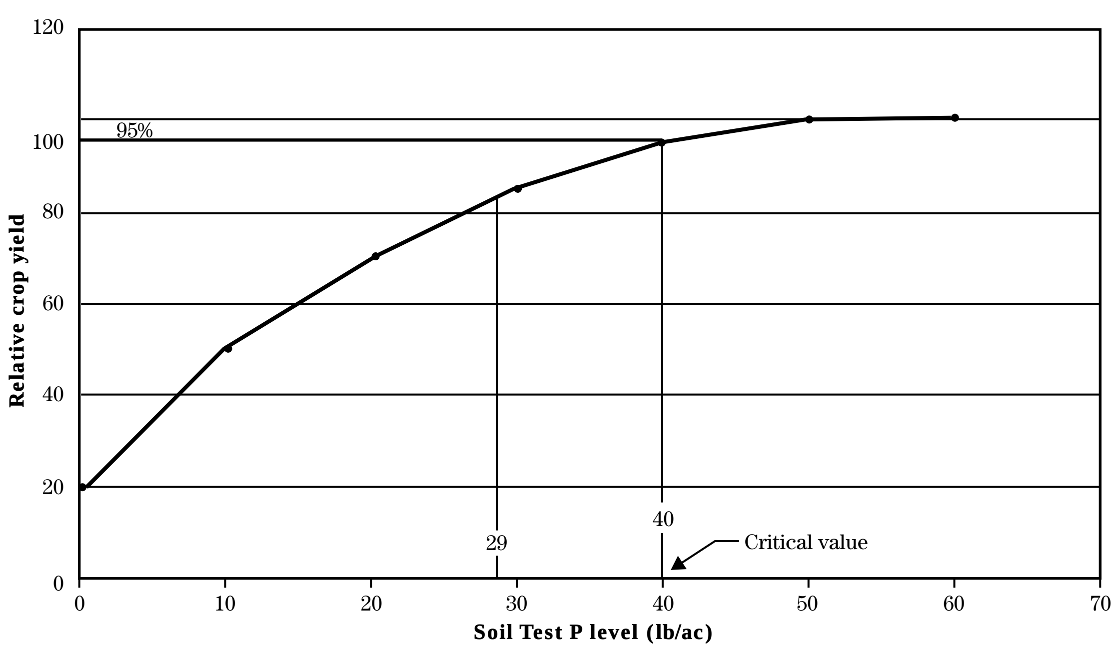
In this example, the soil test level for P is 29 pounds per acre and the optimum range of soil test level for this soil and climate is 40 pounds per acre. This means that the soil test level must be raised 11 pounds per acre to reach the critical optimum level for the yield desired. Calculating the required fertilizer required to raise the soil test level:

10 pounds P_2O_5 ———> 1 pound soil test P

X pounds of P_2O_5 ———> 11 pounds soil test P

X = 110 pounds P_2O_5

Figure 2 Using a yield response curve to develop a nutrient recommendation



Appendix E—Pre-sidedress Soil Nitrate Test Recommendation

A procedure that is available to producers to help them more accurately determine their nitrogen needs is the pre-sidedress soil nitrate test (PSNT). This test is useful on fields that have a history of manure or other organic material application. It was developed in the Northeast where because of the high concentration of livestock operations, particularly dairies, many fields have a long history of annual manure application. Only about 75 percent of the nitrogen in manure is available to crops in the year the manure is spread. The rest becomes available over the next 2 to 3 years. The PSNT can tell producers how much residual nitrogen will become available to their crop in the current year, allowing them to reduce their application of chemical fertilizers.

The Pennsylvania State University developed a procedure (fig. 1) that refines the PSNT recommendation using cropping history, expected yield, and the PSNT test results.

Using the cropping history and expected yield from the nutrient budget example:

Soil nitrate – N = 10 ppm
Previous crop = soybeans
Planned crop = corn
Expected yield = 140 bu/ac
No manure application since last harvest.
Manure has been applied to this field in the past 3 years.

Figure 2 is an example of the completed PSNT calculation.

Figure 1 Procedure to calculate PSNT recommendation

Enter soil nitrate – N (in ppm) [ ] (1)

If soil nitrate level is ≥ 21 ppm, the N recommendation is zero; otherwise, continue with the calculations below.

Calculation: 1.1 x [ ] = [ ]
Expected Yield (bu/ac) — **Yield Factor** (2)

[ ] + [ ] + [ ] = [ ]

Manure history since last harvest
None = 0.75
Any = 3.50

Previous crop
corn = 0.00
soybeans = 1.00
forage legume = 3.5
other = 0.00

Manure history past 3 years
None = 0.00
Any = 1.75

History factor (3)

[ ] – [[ ] x [ ]] = [ ]

Yield factor (2) — **History factor** (3) — **Soil nitrate-N** (1) — **Recommendation** lb/ac

If the calculated amount is less than 30 pounds per acre, a zero recommendation is suggested.

Figure 2 Example calculation of PSNT recommendation

Enter soil nitrate – N (in ppm) [10] (1)

If soil nitrate level is ≥ 21 ppm, the N recommendation is zero; otherwise, continue with the calculations below.

Calculation: 1.1 x [140] = [154]

Expected Yield (bu/ac) — **Yield Factor** (2)

0.75	+	1.00	+	1.75	=	3.50
Manure history since last harvest None = 0.75 Any = 3.50		**Previous crop** corn = 0.00 soybeans = 1.00 forage legume = 3.5 other = 0.00		**Manure history** past 3 years None = 0.00 Any = 1.75		**History factor** (3)

154	– [	3.50	x	10]	=	119
Yield factor (2)		**History factor** (3)		**Soil nitrate-N** (1)		**Recommendation** lb/ac

If the calculated amount is less than 30 pounds per acre, a zero recommendation is suggested.

Glossary

Absorption
Movement of ions and water into the soil or plant roots. **Active** absorption is the result of a metabolic process by the root. **Passive** absorption is the result of diffusion along a gradient

Adsorption
The process by which molecules or ions are taken and retained on the surface of solids by chemical or physical binding; e.g., the adsorption of cations by negatively charged minerals.

Aeration
The exchange of air in soil with air from the atmosphere. Air in a well-aerated soil has a composition similar to the air in the atmosphere. Air in a poorly-aerated soil is higher in carbon dioxide and lower in oxygen than the air above the soil.

Aerobic
Growing or occurring only in the presence of molecular oxygen.

Agronomic rate
The amount of crop nutrients required to achieve the expected yield after considering the contribution of the soil, plant, water, and atmospheric nutrient sources. The state land grant university determines this rate. Also referred to as the recommended crop nutrient requirement.

Algae-available phosphorus
Phosphorous that is in a soluble and available form for uptake by algae and other micro-organisms in the water column.

Amendment
Any material, such as lime, gypsum, sawdust, or other conditioners, that is applied to the soil either incorporated or left on the surface to make it more productive.

Ammonia fixation
Adsorption of ammonia ($NH4^+$) by the organic and clay fraction of the soil.

Ammonification
The biological process leading to the formation of ammoniacal nitrogen.

Ammonium ($NH4^+$)
A form of nitrogen that is available to plants and is produced in the early stage of organic matter decomposition.

Ammonium phosphate
A type of phosphorus fertilizer manufactured by the reaction of anhydrous ammonia with superphosphoric acid to produce either solid or liquid fertilizer.

Anaerobic
Growing or occurring in the absence of molecular oxygen.

Available nutrient
The form of a nutrient that the plant is able to use. Many nutrients in the soil are in forms the plant cannot use (such as organic forms of nitrogen) and must be converted to forms available to the plant (such as nitrate nitrogen).

Available phosphorus
A chemically extracted amount of phosphorus from the soil that represents the portion of P that is available to a growing plant. This extracted amount of P is correlated to a field test measuring yield for the crop.

Banding
Placing fertilizer close to the seed at planting, or surface or subsurface applications of solids or fluids in strips before or after planting.

Bioavailable phosphorus
The form of phosphorus that is absorbed by biological organisms, such as plants and animals. Mostly orthophosphates, but can be some forms of organic P.

Broadcast
The uniform application of fertilizer on the soil surface. Usually done before planting, and normally incorporated with tillage, but may be unincorporated in no-till systems.

Carbon cycle
The sequence of transformations in which carbon dioxide is converted to organic forms by photosynthesis or chemosynthesis, recycled through the biosphere, and ultimately returned to its original state through respiration or combustion.

Carbon-nitrogen (C:N) ratio
The ratio of the mass of organic carbon to the mass of organic nitrogen in the soil, organic material, or plants.

Cation
A substance that has a positive electrical charge. Common soil cations are calcium, magnesium, hydrogen, sodium, and potassium.

Cation exchange capacity (CEC)
The amount of exchangeable cations that a soil can adsorb at a specific pH, expressed as milliequivalents per liter (meq/L).

Citrate-insoluble phosphorus
That part of the P in fertilizers that is considered immediately unavailable to plants in the guaranteed analysis of fertilizer.

Citrate-soluble phosphorus
That part of the total P in fertilizer that, along with the water-soluble P, is considered immediately available to plants.

Compost
Organic material that has been well decomposed by organisms under conditions of good aeration and high temperature. Normally used to improve soil tilth, although it does supply small amounts of nutrients.

Cover crop
A crop grown to: (1) protect the soil from erosion during periods when it would otherwise be bare; (2) scavenge excess nutrients from a previous crop to prevent nutrient loss; or both.

Critical nutrient concentration
The nutrient concentration in the plant or specific plant part below which the nutrient becomes deficient for optimum growth.

Crop removal rate
Amount of crop nutrients in the harvested part of the plant, such as in the grain, fruit, forage, stover, tuber, or any other plant material removed from the field.

Crop rotation
A planned sequence of crops growing in a regularly recurring succession on the same area of land, as contrasted to continuous culture of one crop or growing a variable sequence of crops.

Crop utilization rate
Amount of crop nutrients required to grow the plant and meet the expected yield of the specific crop regardless of the nutrient supplying power of the soil, plant, air, and water. This includes nutrients to produce all of the plant biomass including roots, stems, and leaves.

Denitrification
The transformation of nitrates or nitrites to nitrogen or nitrous oxide gas occurring under anaerobic conditions.

Dissolved phosphorus
Phosphorus, either in organic or inorganic form, in solution with water. Determined by passing through a 0.45 micron filter.

Dissolved reactive phosphorus
Inorganic P that reacts with molybdenum.

EC
The electrical conductivity of a soil, which is a measure of the salt content of that soil. EC is expressed in millimhos per centimeter (mmhos/cm) or deciSiemens per meter (dS/m).

Effective precipitation
That part of the total precipitation that becomes available for plant growth.

Eutrophication
The enrichment of an ecosystem with nutrients that provides a potential for increase in biological production. Both N and P provide vital nutrient elements for growth in an ecosystem.

Evapotranspiration
The combined loss of water from a given area by evaporation from soil and plant surfaces and by transpiration from plants.

Expected yield
The yield commonly expected under good husbandry, adequate fertility, and adequate moisture for the area in which the crop is grown. Also called realistic yield.

Fertigation
Application of plant nutrients in irrigation water.

Fertility, soil
The ability of a soil to supply the nutrients essential to plant growth.

Fertilization, foliar
Application of a dilute solution of fertilizer to plant foliage, usually made to supplement soil-applied nutrients.

Fertilizer
Any organic or inorganic material of natural or synthetic origin (other than liming material) that is added to a soil to supply one or more elements essential to plant growth.

Fertilizer analysis
The percent composition of a fertilizer, expressed as total N, available phosphoric acid (P_2O_5), and water-soluble potash (K_2O).

Fertilizer, controlled release
A fertilizer product formulated so that its nutrients become available at a slower rate than conventional water-soluble fertilizers.

Fertilizer equivalent
The amount of phosphorus and potassium contained in a nutrient material expressed in the fertilizer terms of P_2O_5 and K_2O. To convert P to P_2O_5, multiply by 2.29. To convert K to K_2O, multiple by 1.2.

Fertilizer, fluid
Fertilizer wholly or partly in solution that can be handled as a liquid, including clear liquids and liquids containing solids in suspension.

Fertilizer, salt index
A measure of how much soluble salts a fertilizer product will add to the soil.

Fertilizer, starter
A fertilizer applied in relatively small amounts with or near the seed for the purpose of accelerating early growth of the crop.

Fertilizer, suspension
A fluid fertilizer containing dissolved and undissolved plant nutrients. The undissolved nutrients are kept in suspension usually by swelling type clay.

Fertilizer, topdressed
A surface application of fertilizer applied to the soil after the crop is established.

Fixed phosphorus
Adsorbed P bonded to mineral material in the soil (including iron, aluminum, and calcium) so tightly that the P is unavailable to plants and animals.

Green manure
Plant material incorporated into the soil, while green or at maturity, for soil improvement.

Hydrologic cycle
The fate of water from the time it falls as precipitation until the water has been returned to the atmosphere by evaporation and is ready to be precipitated again.

Immobilization
The conversion of an element from the inorganic to the organic form in microbial tissue or plant tissue.

Infrared photography
A remote sensing method that can be used to monitor crop production systems. Healthy plants reflect a large amount of infrared light while stressed plants reflect lesser amounts depending on the degree of stress. Onsite investigation may be needed to determine the source of stress: inadequate fertility, insect, disease, or poor drainage.

Inorganic phosphorus
Mineral or orthophosphate forms of P.

Irrigation efficiency
The ratio of the amount of water actually consumed by a crop in an irrigated area to the amount of water applied to the area.

Labile phosphorus
Phosphorus that is weakly adsorbed or bound in the soil to minerals and organic material and can easily be extracted by some chemical or plant root and released into soil solution for plant uptake.

Leaching
The removal of material in solution by the passage of water through the soil.

Leaching index (LI)
An estimate of the average annual percolation for a site. It is a function of annual precipitation, the seasonal distribution of precipitation, and hydrologic soil group.

Limiting nutrient
Any one nutrient that if not available to the plant in adequate amounts limits the potential yield of a crop even though all other nutrients are available in adequate amounts.

Luxury consumption
The absorption by plants of an essential nutrient in excess of their need for growth. Luxury concentrations in early growth may be used in later growth.

Macronutrient
A nutrient that a plant needs in relatively large amounts. Essential macronutrients are nitrogen, phosphorus, and potassium.

Maintenance application
Application of fertilizer material in amounts and at intervals to maintain available soil nutrients at levels necessary to produce a desired yield.

Micronutrient
Nutrients that plants need in only small or trace amounts. Boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn) are considered micronutrients.

Mineralization
The conversion of an element by soil organisms from an organic form to an inorganic form, such as the conversion of organic forms of nitrogen to nitrates.

NLEAP
Nitrogen Leaching and Economic Assessment Package. A model that estimates the potential for nitrogen losses by leaching.

Nitrate (NO_3^-)
The form of nitrogen most readily available to plants, and the form found in greatest abundance in agricultural soils.

Nitrate toxicity
A variety of conditions in animals resulting from ingestion of feed high in nitrate. The toxicity actually results when nitrate (NO_3^-) is reduced to nitrite (NO_2^-) in the rumen.

Nitrification
Biological oxidation of ammonium to nitrite and nitrate.

Nitrogen cycle
The sequence of biochemical changes undergone by nitrogen in which it is used by a living organism, transformed upon the death and decomposition of the organism, and converted ultimately to its original state.

Nitrogen fixation
Conversion of molecular nitrogen to ammonia and subsequently to organic combinations or to forms useable in biological processes.

Nitrogen immobilization
The transformation of available forms of nitrogen, such as nitrates, into organic forms not readily available to plants.

Nutrient balance
An as yet undefined ratio among concentrations of nutrients necessary for optimum growth and yield. An imbalance results when one or more nutrients are present either in deficit or in excess.

Organic material
Material, such as manure, compost, sewage sludge, or yard wastes, in which the nutrients become available as they are broken down by microbial activity in the soil.

Organic phosphorus
Phosphorus that is bound with organic carbon and forms organic molecules.

Orthophosphate
The inorganic form of phosphorus that is plant available. Two species are $H_2PO_4^-$ and $H_2PO_4^{-2}$.

Oxidation
The loss of electrons from a molecule as the charge becomes more positive. An example is the oxidation of ferrous phosphate, a relative soluble iron form of P, to ferric phosphate, an insoluble P form.

Particulate phosphorus
Phosphorus that is attached to mineral or organic material on the soil surface and carried as sediment by erosion.

Percolation
The downward movement of water through the soil profile.

pH, soil
The degree of acidity or alkalinity of a soil, expressed on a scale from 0 to 14 with 7.0 indicating neutrality. Values higher indicate increasing alkalinity, while lower values indicate increasing acidity.

Phosphate
In fertilizer terminology, phosphate is the sum of water-soluble and citrate-soluble phosphoric acid (P_2O_5), also referred to as available phosphoric acid (P_2O_5).

Phosphorus
Essential nutrient both for plants and animals. Makes up cell walls, DNA, and energy transfer molecules.

Phosphorus index (PI)
An assessment tool to show the potential for phosphorus movement and losses from the landscape.

Phytomass
The total of all plant material in an ecosystem at a given time.

P_2O_5
Phosphorus pentoxide designation on the fertilizer label that denotes the percentage of available phosphorus.

Plant nutrient
An element that is absorbed by plants and is necessary for the completion of their life cycle.

Parts per million (ppm)
A means of expressing concentration, generally by weight. Equivalent expression are milligrams per liter (mg/L) and milligrams per kilogram (mg/kg).

Reaction, soil
The degree of acidity or alkalinity of a soil, generally expressed as a pH value.

Redox (oxidation-reduction) potential
An important chemical characteristic of soils, related to soil aeration. This characteristic determines in which form a given nutrient will occur in the soil.

Remote sensing
The collection and analysis of data from a distance using sensors that respond to different heat intensities or light wavelengths. Remotely-sensed data are often collected using cameras mounted on aircraft or in satellites.

Residual fertility
The available nutrient content of a soil carried over to subsequent crops.

Rhizobia
Several species of bacteria capable of living symbiotically in roots of leguminous plants. The bacteria receive energy from the plants and in turn convert atmospheric nitrogen into ammonia, which the plant uses.

Runoff
That part of the precipitation in an area that moves over the soil surface and is discharged through stream channels.

Salt-affected soil
Soil that has been adversely modified for the growth of most crop plants by the presence of soluble salts, exchangeable sodium, or both.

Saturated hydraulic conductivity
The rate at which water moves through a saturated soil.

Secondary nutrients
Refers to calcium (Ca), magnesium (Mg), and sulfur (S) in fertilizers.

Sensitivity
A measure of the potential for environmental degradation of an area, based on the inherent characteristics of the site or area.

Slow release
See Fertilizer, controlled release.

Soil amendment
Any material, such as lime, gypsum, sawdust, compost, animal manure, crop residue, or synthetic soil conditioners, that is incorporated into the soil or applied on the surface to enhance plant growth. Amendments may contain important fertilizer elements, but the term commonly refers to added material other than that commonly used as fertilizer.

Soil organic matter (SOM)
The organic fraction of the soil exclusive of undecayed plant and animal residue. Often used synonymously with humus.

Soil salinity
The amount of soluble salts in a soil. The conventional measure of soil salinity is the electrical conductivity of a saturation extract.

Soil solution
The liquid part of the soil contained in soil pores. Chemical molecules including plant nutrients are diffused or flow in soil solution.

Soil test
A chemical, physical, or biological procedure that estimates the plant availability of nutrients to support plant growth.

Soluble phosphorus
Phosphorus that mixes and is transported as a solution by water. The P can be in the organic or inorganic form.

Solute
Any material dissolved in another substance.

Solvent
A substance, generally liquid, capable of dissolving or dispersing one or more substances.

Source-sink
A relationship between two parts of a system in which one part serves as the producer or source of the material that is moved to another, the sink, where the material accumulates or is consumed.

Superphosphate, concentrated
Also called triple or treble superphosphate, made with phosphoric acid and usually containing 19 to 21 percent P (44-48% P_2O_5).

Superphosphate, normal
Also called ordinary or single superphosphate, made by reaction of phosphate rock with sulfuric acid, usually containing 7 to 10 percent P (16-22% P_2O_5).

Tilth
The physical condition of the soil as it influences tillage, fitness as a seedbed, and impedance to seedling emergence and root penetration.

Total phosphorus
The sum total of all the phosphorus forms contained in the material including organic, particulate, and soluble forms.

Volatilization
The loss of compounds in gaseous form from a solid or liquid surface. Ammonia volatilizes from fertilizers and organic material.

Vulnerability
A measure of the potential for environmental degradation of an area based on the management practices used in that area.

Yield
The amount of a specified substance produced (e.g., grain, straw, total dry matter) per unit area.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

NUTRIENT MANAGEMENT

(Acre)

CODE 590

DEFINITION

Managing the amount, source, placement, form and timing of the application of nutrients and soil amendments.

PURPOSES

- To budget and supply nutrients for plant production.
- To properly utilize manure or organic by-products as a plant nutrient source.
- To minimize agricultural nonpoint source pollution of surface and ground water resources.
- To maintain or improve the physical, chemical and biological condition of soil.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to all lands where plant nutrients and soil amendments are applied.

CRITERIA

General Criteria Applicable to All Purposes

Plans for nutrient management shall comply with all applicable Federal, state, and local laws and regulations.

Plans for nutrient management shall be developed in accordance with policy requirements of the NRCS General Manual Title 450, Part 401.03 (Technical Guides, Policy and Responsibilities) and Title 190, Part 402 (Ecological Sciences, Nutrient Management, Policy); technical requirements of the NRCS Field Office Technical Guide (FOTG); procedures contained in the National Planning Procedures Handbook (NPPH), and the NRCS National Agronomy Manual (NAM) Section 503.

Persons who review or approve plans for nutrient management shall be certified through any certification program acceptable to NRCS within the state.

Plans for nutrient management that are elements of a more comprehensive conservation plan shall recognize other requirements of the conservation plan and be compatible with its other requirements.

A nutrient budget for nitrogen, phosphorus, and potassium shall be developed that considers all potential sources of nutrients including, but not limited to animal manure and organic by-products, waste water, commercial fertilizer, crop residues, legume credits, and irrigation water.

Realistic yield goals shall be established based on soil productivity information, historical yield data, climatic conditions, level of management and/or local research on similar soil, cropping systems, and soil and manure/organic by-products tests. For new crops or varieties, industry yield recommendations may be used until documented yield information is available.

Plans for nutrient management shall specify the form, source, amount, timing and method of application of nutrients on each field to achieve realistic production goals, while minimizing nitrogen and/or phosphorus movement to surface and/or ground waters.

Erosion, runoff, and water management controls shall be installed, as needed, on fields that receive nutrients.

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Soil Sampling and Laboratory Analysis (Testing)

Nutrient planning shall be based on current soil test results developed in accordance with Land Grant University guidance or industry practice if recognized by the Land Grant University. Current soil tests are those that are no older than five years.

Soil samples shall be collected and prepared according to the Land Grant University guidance or standard industry practice. Soil test analyses shall be performed by laboratories that are accepted in one or more of the following programs:

- State Certified Programs,
- The North American Proficiency Testing Program (Soil Science Society of America), or
- Laboratories whose tests are accepted by the Land Grant University in the state in which the tests will be used.

Soil testing shall include analysis for any nutrients for which specific information is needed to develop the nutrient plan. Request analyses pertinent to monitoring or amending the annual nutrient budget; e.g., pH, electrical conductivity (EC), soil organic matter, nitrogen, phosphorus, and potassium.

Plant Tissue Testing

Tissue sampling and testing, where used, shall be done in accordance with Land Grant University standards or recommendations.

Nutrient Application Rates

Soil amendments shall be applied, as needed, to adjust soil pH to the specific range of the crop for optimum availability and utilization of nutrients.

Recommended nutrient application rates shall be based on Land Grant University recommendations (and/or industry practice when recognized by the university) that consider current soil test results, realistic yield goals and management capabilities. If the Land Grant University does not provide specific recommendations, application shall be based on realistic yield goals and associated plant nutrient uptake rates.

The planned rates of nutrient application, as documented in the nutrient budget, shall be determined based on the following guidance:

- **Nitrogen Application** - Planned nitrogen application rates shall match the recommended rates as closely as possible, except when manure or other organic by-products are a source of nutrients. When manure or other organic by-products are a source of nutrients, see “Additional Criteria” below.
- **Phosphorus Application -** Planned phosphorus application rates shall match the recommended rates as closely as possible, except when manure or other organic by-products are a source of nutrients. When manure or other organic by-products are a source of nutrients, see “Additional Criteria” below.
- **Potassium Application** - Excess potassium shall not be applied in situations in which it causes unacceptable nutrient imbalances in crops or forages. When forage quality is an issue associated with excess potassium application, state standards shall be used to set forage quality guidelines.
- **Other Plant Nutrients -** The planned rates of application of other nutrients shall be consistent with Land Grant University guidance or industry practice if recognized by the Land Grant University in the state.
- **Starter Fertilizers** - Starter fertilizers containing nitrogen, phosphorus and potassium may be applied in accordance with Land Grant University recommendations, or industry practice if recognized by the Land Grant University within the state. When starter fertilizers are used, they shall be included in the nutrient budget.

Nutrient Application Timing

Timing and method of nutrient application shall correspond as closely as possible with plant nutrient uptake characteristics, while considering cropping system limitations, weather and climatic conditions, and field accessibility.

Nutrient Application Methods

Nutrients shall not be applied to frozen, snow-covered, or saturated soil if the potential risk for runoff exists.

Nutrient applications associated with irrigation systems shall be applied in accordance with the requirements of Irrigation Water Management (Code 449).

Additional Criteria Applicable to Manure or Organic By-Products Applied as a Plant Nutrient Source

Nutrient values of manure and organic by-products (excluding sewage sludge) shall be determined prior to land application based on laboratory analysis, acceptable "book values" recognized by the NRCS and/or the Land Grant University, or historic records for the operation, if they accurately estimate the nutrient content of the material. Book values recognized by NRCS may be found in the Agricultural Waste Management Field Handbook, Chapter 4 - Agricultural Waste Characteristics.

Nutrient Application Rates

The application rate (in/hr) for material applied through irrigation shall not exceed the soil intake/infiltration rate. The total application shall not exceed the field capacity of the soil.

The planned rates of nitrogen and phosphorus application recorded in the plan shall be determined based on the following guidance:

- ♦ **Nitrogen Application -** When the plan is being implemented on a phosphorus standard, manure or other organic by-products shall be applied at rates consistent with the phosphorus standard. In such situations, an additional nitrogen application, from non-organic sources, may be required to supply the recommended amounts of nitrogen. Manure or other organic by-products may be applied on legumes at rates equal to the estimated removal of nitrogen in harvested plant biomass.
- ♦ **Phosphorus Application** - When manure or other organic by-products are used, the planned rates of phosphorus application shall be consistent with any one of the following options:
  - **Phosphorus Index (PI) Rating.** Nitrogen based manure application on Low or Medium Risk Sites, phosphorus based or no manure application on High and Very High Risk Sites.**
  - **Soil Phosphorus Threshold Values.** Nitrogen based manure application on sites on which the soil test phosphorus levels are below the threshold values. Phosphorus based or no manure application on sites on which soil phosphorus levels equal or exceed threshold values.**
  - **Soil Test.** Nitrogen based manure application on sites on which there is a soil test recommendation to apply phosphorus. Phosphorus based or no manure application on sites on which there is no soil test recommendation to apply phosphorus.**

  ** Acceptable phosphorus based manure application rates shall be determined as a function of soil test recommendation or estimated phosphorus removal in harvested plant biomass. Guidance for developing these acceptable rates is found in the NRCS General Manual, Title 190, Part 402 (Ecological Sciences, Nutrient Management, Policy), and the National Agronomy Manual, Section 503.

A single application of phosphorus applied as manure may be made at a rate equal to the recommended phosphorus application or estimated phosphorus removal in harvested plant biomass for the crop rotation or multiple years in the crop sequence. When such applications are made, the application rate shall:

- not exceed the recommended nitrogen application rate during the year of application, or
- not exceed the estimated nitrogen removal in harvested plant biomass

during the year of application when there is no recommended nitrogen application.

- not be made on sites considered vulnerable to off-site phosphorus transport unless appropriate conservation practices, best management practices, or management activities are used to reduce the vulnerability.

Field Risk Assessment

When animal manures or other organic by-products are applied, a field-specific assessment of the potential for phosphorus transport from the field shall be completed. This assessment may be done using the Phosphorus Index or other recognized assessment tool. In such cases, plans shall include:

- ♦ a record of the assessment rating for each field or sub-field, and
- ♦ information about conservation practices and management activities that can reduce the potential for phosphorus movement from the site.

When such assessments are done, the results of the assessment and recommendations shall be discussed with the producer during the development of the plan.

Heavy Metals Monitoring

When sewage sludge is applied, the accumulation of potential pollutants (including arsenic, cadmium, copper, lead, mercury, selenium, and zinc) in the soil shall be monitored in accordance with the US Code, Reference 40 CFR, Parts 403 and 503, and/or any applicable state and local laws or regulations.

Additional Criteria to Minimize Agricultural Non-point Source Pollution of Surface and Ground Water Resources

In areas with an identified or designated nutrient-related water quality impairment, an assessment shall be completed of the potential for nitrogen and/or phosphorus transport from the field. The Leaching Index (LI) and/or Phosphorus Index (PI), or other recognized assessment tools, may be used to make these assessments. The results of these assessments and recommendations shall be discussed with the producer and included in the plan.

Plans developed to minimize agricultural nonpoint source pollution of surface or ground water resources shall include practices and/or management activities that can reduce the risk of nitrogen or phosphorus movement from the field.

Additional Criteria to Improve the Physical, Chemical, and Biological Condition of the Soil.

Nutrients shall be applied in such a manner as not to degrade the soil's structure, chemical properties, or biological condition. Use of nutrient sources with high salt content will be minimized unless provisions are used to leach salts below the crop root zone.

Nutrients shall not be applied to flooded or saturated soils when the potential for soil compaction and creation of ruts is high.

CONSIDERATIONS

Consider induced deficiencies of nutrients due to excessive levels of other nutrients.

Consider additional practices such as Conservation Cover (327), Grassed Waterway (412), Contour Buffer Strips (332), Filter Strips (393), Irrigation Water Management (449), Riparian Forest Buffer (391A), Conservation Crop Rotation (328), Cover and Green Manure (340), and Residue Management (329A, 329B, or 329C, and 344) to improve soil nutrient and water storage, infiltration, aeration, tilth, diversity of soil organisms and to protect or improve water quality.

Consider cover crops whenever possible to utilize and recycle residual nitrogen.

Consider application methods and timing that reduce the risk of nutrients being transported to ground and surface waters, or into the atmosphere. Suggestions include:

- ♦ split applications of nitrogen to provide nutrients at the times of maximum crop utilization,

- avoiding winter nutrient application for spring seeded crops,
- band applications of phosphorus near the seed row,
- applying nutrient materials uniformly to application areas or as prescribed by precision agricultural techniques, and/or
- immediate incorporation of land applied manures or organic by-products,
- delaying field application of animal manures or other organic by-products if precipitation capable of producing runoff and erosion is forecast within 24 hours of the time of the planned application.

Consider minimum application setback distances from environmentally sensitive areas, such as sinkholes, wells, gullies, ditches, surface inlets or rapidly permeable soil areas.

Consider the potential problems from odors associated with the land application of animal manures, especially when applied near or upwind of residences.

Consider nitrogen volatilization losses associated with the land application of animal manures. Volatilization losses can become significant, if manure is not immediately incorporated into the soil after application.

Consider the potential to affect National Register listed or eligible cultural resources.

Consider using soil test information no older than one year when developing new plans, particularly if animal manures are to be a nutrient source.

Consider annual reviews to determine if changes in the nutrient budget are desirable (or needed) for the next planned crop.

On sites on which there are special environmental concerns, consider other sampling techniques. (For example: Soil profile sampling for nitrogen, Pre-Sidedress Nitrogen Test (PSNT), Pre-Plant Soil Nitrate Test (PPSN) or soil surface sampling for phosphorus accumulation or pH changes.)

Consider ways to modify the chemistry of animal manure, including modification of the animal's diet to reduce the manure nutrient content, to enhance the producer's ability to manage manure effectively.

PLANS AND SPECIFICATIONS

Plans and specifications shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose(s), using nutrients to achieve production goals and to prevent or minimize water quality impairment.

The following components shall be included in the nutrient management plan:

- aerial photograph or map and a soil map of the site,
- current and/or planned plant production sequence or crop rotation,
- results of soil, plant, water, manure or organic by-product sample analyses,
- realistic yield goals for the crops in the rotation,
- quantification of all nutrient sources,
- recommended nutrient rates, timing, form, and method of application and incorporation,
- location of designated sensitive areas or resources and the associated, nutrient management restriction,
- guidance for implementation, operation, maintenance, recordkeeping, and
- complete nutrient budget for nitrogen, phosphorus, and potassium for the rotation or crop sequence.

If increases in soil phosphorus levels are expected, plans shall document:

- the soil phosphorus levels at which it may be desirable to convert to phosphorus based implementation,
- the relationship between soil phosphorus levels and potential for phosphorus transport from the field, and
- the potential for soil phosphorus drawdown from the production and harvesting of crops.

When applicable, plans shall include other practices or management activities as determined by specific regulation, program requirements, or producer goals.

In addition to the requirements described above, plans for nutrient management shall also include:

- discussion about the relationship between nitrogen and phosphorus transport and water quality impairment. The discussion about nitrogen should include information about nitrogen leaching into shallow ground water and potential health impacts. The discussion about phosphorus should include information about phosphorus accumulation in the soil, the increased potential for phosphorus transport in soluble form, and the types of water quality impairment that could result from phosphorus movement into surface water bodies.
- discussion about how the plan is intended to prevent the nutrients (nitrogen and phosphorus) supplied for production purposes from contributing to water quality impairment.
- a statement that the plan was developed based on the requirements of the current standard and any applicable Federal, state, or local regulations or policies; and that changes in any of these requirements may necessitate a revision of the plan.

OPERATION AND MAINTENANCE

The owner/client is responsible for safe operation and maintenance of this practice including all equipment. Operation and maintenance addresses the following:

- periodic plan review to determine if adjustments or modifications to the plan are needed. As a minimum, plans will be reviewed and revised with each soil test cycle.
- protection of fertilizer and organic by-product storage facilities from weather and accidental leakage or spillage.
- calibration of application equipment to ensure uniform distribution of material at planned rates.
- documentation of the actual rate at which nutrients were applied. When the actual rates used differ from or exceed the recommended and planned rates, records will indicate the reasons for the differences.
- Maintaining records to document plan implementation. As applicable, records include:
  - soil test results and recommendations for nutrient application,
  - quantities, analyses and sources of nutrients applied,
  - dates and method of nutrient applications,
  - crops planted, planting and harvest dates, yields, and crop residues removed,
  - results of water, plant, and organic by-product analyses, and
  - dates of review and person performing the review, and recommendations that resulted from the review.

Records should be maintained for five years; or for a period longer than five years if required by other Federal, state, or local ordinances, or program or contract requirements.

Workers should be protected from and avoid unnecessary contact with chemical fertilizers and organic by-products. Protection should include the use of protective clothing when working with plant nutrients. Extra caution must be taken when handling ammonia sources of nutrients, or when dealing with organic wastes stored in unventilated enclosures.

The disposal of material generated by the cleaning nutrient application equipment should be accomplished properly. Excess material should be collected and stored or field applied in an appropriate manner. Excess material should not be applied on areas of high potential risk for runoff and leaching.

The disposal or recycling of nutrient containers should be done according to state and local guidelines or regulations.

NRCS, NHCP

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CORE4 Key Conservation Practices

Part 3 Pest Management

Chapter 1 Pest Management Planning — Overview

Pest management is a critical component of conservation planning. It should be used in conjunction with crop residue management, nutrient management, conservation buffers, and other practices to address natural resource concerns and to maximize economic returns by enhancing the quantity and quality of agricultural commodities. Pesticides used in pest management can negatively impact nontarget plants, animals, and humans. Unintentional exposure may occur in transport and handling, in the field, and after transport from the field in soil, water, and air. Ground and surface water quality impairment resulting from nonpoint source pesticide contamination is a major concern in many agricultural areas. Other forms of pest management also have environmental risks. Cultivation for weed control, burying or burning crop residue for disease and insect control, and biological methods of weed, insect, and disease control can negatively impact soil, water, air, plants, animals, and humans. To adequately address these environmental risks, conservation planning must include a pest management component that minimizes negative impacts to all identified resource concerns.

Many pest management principles are detailed and complex. Formal academic training is often required to master these principles. The Natural Resources Conservation Service's (NRCS) National Employee Development Center (NEDC) is developing a course to help conservationists gain the technical background they need to develop conservation plans with an effective pest management component. The name of the course is *Nutrient and Pest Management Considerations in a Conservation Management System Plan*. This self-paced study course will take about 60 hours to complete. A prerequisite course entitled Introduction to Water Quality is currently available from the NEDC.

Core4 Pest Management training is designed to complement NEDC technical courses by focusing on the pest management conservation planning process. This includes implementation of the pest management standard and filling out job sheets and specification sheets. Core4 Pest Management training briefly introduces many of the topics covered in detail in the NEDC courses. Although these courses cannot take the place of formal academic training, they can complement local Cooperative Extension and Land Grant University training to provide conservationists with the information they need to work effectively with Extension agents, certified crop advisors (CCA's), agrichemical dealers, and others who make pest management recommendations. Cooperative development of the pest management component of a conservation plan will support pest management decisions that produce an abundant supply of food and fiber while simultaneously conserving our Nation's natural resources.

Conservation planning involves more than just considering individual resources. It focuses on the natural systems and ecological processes that sustain the resources. The planner must strive to balance natural resource issues with economic and social needs through the development of a Resource Management System (RMS). A CMS combines management and conservation practices that, when installed, will achieve a specified level of treatment for all resources (soil, water, air, plants, animals, and humans). Progressive planning at incrementally higher levels of treatment eventually results in an RMS that prevents degradation and permits sustained use of all natural resources.

Pest management policy

NRCS's primary role in pest management is to help producers understand the environmental risks associated with different pest control options so that they can incorporate them into their pest management decisionmaking process. Currently, the major emphasis is on quantifying how pesticide choice and management factors can affect the potential for pesticide movement below the root zone and beyond the edge of the field.

Our policy does not support NRCS originating site-specific pesticide recommendations. We do, however, have responsibility for supplementing recommendations made by Cooperative Extension, CCA's, and others with environmental risk information. The goal is to help producers understand how pest management (including the use of specific pesticides) interrelates with climate, water management, crop management, and soil management so they can implement strategies to minimize environmental hazards related to offsite contaminant movement and its potential impacts on nontarget plants, animals, and humans.

NRCS Policy on Pesticides

(This policy is excerpted from: GM-190 Ecological Sciences, Part 404, Pesticides, May 1981.)

404.2 Policy
(a) Secretary's Memorandum No. 1929 dated December 12, 1977; (404.4) provides the USDA policy statement on management of pest problems.

(b) It is the policy of USDA and NRCS to encourage the use of Integrated Pest Management (IPM) methods, systems, and strategies that are practical, effective, and energy efficient. Further, the policy advocates adequate protection against significant pests with pesticides that minimize hazards to man and the natural environment, including soil, water, and related plant and animal resources.

404.3
(a) NRCS does not originate specific instructions, specifications, formulations, or recommendations regarding pesticides. If such information is required, it is to be derived from official publications and documents of the USDA or its cooperating agencies.

(b) If pesticide use is an essential part of a conservation practice, specific information regarding kind of pesticide, amounts, and the proper use may be included in technical guide specifications, resource conservation plans, technical notes, job sheets, and contracts. When needed pesticide information is not included in NRCS documents, it is to be referenced in the practice standard(s) and specifications, and the reference material is to be available in the field office. Such technical information and use of pesticides must be consistent with label instructions. It may be necessary to include more detail, such as timing of application, equipment, and climatic conditions, than is included on the label. All technical notes, "how to do it" sheets, publications, and other information for general distribution that include specific information on pesticides will be dated and will include appropriate precautionary statement(s).

(This policy is excerpted from proposed policy in GM 450, part 401, subpart A. It is not yet final, but it is included to show what is being proposed to clarify and enhance NRCS's role in pest management.)

General Manual — Title 450, Part 401
(Proposed policy revisions — changes to existing policy are bolded.)

401.03(b)(3)(iv)(B)[2] Water quality
When nutrients and pest management negatively impact surface or ground water or potential problems exist, nutrient and/or pest management practices, including timing, forms, and rate and method application, shall be recommended to reduce adverse effects. The use of pesticides and nutrients with high potential for polluting water are avoided where site limitations, such as slope, **proximity to a surface waterbody,** depth to ground water, soil, and materials in the vadose zone or aquifer could **cause contamination. the soil pesticide screening tool, leaching index (LI), the phosphorus index (PI), and or other approved assessment procedures are used according to FOTG guidelines** to identify potential problem situations from surface runoff and/or leaching. Alternative practices for **pest management (i.e., chemical, mechanical, cultural, or biological) or nutrient management (i.e., phosphorus based manure management, legume cover crops, split nitrogen applications)** or integrated methods are recommended where site limitations exist that increase the probability of degrading water supplies.

401.03(b)(3)(iv)(D) Plants
Pest management methods for any land use are based on target pests, environmental considerations, production requirements, soil, climate and other planned practices. The timing, method and rate of application, and forms of management are considered in the planning process. Other considerations of pest management such as economics, health and availability of products and management skills are considered in planning process using the conservation practice standard "Pest Management" (code 595) in the FOTG. Recommended procedures for developing and documenting the pest management component are found in the National Agronomy Manual, section 503, Part C.

(This policy is excerpted from a new draft of GM 190, Ecological Sciences, Part 404 Pest Management. It is not yet final, but it is included to show what is being proposed to clarify and enhance NRCS's role in pest management.)

Part 404 - Pest Management
404.1(g) 404.1 Overall Policy

a. Guidance and procedures in this section are applicable to all technical assistance that involves pest management. NRCS employees will follow these procedures when providing such technical assistance. Third party vendors and other non-NRCS employees will use these pest management procedures when assisting with the implementation of federal conservation programs for which NRCS has technical responsibility.

b. NRCS promotes the protection of natural resource functions and values in all NRCS planning and application assistance. NRCS recognizes the need to protect soil, water, air, and related plant and animal resources while producing abundant high quality food, fiber and forage and promoting viable agricultural enterprises.

c. NRCS's role in pest management is to:

1. evaluate environmental risks associated with pest management;
2. develop appropriate mitigation alternatives for decision-maker consideration;
3. encourage widespread adoption of Integrated Pest Management (IPM) programs that help protect natural resources;
4. assist landowners with development and implementation of an acceptable pest management component of the overall conservation plan.

d. When providing technical assistance, NRCS will conduct an environmental evaluation and consider the objectives of the client in the context of environmental, economic and other pertinent factors.

e. The pest management component of a conservation plan shall be developed in compliance with all applicable federal, state and/or local regulations. Federal, State and/or local regulations take precedence over NRCS policy when more restrictive.

Chapter 2 Integrated Pest Management

(Chapter 2, Integrated Pest Management, was adapted from Module 3 of Nutrient and Pest Management Considerations in a Conservation Management System Plan, NRCS National Employee Development Center self-paced study course, 1999.)

What is a pest?

A pest is any organism (plant or animal) that causes trouble, annoyance, or discomfort or becomes a nuisance by destroying food and fiber products, causing structural damage, or creating a poor environment for other organisms. Ecologically speaking, no organism is born a pest; it all depends on human perspective.

Major pests of agricultural and horticultural crops

Insects and related arthropods—Invertebrate animals, such as caterpillars, bugs, beetles, and mites that cause injury by feeding on plants and animals and by transmitting pathogens that cause diseases.

Nematodes—Microscopic, multicellular, unsegmented roundworms that parasitize animals and plants. Most nematodes that attack agricultural crops feed on the roots, but a few feed aboveground on inside stems and leaves.

Pathogens—Disease-causing bacteria, fungi, viruses, and related organisms. Note that a pathogen is the agent whose injury causes a disease, whereas a disease is the process of injury that the pathogen causes. Most pathogens are too small to be seen with the naked eye, while diseases manifest themselves visually as symptoms and signs.

Vertebrates—Any native or introduced, wild or feral, nonhuman species of vertebrate animal that is detrimental to one or more persons as a health hazard or general nuisance, or by destroying food, fiber, or natural resources. Vertebrate feeding in agricultural crops causes the majority of direct damage including animals, such as mice, rats, and birds. Vertebrates may also cause damage indirectly by transmitting human diseases.

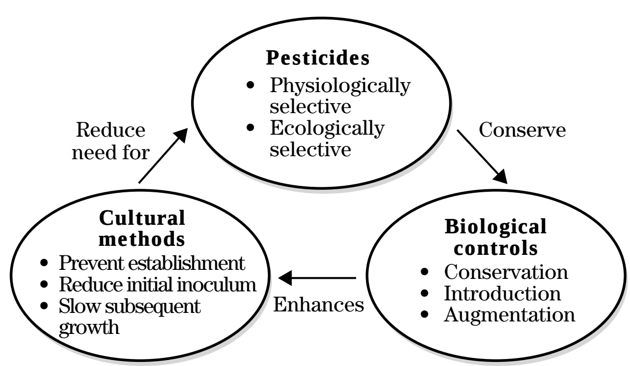
Weeds—Undesirable plants that reduce crop yield and quality by competing for space, water, and nutrients; weeds also may harbor crop-attacking insects and pathogens. Weeds also include plants that interfere with other human activities, such as by prolifically growing in waterways, or those that cause discomfort, such as skin irritation or hay fever.

Integrated pest management defined

Integrated pest management is an approach to pest control that combines biological, cultural, and other alternatives to chemical control with the judicious use of pesticides. The objective of IPM is to maintain pest levels below economically damaging levels while minimizing harmful effects of pest control on human health and environmental resources. Figure 2–1 shows a model for IPM.

Pest problems do not arise as independent or isolated events. Crops and pests are part of an agroecosystem, and they are governed by the same biological processes as those in natural ecosystems. Attempts to control one pest species without regard for the entire ecosystem can disrupt checks and balances between crop plants, pests, beneficials, and the physical environment. Failure to appreciate ecological interactions may increase the severity of pest infestations. Action taken against one pest may exacerbate problems with

Figure 2–1 Conceptual model for integrated pest management showing how control tactics are integrated into a complementary system



another or may be incompatible with other control tactics. Integrated pest management (IPM) depends on a detailed understanding of pest growth and development, and in particular, what causes outbreaks and determines survival.

Integrated means that a broad interdisciplinary approach is taken using scientific principles of plant protection to bring together a variety of management tactics into an overall strategy.

- IPM strives for maximum use of naturally occurring control forces in the pest's environment including weather, pest diseases, predators, and parasites (fig. 2–2). Biointensive IPM attempts to reduce the use of conventional pesticides by looking first to biological and cultural alternatives as well as use of least-toxic biorational (derived from items in nature) products that only affect the target pest.
- With IPM, the role for chemical pesticides is one of last resort if alternatives fail to correct the problem. Pesticides are never applied according to a preset schedule or spray calendar in an IPM program. Instead, they only are used if scouting shows they really are needed to prevent severe damage (fig 2–3).
- Prescriptive IPM depends largely on judicious use of pesticides based on field scouting that shows pest infestation has exceeded economic thresholds.

Management refers to the decisionmaking process used to keep pest numbers below economical threshold levels. Eradication is never the goal because low levels of pest are tolerable from an economic point of view. The essence of IPM is decisionmaking: determining if, when, where, and what mix of control methods are needed. Diverse IPM strategies help to control pest resistance, pest resurgence, and pest replacement. IPM decisionmaking also helps to control pest resistance, pest resurgence, and pest replacement.

Resistance is the innate (genetically inherited) ability of organisms to evolve strains that can survive exposure to pesticides formerly lethal to earlier generations (fig 2–4). Resistance can develop when pesticide application kills susceptible individuals while allowing naturally resistant individuals to survive. These survivors pass to their offspring the genetically determined resistance trait. With repeated pesticide application, the pest population increasingly is comprised of resistant individuals.

In theory, pests can develop resistance to any type of IPM tactic: biological, cultural, or chemical. In the Midwest, farmers routinely rotate corn with soybeans to break the infestation cycle of the corn rootworm, an insect that only feeds on grassy plants and so has become the key insect pest of field corn. Yet the rootworm has developed strains that overcome crop rotation by extending their overwintering resting stage in the soil from one winter to several winters. This allows them to be ready to attack corn the next time it is planted in the field. Still other rootworm populations have developed strains that feed on both corn and soybeans.

Figure 2–2 Biointensive IPM

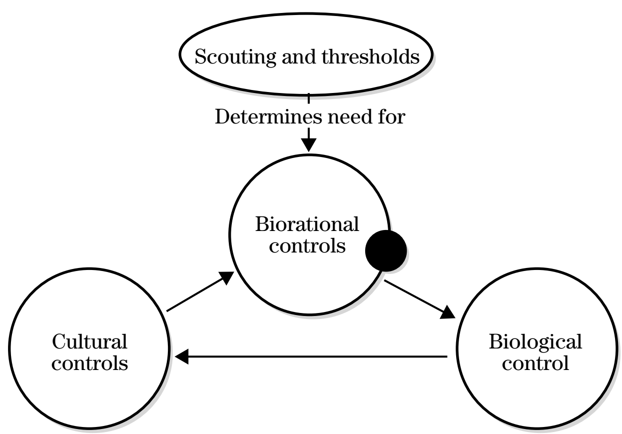
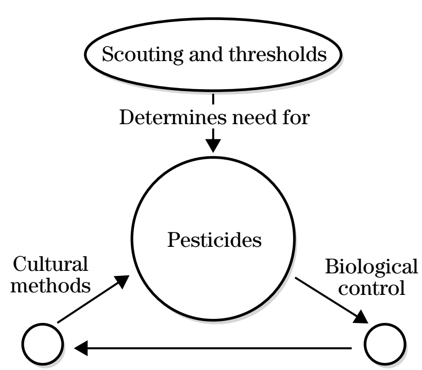


Figure 2–3 Prescriptive IPM



In practice, resistance occurs most frequently in response to pesticide use. Insects were the first group of pests to develop pesticide resistant strains. Worldwide, over 600 species are resistant to at least one insecticide; some are resistant to all the major classes of insecticides. Herbicide-resistant weeds now number more than 100 worldwide and fungicide-resistant plant pathogens have also been observed.

Resurgence is the situation where insecticide application initially reduces an infestation, but soon afterwards the pest rebounds (resurges) to higher levels than before treatment.

Replacement, or secondary pest outbreak, is resurgence of nontarget pests. It occurs when a pesticide is used to control the target pest, but afterwards a formerly insignificant pest replaces the target pest as an economic problem. Figure 2–5 illustrates the treadmill effect of over-reliance on pesticides.

Figure 2–5 Pesticide treadmill where over-reliance on pesticides creates an ever-increasing need to use pesticides

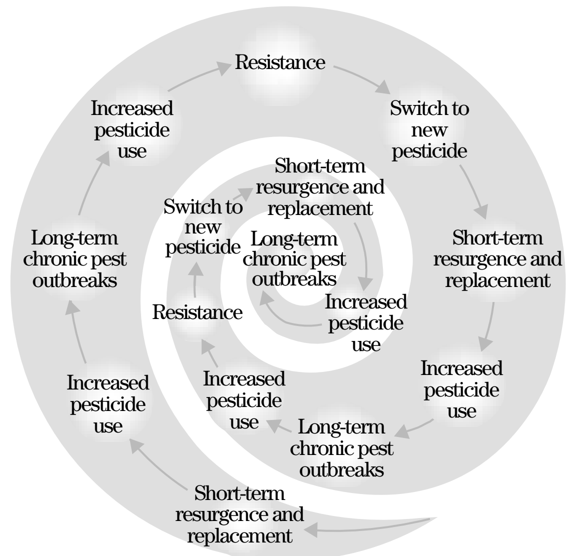
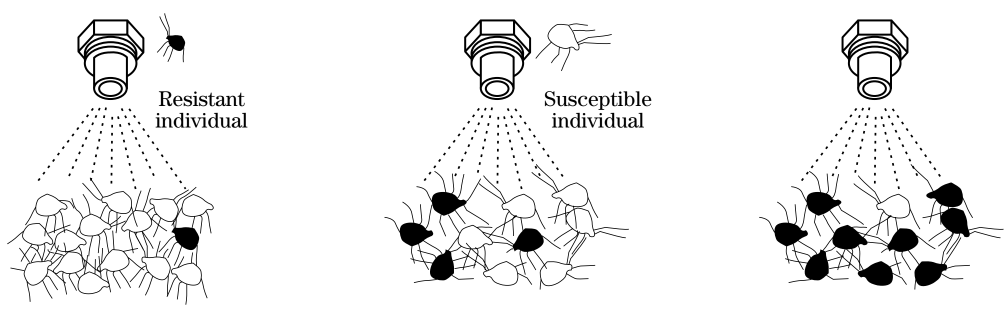


Figure 2–4 Resistance by organisms to pesticides (modified from The Safe and Effective Use of Pesticides, University of California)



Some individuals in a pest population are genetically adapted to survive applications of a pesticide.

Some of the survivors' offspring inherit resistance traits and will survive other applications of the pesticide.

If applications of the same pesticide continue, the pest population consists mostly of resistant individuals.

IPM principles

Principle #1. There is no silver bullet.
Over-reliance on any single control measure can have undesirable effects. This especially has been documented for pesticides where over-reliance can lead to the "3-R's": resistance, resurgence, and replacement. IPM considers all possible control actions, including taking no action at all, and fits tactics together into mutually complementary strategies. The idea is to combine different control tactics into an overall strategy that balances the strengths of each against any individual weaknesses.

Principle #2. Tolerate, do not eradicate.
IPM recognizes that keeping fields entirely pest-free is neither necessary nor desirable—it is not necessary to totally eliminate pests and, in fact, low levels of pest help maintain a preditor population. Because most crops can tolerate low pest infestation levels without any loss in harvestable produce or quality, the presence of a pest does not necessarily mean that you have a pest problem. IPM seeks to reduce pest populations below levels that are economically damaging rather than to totally eliminate infestations.

Principle #3. Treat the causes of pest outbreaks, not the symptoms.
IPM requires detailed understanding of pest biology and ecology so that the cropping system selectively can be manipulated to the pest's disadvantage. The idea is to make the crop less favorable for pest survival and reproduction with as little disturbance to the rest of the ecosystem as possible.

Principle #4. If you kill the natural enemies, you inherit their job.
Naturally occurring predators, parasites, pathogens, antagonists, and competitors (collectively known as biological control agents) help keep many pest populations in check. IPM strives to enhance the impact of beneficials and other natural controls by conserving or augmenting those agents already present.

Principle #5. Pesticides are not a substitute for good farming.
A vigorously growing plant better can defend itself against pests than a weak, stressed plant. IPM takes maximum advantage of farming practices that promote plant health and allow crops to escape or tolerate pest injury. IPM begins from the premise that killing pests is not the objective; protecting the commodity is. Pest status can be reduced by repelling the pest, avoiding the pest, or reducing its rate of colonization or invasion, as well as by directly killing the pest.

Overview of pest management practices

Farmers put IPM philosophy into practice by following these three steps:

Step 1. Use cultural methods, biological controls, and other alternatives to conventional chemical pesticides when practical.

Step 2. Use field scouting, pest forecasting, and economic thresholds to ensure that pesticides are used for real (not perceived) pest problems.

Step 3. Match pesticides with field site features so that the risk of contaminating water is minimized.

Alternatives to pesticides

Cultural methods

Cultural methods are those good farming (or good horticultural) practices that either control pests mechanically or break their infestation cycle by making the living and nonliving environment less suitable for pest survival by:

- Tillage operations that disrupt weeds
- Mowing
- Vacuuming
- Burning
- Reducing the overall favorableness of the habitat (by destroying pest over-wintering sites and other infestation sources both in the crop field and alternate hosts or habitats)
- Altering planting patterns to disrupt or interrupt in time and space the food or other habitat resources required by the pest
- Diverting mobile pests from the crop
- Enhancing the vigor of the crop so that it can better tolerate pest injury

Examples of cultural controls used in IPM programs include:

- Crop rotation
- Tillage operations that turn the soil and bury crop debris
- Altering planting and harvest dates
- Altering seeding rates and crop spacing
- Seedbed preparation, fertilizer application, and irrigation schedules that maintain plant vigor and help plants outgrow pests

- Sanitation practices, such as cleaning tillage and harvesting equipment
- Certified seed that is free of pathogens and weed seed
- Cover crops
- Trap crops
- Pest-resistant varieties that can tolerate pest injury, be less attractive to pests, or control pests by producing chemicals that are toxic to them

Biological controls

Biological controls use living organisms (natural enemies) to suppress populations of other pests. Examples are:

- Predators are free-living animals (most often other insects or arthropods, but also birds, reptiles, and mammals) that eat other animals (the prey).
- Parasitoids are insect (or related arthropods) parasites of other insects (or other arthropods). Most parasitoids are tiny wasps and flies. They differ zoologically from true parasites (fleas, lice, or intestinal tapeworms) primarily in that parasitoids kill their host whereas parasites may weaken, but seldom kill the host.
- Pathogens are disease-causing micro-organisms. including viruses, bacteria, fungi, and nematodes.

Field scouting, pest forecasts, and thresholds

A principle of IPM is that pesticides should be used only when field examination or scouting shows that infestations exceed economic thresholds, guidelines that differentiate economically insignificant infestations from intolerable populations (fig 2–6). Pest scouting generally should be random and representative. In figure 2–6, the IPM scout used an understanding of pest biology to divide a large and variable wheat field into three subsections.

The only time to take control action and apply pesticides is when pest density reaches the economic threshold (ET) value. Pesticide application here keeps infestations from increasing to the breakeven economic injury level (EIL) value. The shaded part of the pest population curve in figure 2–7 shows actual pest density while the dotted curve shows a pest population increase in the absence of control.

Figure 2–6 Pest scouting

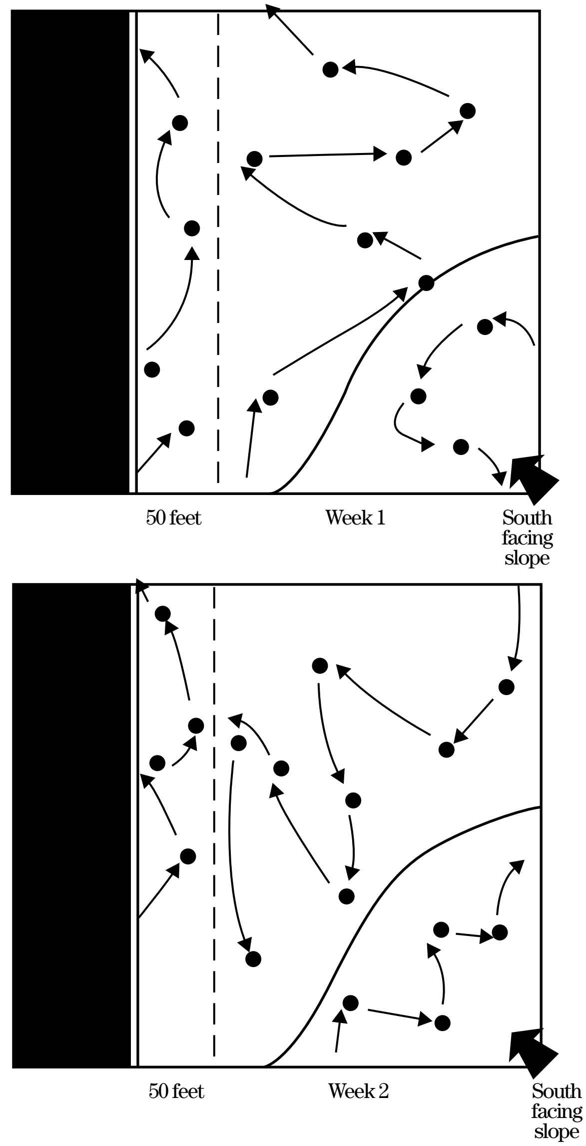
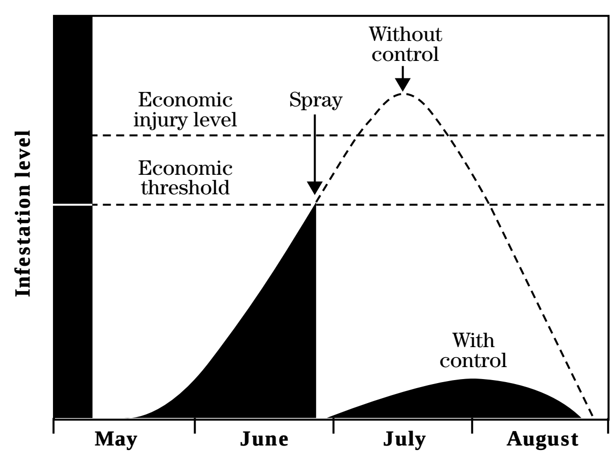


Figure 2–7 Relationship of economic injury level, economic threshold, and seasonal pest population growth



Site-specific pesticide selection

The final component of IPM is selection of pesticides that pose the least risk of leaching through soil or being transported from fields in runoff water and sediment or drifting as spray particles on the wind.

USDA National IPM Initiative

The United States Department of Agriculture, U.S. Environmental Protection Agency, and Food and Drug Administration responded to the President's proposal for reduced pesticide risk by jointly calling for the voluntary goal of implementing IPM methods on 75 percent of U.S. cropland by the year 2000. This voluntary approach to reducing pesticide risks contrasts with mandatory pesticide reduction strategies adopted by several European governments in the early 1990s.

To achieve the 75 perce¸t adoption goal, the USDA announced on December 14, 1994, its National IPM Initiative. The Initiative is based on two premises:

- Involving farmers and other pest control advisors from the beginning in the development of IPM programs will increase the adoption of IPM methods.
- IPM benefits both consumers and farmers. It can reduce environmental and food safety risks from pesticides and increase farmer profitability by ensuring pest controls are used in the most judicious way.

In essence, the National IPM Initiative seeks to develop new IPM tools and then move them to the farm where they can be applied to solving priority pest control problems identified by farmers.

Pesticides

Pesticides are defined as *"any substance used for controlling, preventing, destroying, repelling, or mitigating any pest."* Tables 2–1 and 2–2 show the common pesticide classes and their target pests and functions.

Herbicides, insecticides, and fungicides represent more than 93 percent of the pesticide active ingredient used worldwide. Herbicides typically represent more than 50 percent of pesticide use, followed by insecticides (23 to 35 percent), and fungicides (11 to 14 percent).

Formulations

Most end-use pesticide products are not 100 percent active ingredients. Typically, they are diluted with water, oil, air, or chemically inactive (inert) solids so they can be handled by application equipment and spread evenly over the area to be treated. Because the basic chemical generally cannot be added directly to water or mixed in the field with solids, manufacturers must further modify their products by combining them with other material, such as solvents, wetting agents, stickers, powders, or granules. The final product is called a pesticide formulation and is ready either for use as packaged or after being diluted with water or other carriers. Formulation types are:

WP	wettable powder
S	solutions
F	flowable
G	granules or granular
D	dusts
SP	soluble powder
EC	emulsifiable concentrate

Adjuvants are chemicals that are added to a pesticide formulation or spray mixture to improve performance and/or safety. Most pesticide formulations contain at least a small percentage of one or more adjuvants.

- Wetting agents allow wettable powders to mix with water.
- Emulsifiers allow petroleum-based pesticides (ECs) to mix with water.
- Invert emulsifiers allow water-based pesticides to mix with petroleum carrier.
- Spreaders allow pesticide to form a uniform coating layer over the treated surface.
- Stickers allow pesticide to stay on the treated surface for a longer time without being dislodged.
- Penetrants allow the pesticide to get through the outer surface to the inside of the treated target.
- Foaming agents reduce drift.
- Thickeners reduce drift by increasing droplet size.
- Safeners reduce the toxicity of a pesticide formulation to the pesticide handler or to the treated surface.
- Compatibility agents aid in combining pesticides effectively.
- Buffers allow pesticides to be mixed with diluents or other pesticides of different acidity or alkalinity.
- Antifoaming agents reduce foaming or spray mixtures that require vigorous agitation.

Table 2-1 Common pesticide classes and target pests

Pesticide class	Target pest
Acaricide	Mites
Avicide	Birds (kills or repells)
Bactericide	Bacteria
Fungicide	Fungi
Herbicide	Weeds
Insecticide	Insects
Larvicide	Larvae (usually mosquito)
Miticide	Mites
Nematicide	Nematodes
Ovicide	Eggs
Rodenticide	Rodents

Table 2–2 Pesticide classes and functions

Pesticide class	Function
Attractants	Attract insects
Chemosterilants	Sterilize insect or pest vertebrates
Defoliants	Remove leaves
Desiccants	Speed drying of plants
Growth regulators	Stimulate or retard growth of plants or insects
Pheromones	Attract insects or vertebrates
Repellents	Repel insects, mites and ticks, or pest vertebrates

Chapter 3 Environmental Risks of Pest Management

Chemical control

The environmental risks of pest management using chemical control are:

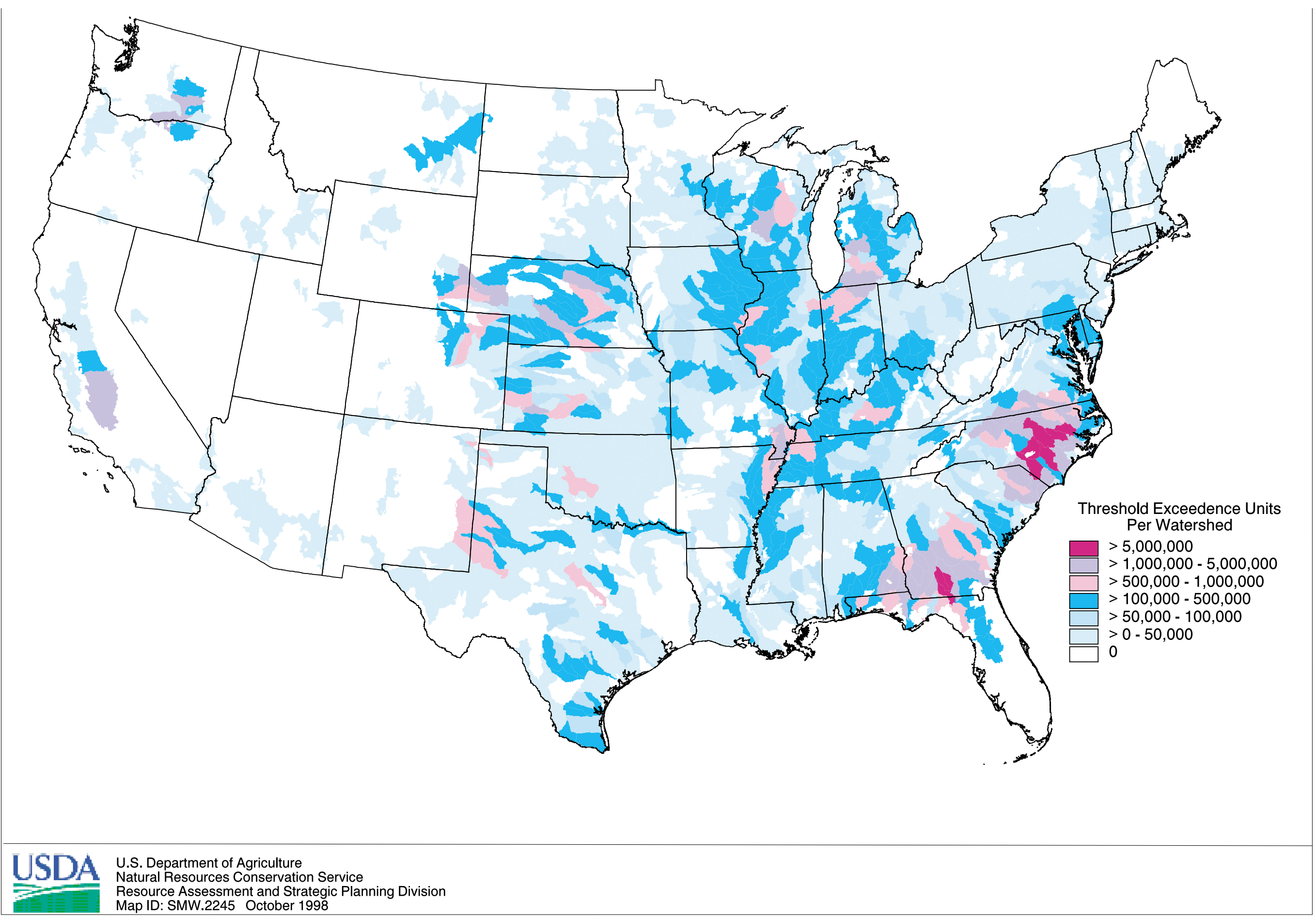
- Risk of pesticides leaving the agricultural management zone (AMZ) in soil, water and air, and negatively impacting nontarget plants, animals, and humans. (The boundaries of the AMZ are the edge of the field, the bottom of the root zone, and the top of the crop canopy.)
- Risk of harming beneficial organisms with pesticide application.
- Risk to personal safety during pesticide application.

Tools are available to help evaluate the potential for pesticides to leave the AMZ and impact nontarget plants, animals, and humans. National assessments can be used for strategic planning purposes. Figures 3–1 and 3–2 show national pesticide leaching and runoff indexes. The full text describing these maps can be viewed at http://www.nhq.nrcs.usda.gov/land/pubs/gosstext.html. The following is an excerpt from that text:

National Modeling

The National Pesticide Loss Database was used with the National Resources Inventory (NRI) to simulate pesticide loss by watershed for use in identifying potential priority watersheds for implementation of conservation programs.

Figure 3–1 Potential for concentration of pesticide leaching below the root zone to exceed water quality thresholds for humans (map can be viewed at http://www.nhq.nrcs.usda.gov/land/pus/gosstext.html as Map 6)



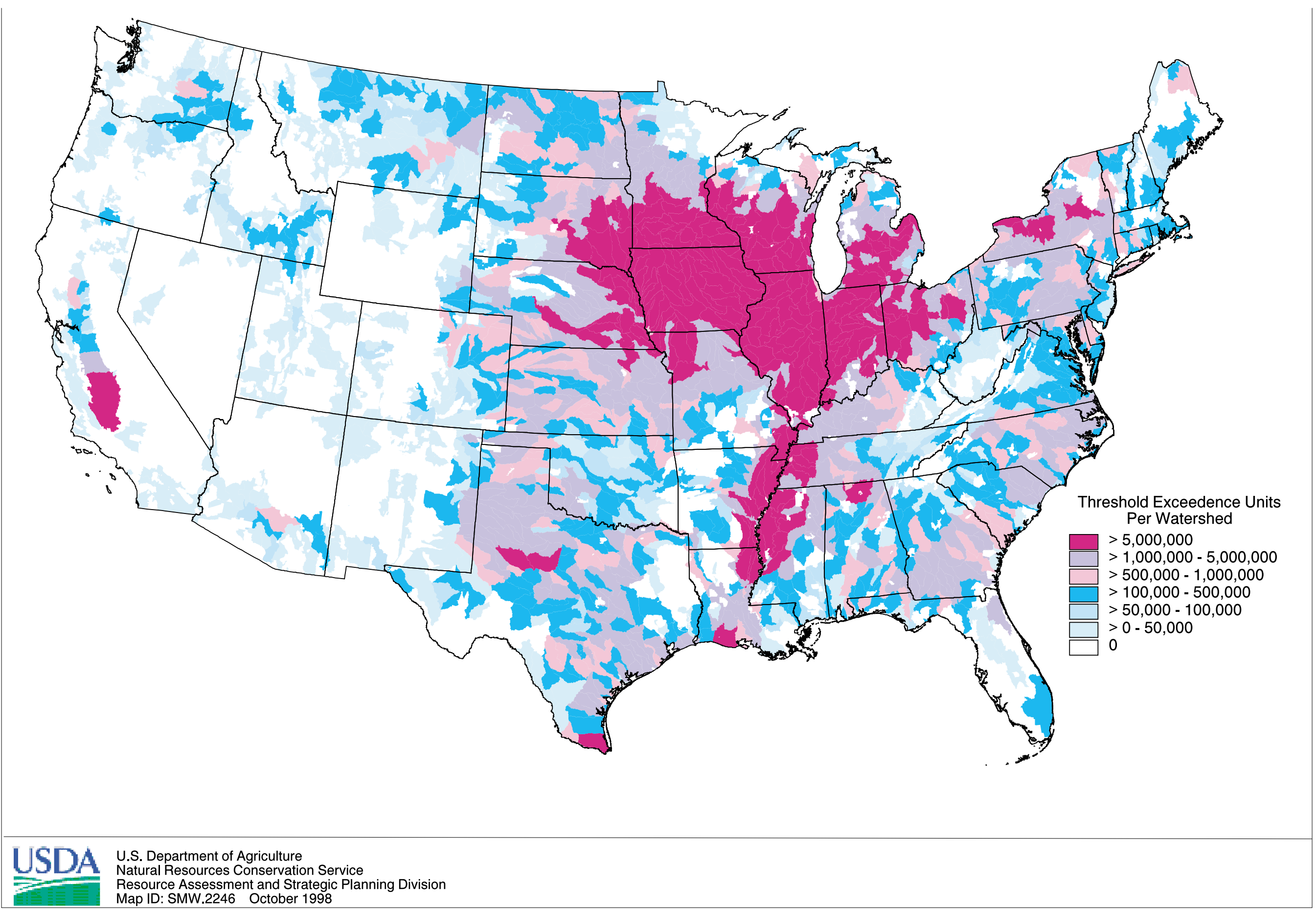
The NRI was used as a modeling framework and as a source of land use data and soil data. Each NRI sample point was treated as a representative field in the simulation model. The simulation was conducted using 13 crops-barley, corn, cotton, oats, peanuts, potatoes, rice, sorghum, soybeans, sugar beets, sunflowers, tobacco, and wheat-which comprise about 170,000 NRI sample points. The statistical weights associated with the NRI sample points are used as a measure of how many acres each representative field represents. Land use for the most recent inventory-1992-was used.

Pesticide use data were taken from Gianessi and Anderson, who estimated the average application rate and the percentage of acres treated by state for over 200 pesticides and for 84 crops for the time period 1990-93. Estimates of percent acres treated and application rate were imputed onto NRI sample points by state and crop. Map 2 was created by multiplying the percent acres treated times the acres represented by each point to obtain the acres treated for each pesticide, and then multiplying by the application rate and summing over the pesticides at each NRI sample point to obtain the total pounds of pesticides applied. These results were aggregated over NRI sample points in each 8-digit hydrologic unit in the 48 states.

Estimates of pesticide loss from the National Pesticide Loss Database were imputed onto the 170,000 sample points according to soil type, geographic location, and pesticide. Mass loss and annual concentration were calculated for each pesticide at each sample point. Mass loss estimates were then aggregated over acres treated in each watershed to produce national maps.

Concentrations were compared to water quality thresholds to derive a measure of environmental risk at each NRI sample point. Health Advisories (HAs) and Maximum Contaminant Levels (MCLs) were used for humans for pesticides that have been assigned drinking water standards by EPA. For other pesticides,

Figure 3–2 Potential for concentration of pesticide runoff at the edge of the field to exceed water quality thresholds for humans (map can be viewed at http://www.nhq.nrcs.usda.gov/land/pus/gosstext.html as Map 14)



"safe" thresholds were estimated from EPA Reference Dose values and cancer slope data. Maximum Acceptable Toxicant Concentrations (MATCs) were used as "safe" thresholds for fish, which were calculated using toxicity data published by EPA.

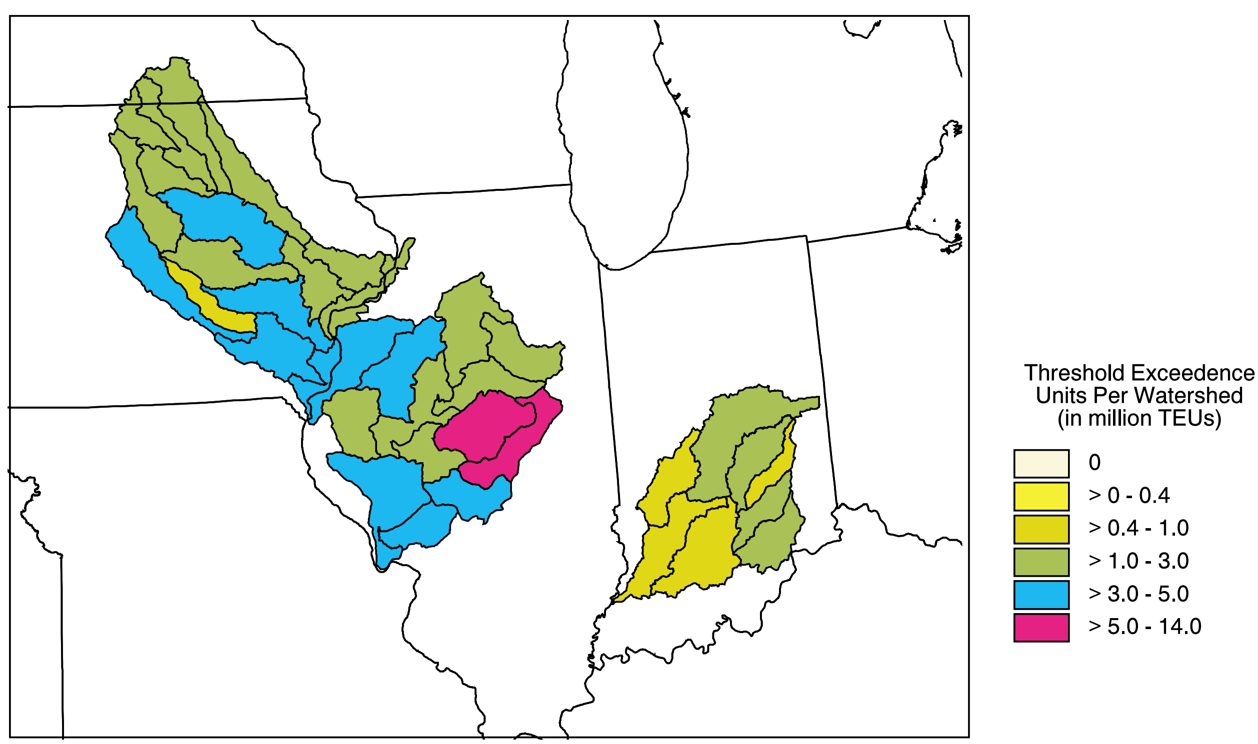
The extent to which the concentration exceeded the threshold was used as a measure of risk for each pesticide. This risk measure was aggregated over the pesticides at each point and then multiplied by the number of acres treated and summed over the points in each watershed to obtain an aggregate risk measure for each watershed—Threshold Exceedence Units (TEUs) per watershed. TEUs are similar in concept to the acre-feet volumetric measure, since they are a multiple of acres times a measure of magnitude at a point. They are used here only to measure relative risk from one watershed to another; the higher the TEU score, the higher the risk.]

Watershed level analysis (fig. 3–3) can be used to address specific water quality concerns and show the potential for management solutions to protect natural resources.

Field scale tools can be used to address identified resource concerns in targeted areas. The Windows Pesticide Screening Tool (WIN-PST) can help field office personnel evaluate the potential for offsite pesticide movement on a field-by-field basis. It is based on the NRCS Soil/Pesticide Interaction Screening Procedure (SPISP II) and National Agricultural Pesticide Risk Analysis (NAPRA) generic scenario results. The tool is illustrated in figures 3–4, 3–5, 3–6, 3–7, and 3–8.

Soil/pesticide interaction ratings for all applicable soils and pesticides provide a means to evaluate the potential environmental risks associated with all recommended alternatives. Appropriate mitigation strategies should be matched with alternatives that have substantial environmental risk(s).

Figure 3–3 National Agricultural Pesticide Risk Analysis (NAPRA) at the watershed level using the Natural Resources Inventory and the National Agriculture Statistics Service Cropping Practices Survey—Envirnomental risk in runoff for humans: 1991 – 1992 baseline



USDA
U.S. Department of Agriculture
Natural Resources Conservation Service
Resource Assessment and Strategic Planning Division
Map ID: SMW.3779 July 1998

Figure 3–4 WIN-PST soil properties and ratings

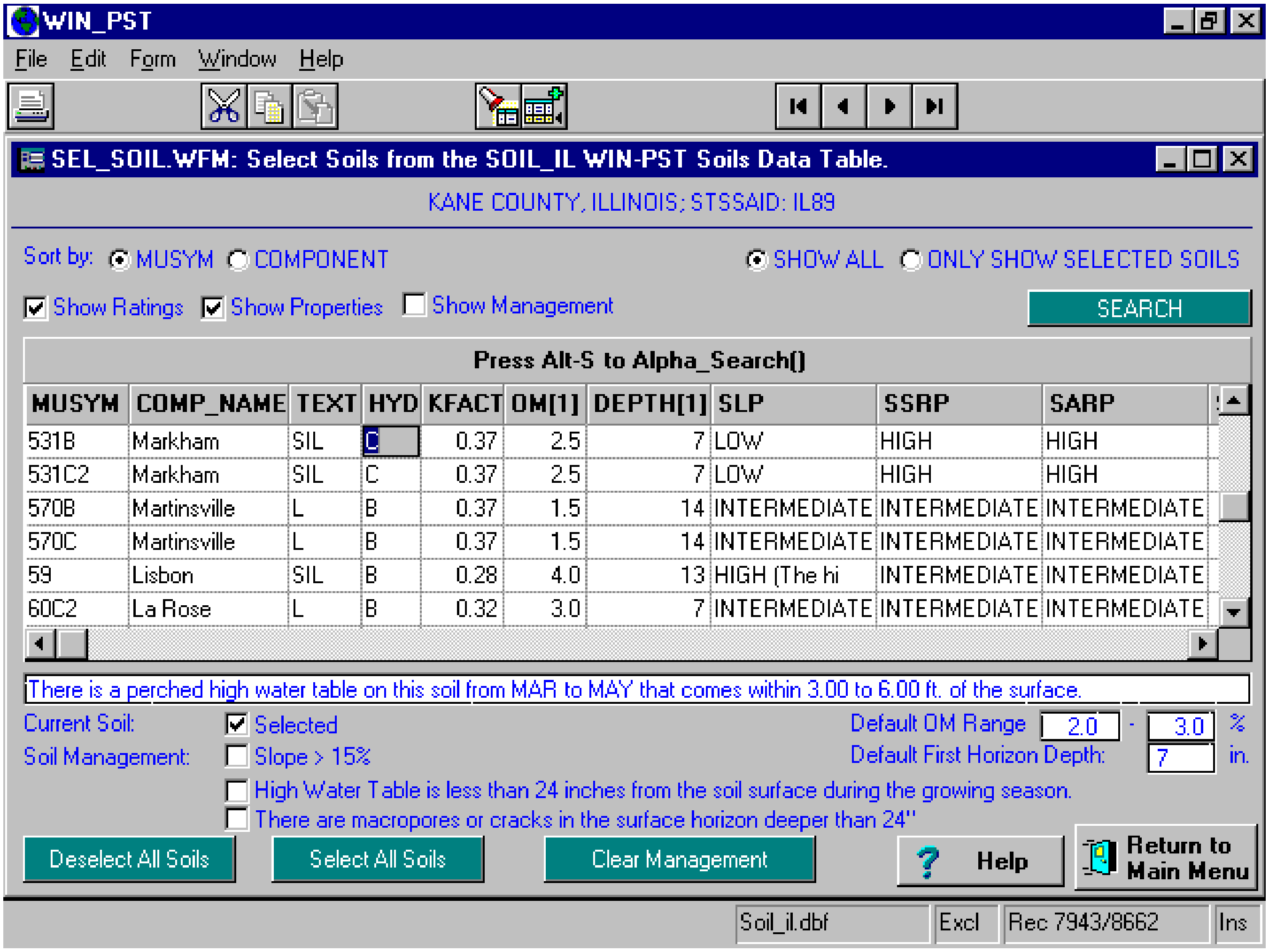


Figure 3–5 WIN-PST pesticide properties and ratings

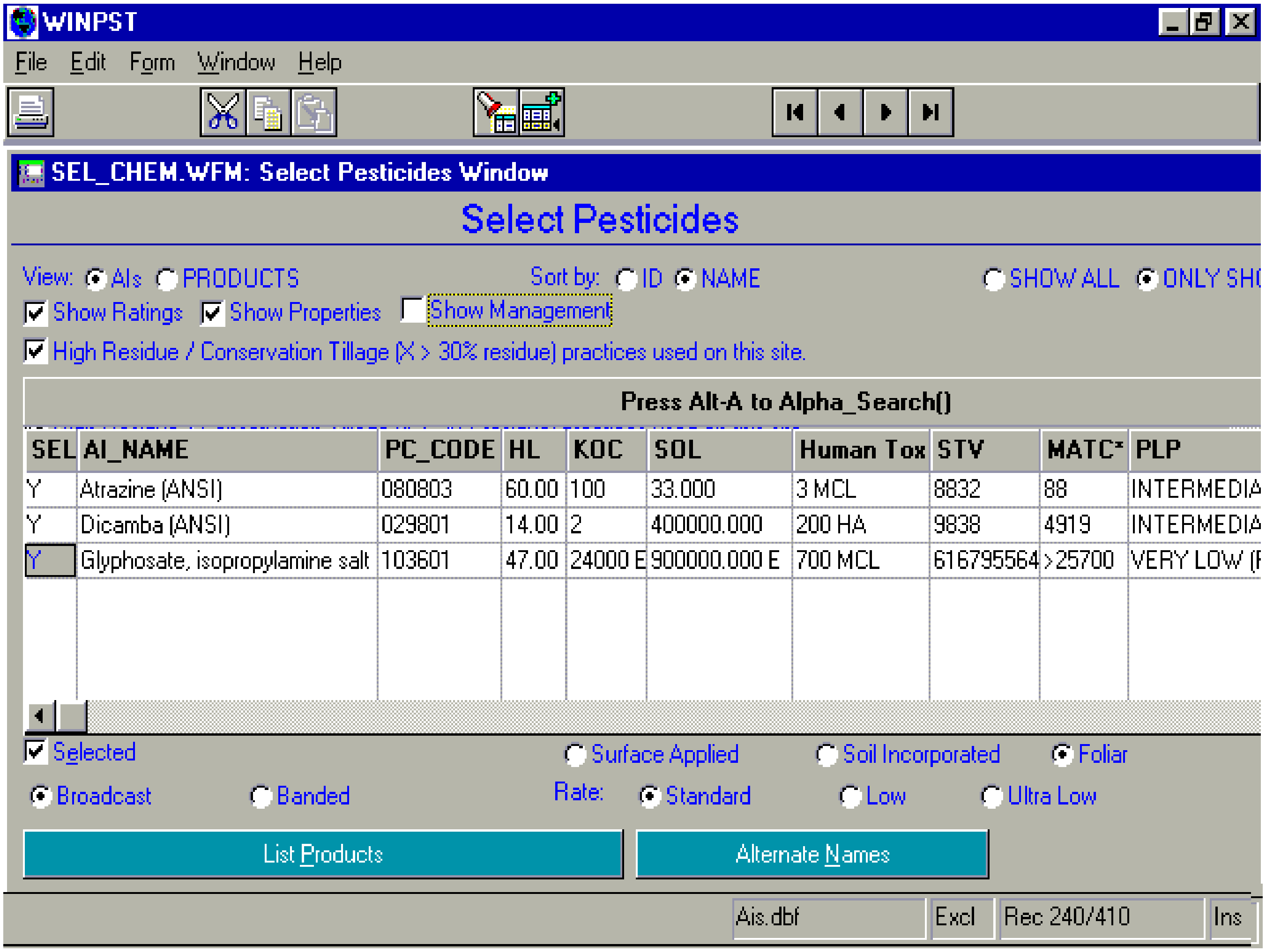


Figure 3–6 WIN-PST soil/pesticide interaction ratings

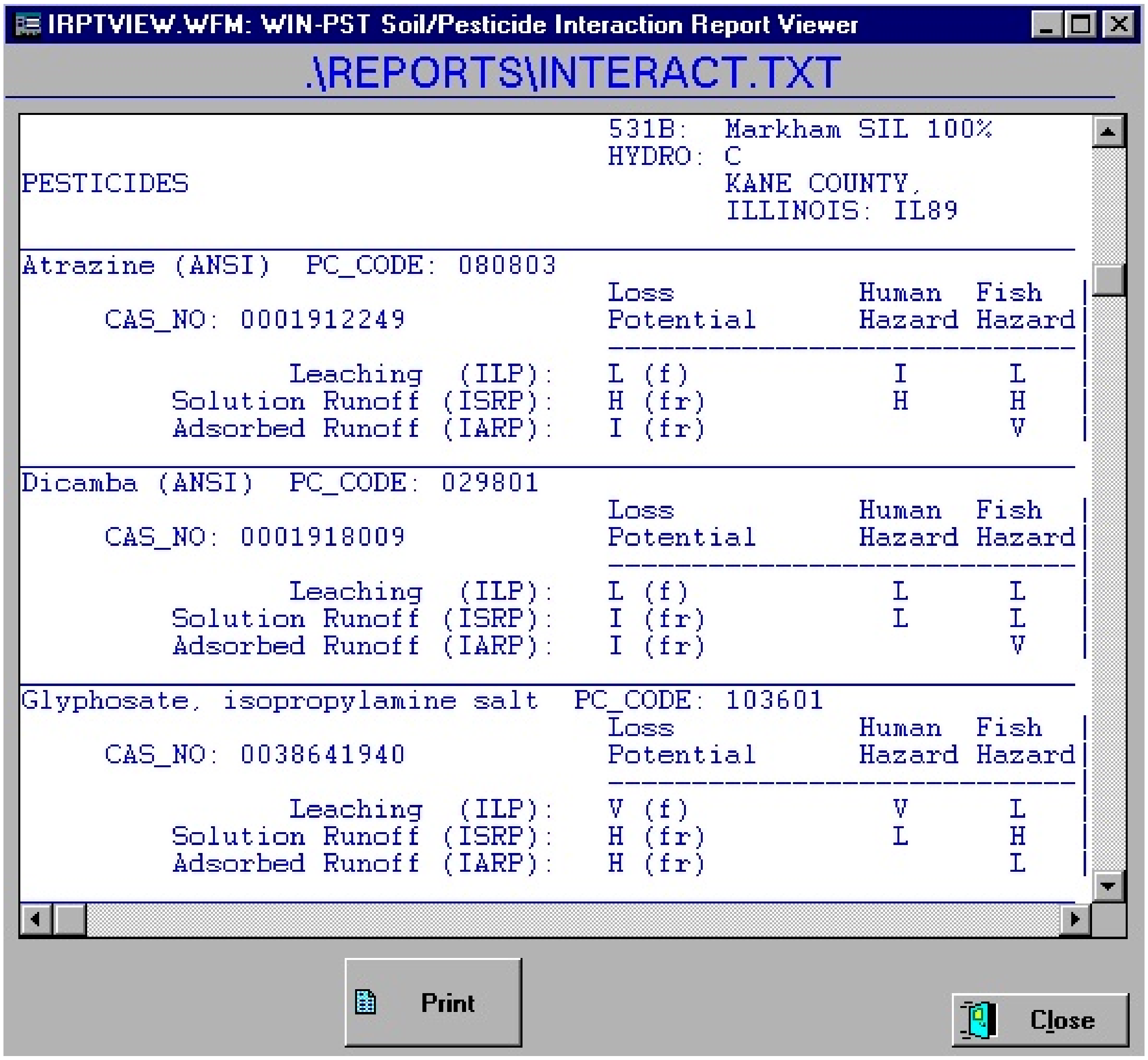
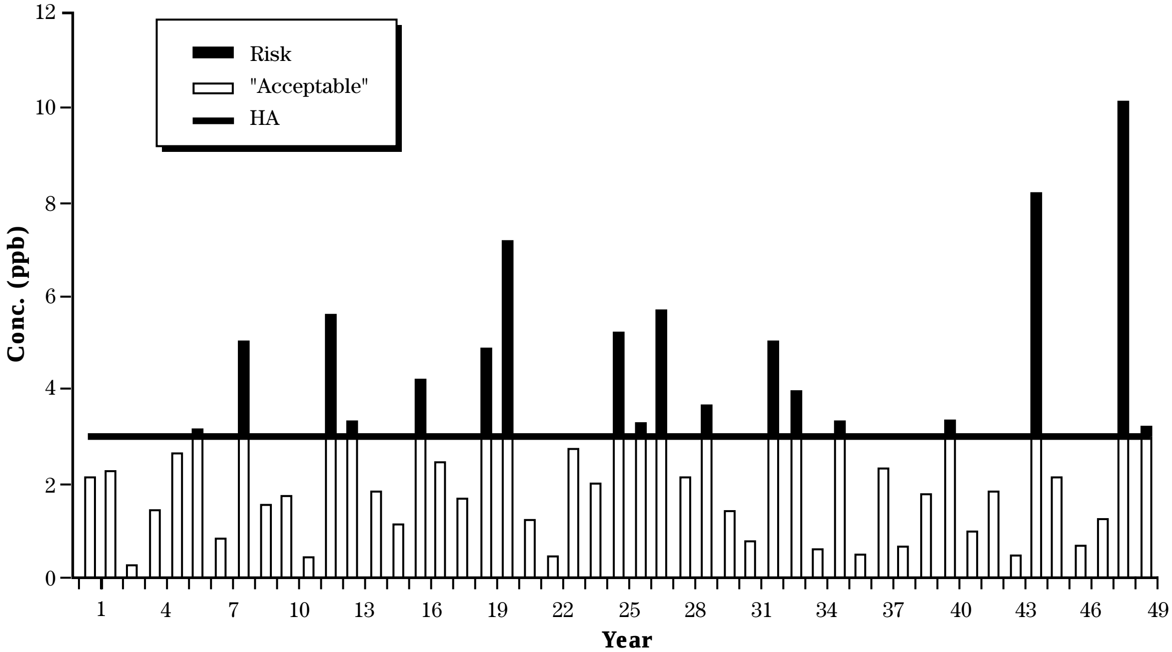
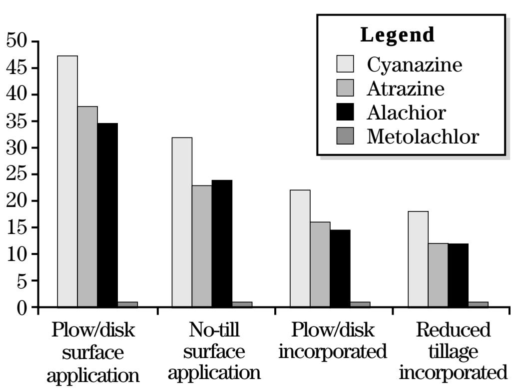


Figure 3–7 Variations in annual pesticide losses and cumulative National Agricultural Pesticide Risk Analysis (NAPRA) risk*



* NAPRA defines risk as a pesticide loss from the field that exceeds a toxicity threshold, such as the human drinking water Health Advisory (HA). Losses can vary greatly from year to year based on the climate, so NAPRA represents the risk associated with a given set of management options as a cumulative risk over time (in this case the sum of the risk over 49 years).

Figure 3–8 Using cumulative NAPRA risk to evaluate management alternatives*



* NAPRA characterizes risk variation associated with different pesticides and different management alternatives.

Chapter 4 Pesticides in the Environment

(The information in Chapter 4, Pesticides in the Environment, is adapted from Module 2 of Nutrient and Pest Management Considerations in a Conservation Management System Plan, NRCS National Employee Development Center self-paced study course, 1999.)

Introduction

Over 1.20 billion pounds of pesticide active ingredients are used annually in the United States in agriculture, forestry, rights-of-way, and by homeowners.

The Federal Insecticide Fungicide and Rodenticide Act (FIFRA) is the primary legislation regulating pesticides in the United States. The Environmental Protection Agency is responsible for the administration of this body of laws. These laws address the registration of pesticide products, prescribing conditions for pesticide use, establishing maximum acceptable levels of pesticide residue in foods, labeling requirements, and other aspects of pesticide regulation.

The 1996 Food Quality Protection Act (FQPA) made substantial amendments to FIFRA. Changes include requiring EPA to:

- Consider all nonoccupational exposure pathways when establishing tolerances.
- Screen pesticides for endocrine disruption.
- Consider cumulative risks of pesticides that have common mechanisms of toxicity.
- Consider risks to infants and children when setting tolerances.
- Expedite approval of "reduced risk" pesticides.
- Report annually to Congress on progress of the pesticide re-registration program.

Pesticide risk analysis

Pesticide registrations and label use restrictions are both based on risk analysis and determining if the benefits of a proposed pesticide use outweigh the potential risks. A *risk assessment* is a detailed risk analysis that includes essentially all potential risks to all species that may be impacted by a particular pesticide use. NRCS pesticide risk analysis is a subset of a full risk assessment. NRCS focuses on pesticide environmental risk screening tools and the data used to identify sensitive pesticide/soil combinations that need mitigation to adequately protect the natural resource base.

The major components of pesticide risk analysis are:

- Determining the potential for exposure to the pesticide
  - — Point source exposure
    - ◊ Mixing/loading
    - ◊ Accidental spills
    - ◊ Container disposal
  - — Nonpoint source exposure
    - ◊ Field leachate in water
    - ◊ Field runoff in water
    - ◊ Field runoff in sediment
    - ◊ Field volatization in air
- Determining the toxicological hazard posed by the pesticide
- Characterizing risk by combining pesticide exposure and toxicity]

Environmental fate: understanding pesticide persistence and mobility in soil

Many factors govern the potential for pesticide contamination of ground water or surface water. These factors include soil properties, pesticide properties, hydraulic loading on the soil, and crop management practices.

Fate processes for a pesticide (fig. 4–1) can be grouped into those that affect persistence, (photodegradation, chemical degradation, and microbial degradation) and those that affect mobility (sorption, plant uptake, volatilization, wind erosion, runoff, and leaching) Figure 4–2 illustrates these groupings. Pesticide persistence and mobility are influenced by properties of the pesticide, soil properties, site conditions, weather, and management factors, such as pesticide application method. Some of the most important properties of a pesticide that can be used to predict environmental fate include half-life, soil sorption coefficient, water solubility, and vapor pressure.

Figure 4–1 Pesticide fate processes

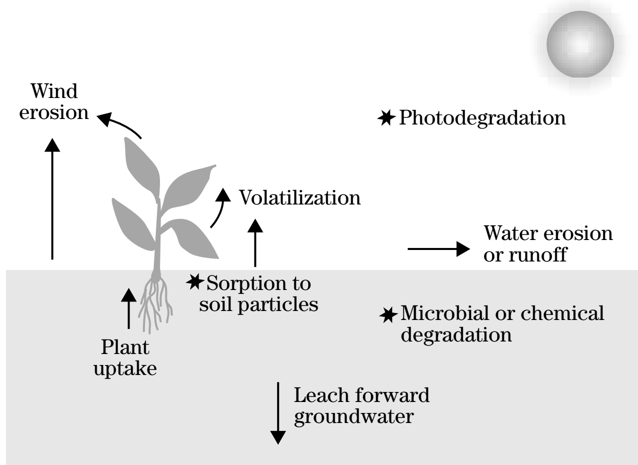


Figure 4–2 Factors affecting pesticide in soil

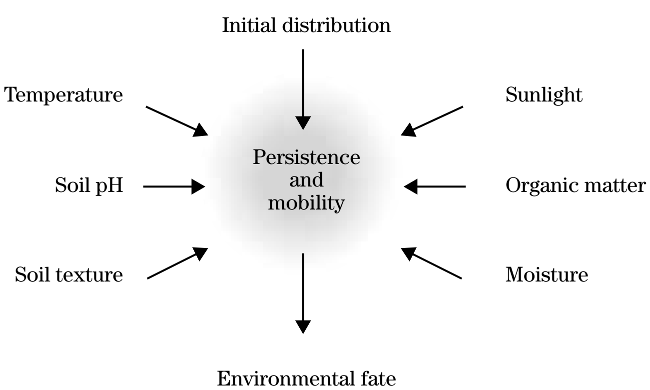
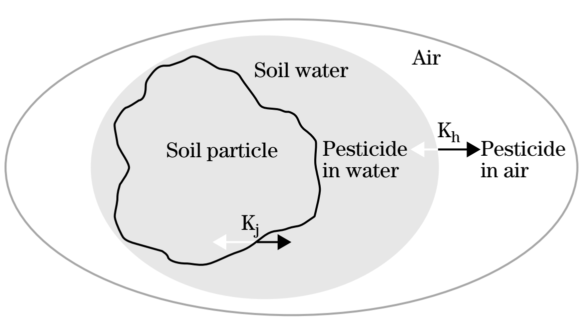


Figure 4–3 Distribution coefficient (K_d) and Henry's Law Constant (K_h)



Pesticide persistence is often expressed in terms of field half-life. This is the length of time required for half of the original quantity to break down or dissipate from the field. The half-life values in table 4–1 represent typical field half-live values. Persistence can vary greatly from one site to the next.

Pesticide mobility may result in redistribution within the application site or movement of some amount of pesticide offsite. After application, a pesticide may:

- Dissolve in water and be taken up by plants, move in runoff, or leach
- Volatilize or erode from foliage or soil with wind and become airborne
- Attach (sorb) to soil organic matter and soil particles and either remain near the site of deposition or move with eroded soil in runoff or wind

Pesticide sorption, water solubility, and vapor pressure affect mobility. Mobility is also influenced by environmental and site characteristics including weather, topography, canopy and ground cover, and soil organic matter, texture, and structure.

Sorption is determined by the chemical characteristics of the pesticide. The specific mechanisms for the sorbing of a chemical to the soil are not easily defined. Numerous mechanisms may operate in a particular situation, including strong or weak ionic attraction, hydrophobic attraction, and hydrogen-bonding. Sorption of pesticides that are weak acids or bases is also influenced by the pH of the soil.

The sorption of a particular pesticide to a soil is measured in a laboratory by mixing water, pesticide, and soil. After equilibrium has been reached, the amount of pesticide remaining in solution is measured. The concentration of pesticide sorbed to the soil in the mixture is divided by the pesticide concentration still in solution. This yields the distribution coefficient, K_d (fig. 4–3). A low distribution coefficient indicates that more of the pesticide is in solution; a higher value indicates that more of the pesticide is sorbed to soil.

K_{oc} is the distribution coefficient K_d normalized for the amount of organic carbon that is in the tested soil (K_d/ percent organic carbon). Soil organic carbon is directly proportional to soil organic matter, which is primarily responsible for a soil's sorption properties.

Pesticide movement pathways

A pesticide in solution can move across cell membranes and be taken up by plants. The amount of uptake is partly determined by the pesticide's water solubility. Adjuvants (additives) can enhance plant uptake of pesticides. Plant uptake of pesticide helps prevent runoff and leaching.

Pesticides may also volatilize or be blown away by the wind (erode). Volatilization from foliage is determined by the pesticide's vapor pressure, which is affected by temperature. Vapor pressure is the pressure exerted by a vapor when it is in equilibrium with the liquid from which it is derived. Pesticides with a high vapor pressure tend to volatilize. Those with a low vapor pressure are less likely to volatilize. The higher the temperature, the greater the volatilization.

Volatilization from moist soil is determined by moisture content of the soil and by the pesticide's vapor pressure (table 4–2), sorption, and water solubility. Because water competes for binding sites, pesticide volatilization is greatest in wet soils.

Airborne pesticide residue is subject to a variety of degradation processes including photodegradation, oxidation, and hydrolysis. The residue is often rapidly degraded in the atmosphere. However, stable airborne pesticide residue and its degradation products may move from the application site and be deposited in dew, rainfall, or dust. This may result in pesticide redistribution within the application site or movement of pesticide offsite. The offsite airborne movement of a pesticide is known as drift. Drift can be harmful to both human and environmental health and may damage nearby crops. It is important to consider the weather conditions and the environmental behavior of pesticides to minimize drift.

Runoff is the movement of water over a sloping surface. Runoff can carry pesticides dissolved in water and pesticides sorbed to sediment. If heavy irrigation or rainfall shortly after application induces runoff, pesticide can be moved offsite. Heavy rainfall or overhead irrigation soon after application may also dislodge pesticide residue on foliage, adding to runoff losses. With time, residue on foliage is less likely to be washed off as it becomes incorporated in surface waxes.

Leaching is the removal of soluble materials by water passing downward through the soil. Ground water contamination occurs when pesticides move with

Table 4–2 Pesticide vapor pressure and potential for volatile loss

Vapor pressure	Potential for volatile loss
Greater than 1.0 x 10^{-4}	High
1.0 x 10^{-4} to 1.0 x 10^{-7}	Medium
Less than 1.0 x 10^{-7}	Low

Table 4–1 Pesticide environmental fate properties and NRCS soil/pesticide interaction screening procedure (SPISP II) pesticide ratings

Pesticide	Field 1/2 life (days)	K_{oc}	Solubility in water (mg/L)	Vapor pressure (mm Hg)	Pesticide leaching potential*	Pesticide solution runoff potential*	Pesticide adsorbed runoff potential*
Malathion	1	1,800	130	8.0 x 10^{-6}	Low	Low	Low
1,3 Dichloropropene	10	32	2,250	29	Intermediate	Intermediate	Low
Dicamba salt 1/	14	2	400,000	0	High	Intermediate	Low
Benomyl	67	1,900	2	<1 x 10^{-10}	Low	High	High
Diuron	90	480	42	6.9 x 10^{-8}	Intermediate	High	Intermediate
Bensulide	120	1,000	5.6	8.0 x 10^{-7}	Intermediate	High	High
Prometon 1/	500	150	720	7.7 x10^{-6}	High	High	Intermediate

1/ Dicamba is a weak acid; Prometon is a weak base; therefore, sorption and solubility are affected by soil pH.

infiltrating water through the soil profile to the water table. The closer the water table is to the surface, the greater the likelihood that it may become contaminated. Soil permeability also plays a key role in determining the likelihood of a pesticide to leach into ground water.

Pesticide trapping with conservation buffers

Pesticides vary in how tightly they are sorbed (adsorbed and/or absorbed) to soil particles. Degree of soil binding is measured by binding coefficients or **K** values. K_{oc} is a type of **K** value that is normalized for organic carbon content. K_{oc} is a measure of sorption to the organic matter and clay fractions of soil, with higher K_{oc} values indicating tighter binding. K_{oc} values can be used to predict whether a specific pesticide will be carried primarily with organic matter and clay in runoff sediment or dissolved in runoff water. K_{oc} values greater than 1,000 indicate that pesticides are very strongly adsorbed to soil. Eroded soil carries the majority of this kind of chemical leaving fields in runoff. Thus, if conservation buffers are effective in trapping sediment, they will be effective in trapping this type of pesticide.

Pesticides with lower K_{oc} values (less than 300 to 500) tend to move moredissolved in runoff water than sorbed to runoff sediment. Concentrations carried on sediment are higher than concentrations in water, but because water quantities running off fields are so much greater than eroded soil quantities, water accounts for the majority of this type of chemical leaving fields. To be effective in trapping this type of pesticide, buffers need to increase water infiltration or maximize contact of runoff with vegetation that may sorb pesticide.

Sensitivity and vulnerability of ground and surface water

Sensitivity refers to intrinsic physical and biological characteristics of a particular site that make it more or less susceptible to potential ground or surface water contamination. Sensitivity parameters include climate, soil characteristics (table 4–3), and distance to waterbodies.

Vulnerability refers to extrinsic management factors that could make a sensitive site more or less susceptible to ground or surface water contamination. Vulnerability parameters include cropping practices, tillage practices, pest management practices (including pesticide use practices), and irrigation practices,

Sensitive sites can be carefully managed to reduce ground and surface water vulnerability.

Table 4–3 Windows pesticide screening tool soil leaching and runoff sensitivity

Component	Texture	Hyd	K factor	Depth	% OM	SLP	SSRP	SARP
Markham	sil	C	0.37	7"	2.5%	L	H	H
Ayr	sl	B	0.17	8"	1.5%	H	I	I
Sparta	ls	A	0.17	8"	1.5%	H	L	L

Legend:

Hyd—The hydrologic group assigned to this soil
K factor—Soil erodability factor
Depth—Depth of the first soil layer
% OM—Percent organic matter in the first horizon
SLP—Soil Leaching Potential
SSRP—Soil Solution Runoff Potential
SARP—Soil Adsorbed Runoff Potential
H—High
I—Intermediate
L—Low

Pesticide toxicity: "The dose makes the poison"

One of the more commonly used measures of toxicity is the LD50. The LD50 (lethal dose for 50 percent of the animals tested) of a poison is generally expressed in milligrams of chemical per kilogram of body weight (mg/kg). A chemical with a small LD50 is highly toxic. A chemical that has a large LD50 is unlikely to have lethal effects, but may still produce illness. Table 4–4 shows exposure measurement.

LC50 (lethal concentration for 50 percent of the animals tested) is often used for toxicity to aquatic species.

LD50 and LC50 vary by species and exposure pathway (for example, oral versus dermal), so comparable studies must be used to evaluate one pesticide versus another.

MATC (maximum acceptable toxicant concentration) is a long-term acceptable toxicity for fish. An MATC can be determined empirically by performing lifetime or long-term toxicity tests for fish. Alternatively, MATC's can be estimated from LC50s.

Toxicity assessment is complex because environmental stress factors (temperature, food, and light) and species diversity (age, sex, health, and hormonal status) can cause results to vary widely (table 4–5).

Table 4–4 Common exposure measurements

Dose	Abbreviation	Metric equivalent	Abbreviation	Approximate amount in water
Parts per million	ppm	Milligrams per kilogram or milligrams per liter water	mg/kg mg/L	1 teaspoon per 1,000 gallons
Parts per billion	ppb	Micrograms per kilogram or micrograms per liter water	µg/kg µg/L	1 teaspoon per 1,000,000 gallons

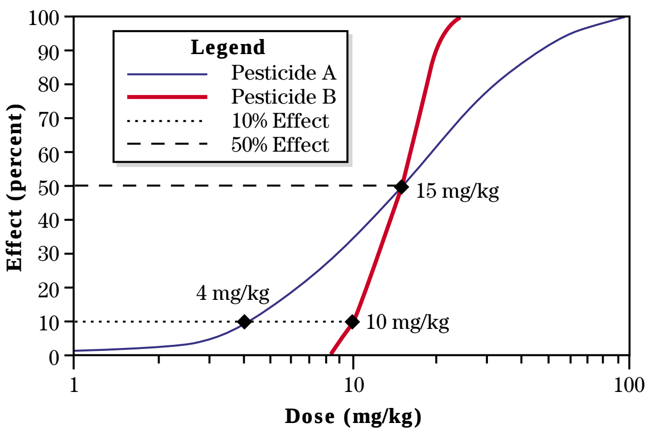
Table 4–5 Toxicity rating scale and labeling requirement for pesticides 1/

Category	Signal word required on label	Characteristic acute toxicity in experimental animal LD50 and LC50	Skin/eye irritation	Probable oral lethal dose
I. Highly toxic	DANGER-POISON	Oral: 0–50 mg/kg Dermal: 0–200 mg/kg Inhalation: 0–0.2 mg/L	Severe	A few drops to a teaspoon
II. Moderately toxic	WARNING	Oral: >50–500 mg/kg Dermal: >200–2,000 mg/kg Inhalation: >0.2–2.0 mg/L	Moderate	More than 1 teaspoon to 1 ounce
III. Slightly toxic	CAUTION	Oral: >500–5,000 mg/kg Dermal: >2,000–20,000 mg/kg Inhalation: >2.0–20 mg/L	Slight	More than 1 ounce
IV. Practically nontoxic	None required	Oral: >5,000 mg/kg Dermal: >20,000 mg/kg Inhalation: >20 mg/L	None	

1/ Source: 40 CFR 156.10 (1994)

Comparing acute toxic effects based on LD50s or LC50s alone is an oversimplified approach in that the LD50s or LC50s are only one point on the dose-response curve that reflects the potential of the compound to cause death. What is more important in assessing chemical safety is the threshold dose and the slope of the dose-response curve, which shows how fast the response increases as the dose increases. Figure 4–4 provides examples of dose-response curves for two chemicals that have the same LD50.

Figure 4–4 Dose response of two chemicals with the same LD50



Note: Although pesticide A and pesticide B have the same LD50, their dose/response curves are quite different. Pesticide A has toxic effects at much lower doses than pesticide B, but once pesticide B reaches a toxic dose, its toxic effects increase much more quickly than pesticide B as the dose is increased.

A true assessment of a chemical's toxicity involves comparisons of numerous acute and long-term dose-response curves covering many types of toxic effects. The determination of which pesticides will be restricted use pesticides uses this approach. Some restricted use pesticides have large LD50s (low acute oral toxicity); however, they may be strong skin or eye irritants that require special handling.

The knowledge gained from dose-response studies in animals is used to set standards for human exposure and the amount of chemical residue that is allowed in the environment. As mentioned previously, numerous dose-response relationships must be determined in many different species. Without this information, the health risks associated with chemical exposure are impossible to accurately predict. Adequate information helps to make informed decisions about chemical exposure so that the risk to human health and the environment is minimized.

Manifestations of toxic effects

Most nonlethal toxic effects are reversible and do not cause permanent damage, but complete recovery may take a long time. However, some poisons cause irreversible (permanent) damage. Poisons can affect just one particular organ system, or they may produce generalized toxicity by affecting a number of systems. The type of toxicity is generally subdivided into categories based on the major organ systems affected. Some of these are listed in table 4–6.

Table 4–6 General toxicity categories

Category	System affected	Common symptoms
Respiratory	Nose, trachea, lungs	Irritation, coughing, choking, tight chest
Gastrointestinal	Stomach, intestines	Nausea, vomiting, diarrhea
Renal	Kidney	Back pain, urinating more or less than usual
Neurological	Brain, spinal cord, behavior	Headache, dizziness, confusion, depression, coma, convulsions
Hematological	Blood	Anemia (tiredness, weakness)
Dermatological	Skin, eyes	Rashes, itching, redness, swelling
Reproductive	Ovaries, testes, fetus	Infertility, miscarriage

Although natural and synthetic chemicals may cause a variety of toxic effects at high enough doses, the effect that is of most concern in the United States is cancer. This is not surprising considering the high incidence of this disease, its often-fatal outcome, and the overall cost to society. To decide on the risk that a particular carcinogen poses, it is important to determine how much of the chemical will cause how many cases of cancer in a specified population. This value can then be compared to what is considered an acceptable risk. Currently, the commonly accepted increase in risk of cancer is one additional cancer in one million people.

Acceptable carcinogen exposure levels (set by EPA) generally represent what is called the "worst case" exposure. An assumption made in the calculation of worst-case exposure levels is that humans will be exposed to the same concentration of the chemical every day of their lives for 70 years. As a result, the published acceptable risk level does not necessarily represent the "safe level," but rather a target level with the expectation that the true risk to exposure is less than the published value. The exposure criteria are guidelines for the protection of sensitive elements of the population and are calculated with many factors of uncertainty (the relationship of animal toxicity to human toxicity, for instance).

Cholinesterase (ko-li-nes-ter-ace) is one of many important enzymes needed for the proper functioning of the nervous systems of humans, other vertebrates, and insects. Certain chemical classes of pesticides, such as organophosphates (OPs), carbamates, and chlorinated derivatives of nicotine (imidacloprid), work against undesirable bugs by interfering with or inhibiting cholinesterase. While the effects of cholinesterase-inhibiting products are intended for insect pests, these chemicals can also be poisonous or toxic to humans in some situations.

Organophosphate insecticides include some of the most toxic pesticides. They can enter the human body through skin absorption, inhalation, and ingestion. They can affect cholinesterase activity in red blood cells and in blood plasma and can act directly, or in combination with other enzymes, on cholinesterase in the body.

Carbamates are similar to organophosphates in that they vary widely in toxicity and work by inhibiting plasma cholinesterase.

Imidacloprid is a recently introduced synthetic insecticide that is similar to nicotine. It mimics the action of acetocholine by binding to the postsynaptic nicotinic receptor. However, nicotine and imidacloprid are insensitive to the action of acetocholinesterase and, therefore, bind persistently to the receptor that leads to nerve overstimulation. This results in hyperexcitation, convulsions, paralysis, and death. Because the nicotinergic neuronal pathway is more abundant in insects, these compounds are selectively more toxic to insects than mammals.

Overexposure to organophosphate and carbamate insecticides can result in low blood pressure, slow heartbeat, breathing difficulty, and possibly death if not promptly treated by a physician.

EPA defines endocrine disrupters as compounds that "interfere with the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body that are responsible for the maintenance of homeostasis (normal cell metabolism), reproduction, development, and/or behavior." Many endocrine disrupters are thought to mimic hormones, such as estrogen or testosterone. They have chemical properties similar to hormones that allow binding to hormone specific receptors on the cells of target organs. A number of pesticides are suspected endoctrine disruptors, but EPA has not yet confirmed these preliminary findings.

Pesticide drinking water standards

EPA has set standards for pesticide residue in drinking water for about 200 organic chemicals, many of which are pesticides. These standards include health advisories (HAs) in mg/L (ppm) for 1-day, 10-day, and longer-term exposures for children and adults.

The HA is the concentration of a chemical in drinking water that is not expected to cause adverse effects over a lifetime of exposure. It is determined separately for pesticides that have not been shown to cause cancer in laboratory animals and for those that have.

Following a more thorough evaluation, EPA has established maximum contaminant levels (MCLs) and maximum contaminant level goals (MCLGs) for many, but not all, pesticides. MCLs are the maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCLGs are nonenforceable concentrations of a drinking water contaminant that are protective of adverse human health effects and allow an adequate margin of safety.

EPA's Office of Water also establishes drinking water equivalent levels (DWELs). The DWEL is a lifetime exposure concentration protective of adverse, noncancer health effects that assumes all of the exposure to a contaminant is from a drinking water source.

EPA also establishes a reference dose (RfD) in mg/kg body weight per day for each registered pesticide. The RfD represents the level of daily exposure to a pesticide (through all possible routes of exposure) that is not expected to result in appreciable risks over a human lifetime. This value is based on studies with laboratory animals and usually incorporates a safety factor of 100 to compensate for differences in species sensitivity and sensitive subpopulations. Table 4–7 lists drinking water standards and health advisories for four example pesticides.

Ecological Effects

Chemicals released into the environment may have a variety of adverse ecological effects ranging from fish and wildlife kills to more subtle effects on reproduction or fitness that also can result in population decline. Ecological effects can be long-term or short-lived changes in the normal functioning of an ecosystem, resulting in economic, social, and aesthetic losses. These potential effects are an important reason for regulation of pesticides, toxic substances, or other sources of pollution.

Scientists are most concerned about the effects of chemicals and other pollutants on communities. Short-term and temporary effects are more easily measured than long-term pollution effects on ecosystem communities. Understanding the impact of effects requires knowledge of the time course and variability of these short-term changes. Pollutants may adversely affect communities by disrupting their normal structure and delicate interdependencies. The structure of a community includes its physical system, generally created by the plant life and geological processes, as well as the relationships between its populations of biota.

A pollutant may eliminate a species essential to the functioning of the entire community; it may promote the dominance of undesirable species (weeds, trash fish); or it may simply decrease the numbers and variety of species present in the community. It may also disrupt the dynamics of the food webs in the community by breaking existing dietary linkages between species. Most of these adverse effects in communities can be measured through changes in productivity in the ecosystem. Under natural stresses, such as unusual temperature and moisture conditions, the community may be unable to tolerate chemical effects that would otherwise cause no harm.

Wildlife may be exposed to pesticides via oral, inhalation, and dermal routes of exposure (and in the case of fish, some amphibians, and many aquatic macroinvertebrates, through the gill). Table 4–8 shows the toxic levels of different exposures. Because pesticides are widespread in the environment and are found in both aquatic and terrestrial ecosystems, wildlife may be exposed in many ways.

Table 4–7 EPA drinking water standards and guidelines

Pesticide	Water quality standards (mg/L)		Health advisories						
			10-kg child (mg/L) drinking water			70-kg adult (mg/L) drinking water		all routes	
	MCLG	MCL	1 day	10 day	long-term	long-term	lifetime	DWEL	RfD
Atrazine	0.003	0.330	0.1	0.1	0.05	0.2	0.003	0.2	0.035
2, 4-D	0.07	0.07	1.0	0.3	0.1	0.4	0.07	0.4	0.01
Glyphosate	0.7	0.7	20	20	1	1	0.7	4	0.1
Methoxychlor	0.04	0.04	0.05	0.05	0.05	0.2	0.04	0.2	0.005

Table 4–8 Categories of ecotoxicology [1/]

Toxicity category	Birds acute oral LD50 (mg/kg)	Birds dermal LC50 (ppm)	Fish water LC50 (ppm)
Very highly toxic	<10	<50	<0.1
Highly toxic	10 – 50	50 – 500	0.1 – 1
Moderately toxic	>50 – 500	>500 – 1000	>1 – 10
Slightly toxic	> 500 – 2,000	>1,000 – 5,000	>10 – 100
Practically nontoxic	> 2,000	>5,000	>100

1/ After: Meister, R. (ed.), Farm Chemicals Handbook, Meister Publishing, Willoughby, OH.

Chapter 5 Specifications Sheet Instructions

A pest management component of the conservation management system is a record of the producers decisions for managing pest populations. The objectives for applying pest management in accordance with the specifications are to manage pest populations while protecting the quantity and quality of agricultural commodities and to minimize negative impacts of pest control on soil, water, and air resources.

Steps to complete the specifications sheet

Step 1. Landowner, date, and assisted by
Complete the spaces provided to identify the landowner, date, and planner providing technical assistance.

Step 2. Tracts/field(s)
Identify the tract and field for which the plan is being developed. More than one tract or field can be included on a single specification sheet if the soils, crop, and target pest are similar and will be managed similarly.

Step 3. Soils
Identify the soil(s) being used to plan the management of the field. If management will be planned differently for each soil, list the soils applicable to this particular specifications sheet. The soils listed will be used in the environmental risk analysis for soil and water quality.

Step 4. Crop sequence/rotation
Identify the crops planned for the field(s). List the crops in the sequence they will be planted, if known. Scheduling the type and sequence of crops can help reduce pest pressures and avoid mistakes, such as crop damage from herbicide carryover. Circle the crop(s) for which this specification sheet is being developed.

Step 5. Management system
Describe the management system applicable to the field(s). Examples include a reduced tillage system with 20 percent residue after planting or a rotational grazing system for dairy cows.

Step 6. Assessment completed for:
Identify if an analysis has been or will be completed for pesticide environmental risk, erosion, or soil quality. If the plan includes the use of pesticides, an environmental risk analysis based on soil and chemical properties of the pesticide will be made. The analysis should include the potential for the pesticide to move offsite through leaching and surface runoff in solution and attached to sediment. Available analysis tools for pesticide risk analysis include the Soil Pesticide Interaction Screening Procedure (SPISP II), The Windows Pesticide Screening Tool (WIN-PST), and the National Agricultural Pesticide Risk Analysis (NAPRA). Available tools to analyze the impacts of management alternatives on erosion and soil quality are the Revised Universal Soil Loss Equation (RUSLE), Wind Erosion Equation (WEQ), and the Soil Conditioning Index (SCI). Other analysis tools may be available locally.

Step 7. Target pest
Identify each target pest for which the pest management plan is being developed.

Step 8. Management method
Describe the specific method planned for managing each target pest. Include the type of control planned, such as mechanical, cultural, biological, or chemical, and applicable details, such as type of tillage, use of pest resistant varieties, biological predators, or name of the pesticide. Information to help the producer decide on the management method(s) will come from university or state agency guidelines, producer experiences, and sound agronomic practices.

Step 9. Application techniques
Describe in detail the planned application techniques that will be used to manage each target pest. Include specific management details, such as the rate, form, timing, and method. For pesticides, the rate, timing, and method of application are based on university or state agency guidelines, producer experience, and the product label.

Step 10. Additional specifications
Provide additional information needed to ensure the pest management practice is applied correctly. This is an excellent location to provide information on mitigation techniques to maintain or improve the natural resources or to offset potential negative environmental impacts of applying the pest management practice. Mitigation may include conservation practices and management techniques that the landowner would install or put in place on the field, such as residue management, nutrient management, water management, or conservation buffers.

Step 11. Job sketch

Provide a map showing the field location and acres. Also, show the boundaries of any sensitive areas, such as waterbodies, setbacks, or highly erodible soils, where restrictions to pest management methods may occur. If the conservation plan map includes these items, place a reference in the sketch area to the applicable field(s) on the plan map instead of completing a new drawing.

Step 12. Operation and maintenance

Several items must be assessed and performed routinely. These include calibration of equipment, maintaining a safe working environment, and review and update of the pest management component plan. The plan should be reviewed by the producer to determine if any short-term adjustments are needed for the immediate or following crops. Records of implementation shall be kept in accordance with Federal and State guidelines. Monitoring the effectiveness of management practices and the efficacy of the pest management itself is part of the operation and management.

Step 13. Additional notes

Complete additional information or guidance, if needed. This space can be used to describe sensitive areas in detail or to continue items from previous pages, such as additional operation and maintenance.

Pest Management

Conservation Practice Job Sheet **595**

Natural Resources Conservation Service (NRCS) ***January 1999***

Landowner____ Date___________

What is pest management?

Pest management is the management of pests, including weeds, insects, diseases, and animals. To protect our Nation's natural resources, special care must be taken to:

- Evaluate the environmental risks of pest management.
- Develop appropriate risk reduction strategies.
- Encourage widespread adoption of Integrated Pest
  Management (IPM) programs.

Purposes

Pest management systems are designed to:

- Enhance the quantity and quality of agricultural commodities.
- Minimize the negative impacts of pest control on soil resources.
- Minimize the negative impacts of pest control on water resources.
- Minimize the negative impacts of pest control on air resources.
- Minimize the negative impacts of pest control on plant resources.
- Minimize the negative impacts of pest control on animal resources.

Benefits

Pest management systems:

- Maximize economic returns.
- Minimize environmental risks.
- Improve food, water, and air quality.
- Integrate all aspects of pest management within the agricultural production system.

Conservation management systems

Pest management is used as a component of a conservation management system. It should be used in conjunction with crop residue management, nutrient management, conservation buffers, and other practices, which are applied on a site-specific basis to address both natural resource concerns and the landowner's objectives.

General criteria

- Follow the attached pest management specification.
- IPM programs that strive to balance economics, efficacy, and environmental risks will be utilized where available. IPM information available for your crops is attached.
- An appropriate set of mitigation and management techniques must be planned to address the environmental risks of pest management activities. These techniques are incorporated in the attached specification.
- When applying cultural or mechanical control methods of pest management, crop rotation, residue management, and other practices, must comply with the rest of the conservation plan.
- When developing alternatives and applying chemical controls of pest management, the following will apply:
  1. Utilize pesticide label instructions when developing chemical control alternatives. Pay special attention to environmental hazards and site-specific application criteria.
  2. Pesticide environmental risks are incorporated in the attached specification.
  3. When a chosen alternative has significant potential to negatively impact important water resources, an appropriate set of mitigation techniques must be used to address risks to humans and non-target aquatic and terrestrial plants and wildlife. Appropriate mitigation techniques are incorporated in the attached specification.
- Methods of pest management must comply with Federal, State, and local regulations.

Operation, maintenance, and safety

Formulate a safety plan complete with names, locations, and telephone numbers of local treatment centers. For human exposure questions, the local center is:

Name: ___________________________________

Location: ________________________________

Phone: __________________________________

A national hotline in Corvallis, OR, is available:

1-800-424-7378

[6:30a.m. - 4:30p.m. Mon.- Fri., Pacific Time]

For emergency assistance with agrichemical spills, the local contact is:

Name: ___________________________________

Location: ________________________________

Phone: __________________________________

National emergency assistance is available from

CHEMTREC®: 1-800-424-9300

- Post signs around treated fields according to label directions and Federal, State, and local laws. Follow re-entry intervals and wear protective clothing according to the Worker Protection Standard.
- Dispose of pesticide containers according to label directions and adhere to attached Federal, State, and local regulations.
- Pesticide users must read and follow label directions, maintain appropriate Material Safety Data Sheets and become certified to apply restricted use pesticides.
- Calibrate application equipment frequently. Replace worn nozzle tips, cracked hoses, and faulty gauges.
- Open mixing of chemicals will not occur in the application field near a well or surface waterbody as specified in operations and maintenance. Open mixing should be performed downgradient of wells.
- Records of pest management required by state law and the USDA Pesticide Record Keeping Program will be maintained by the producer as specified in operations and maintenance. USDA requires that they be kept for at least 2 years.

Pest management guidelines

Provide adequate plant nutrients and soil moisture and favorable pH and soil conditions to reduce plant stress, improve plant vigor, and increase the plant's overall ability to tolerate pests.

- Diversify treatment methods to minimize the development of pest resistance.
- Delay pesticide applications when climatic conditions are conducive to offsite pesticide movement.
- Apply conservation practices and management techniques that reduce runoff and erosion.
- Use conservation buffers to reduce offsite movement of pollutants.
- Prevent disruption of Native American artifacts and other cultural resources with land disturbing activities.

Pest Management – Specifications Sheet

Landowner ______________ Date ________ Assisted by ______________

Tract and field(s) ______________ Soils ______________

Crop sequence/rotation ______________ (Circle applicable crop(s))

Management system ______________

Analysis completed for: ________ Pesticide environmental risk (WIN-PST) ________ Erosion (RUSLE) ________ Soil quality

Target pest name	**Management method type and name**	**Application techniques** (i.e., rate, timing, and method from Extension publication)	**Additional specifications** (i.e., mitigation techniques)

Pest Management – Job Sketch

Sketch a map showing the field location, acreage and location of sensitive resource concerns (including required setback zones, water bodies and buildings).

Scale 1" = ______ ft. (NA indicates sketch not to scale: grid size = ½" by ½")

Perform the following operations and maintenance:

Review this pest management plan whenever the production system changes substantially, or at least every (   ) years.
Post treatment signs according to label directions and/or Federal, State, and local laws. Follow label re-entry intervals.
Properly clean application equipment and dispose of residue according to label instructions.
Handle all pesticides with caution and wear appropriate protective clothing according to label instructions.
Calibrate pesticide application equipment to apply within ± (   )% of the recommended rate.
Open mixing of chemicals will not occur in the application field within (   ) feet of a well or surface waterbody.
Maintain pest management field application records for (   ) years.

Additional specifications and notes:

Chapter 6 Economic Considerations—Integrated Pest Management

Introduction

The concurrent handling of weed, insect, and disease control is known as Integrated Pest Management (IPM). This approach combines biological, cultural, mechanical, and other alternatives to chemical control with the judicious use of pesticides. The objective of IPM is to reduce pest infestations below a level that causes economically significant damage while minimizing harmful effects of pest control on human health and environmental resources.

A key principle of IPM is that pesticides should only be used when field examination or "scouting" shows that infestations exceed a level which, if left untreated, would result in yield or quality reductions that exceed the costs of treatment.

Undesirable weeds and insects can cause crop injury. A small amount may be tolerable if it does not significantly affect crop yield or revenue from selling the crop. Nevertheless, if the level of pest infestation is sufficient to affect crop yield, decisions about using pesticides, biological and cultural treatments must consider whether the cost of treatment is less than the value of expected crop loss.Table 6–1 lists potential pluses and minuses of implementing an IPM system.

The list is not all-inclusive nor is it meant to be limited to any one particular set of circumstances. For example, field cultivation for weed control may increase or decrease, depending upon the management practices that were previously implemented.

The next evaluation step consists of using the above information as a basis from which to determine the net economic impact of implementing IPM.

Example case scenario

This example unit is a 500-acre farm with a confinement hog operation that has recently purchased a 160-acre unit. The farm raises 2,100 hogs @ 130 pounds annually, or a total of 273,000 pounds (273 animal units). For purposes of this analysis, it is assumed that:

- 24 acres are set aside for a conservation buffer, reducing total cropping acreage to 636 acres. The producer plans to maintain:
  - 280 acres in corn
  - 280 acres in soybeans
  - 76 acres in wheat
- Previously, weed and pest management were not actively considered. The producer used the same type and quantity of chemical inputs every year resulting in various infestations (most likely because of weed and pest resistance) and reduced yields.

Table 6-1 Effects of implementing integrated pest management

Pluses +	Minuses —
Economic effects	
Increased yields	Increased management consulting or scouting costs
Potential reduction in production costs (weed cultivation or herbicide/pesticide application)	Potential increase in cultivation time and costs
Social effects	
Decreased risk of water contamination and/or pesticide drift to neighbors	Increase in perceived risk associated with adopting a new technology
Decreased health risks to family and neighbors	
Resource effects	
Improve water quality (reduced pesticide runoff or leaching)	
Reduced residue in crops	

The resource concerns include various weed and pest infestations on the cropland. The producer obtained average per-acre yields of 140 bushels corn, 37 bushels soybeans, and 58 bushels wheat before implementing IPM. It is assumed that with the implementation of IPM, corn yields would increase by 5 bushels and soybean yields would increase by 2 bushels, while there will be no yield change for wheat.

There is an offsite water quality concern in the reservoir downstream. Neighbors are sensitive to any increase in chemical use on cropland that may affect it. After attending a public meeting on the lake's water quality, the producer became concerned about the effects of residual pesticide and herbicide on the family's water supply.

Added returns

Added returns include those items that will increase income to the landowner, such as increased crop yields. In this scenario, IPM would increase per acre crop yields by 5 bushels for corn and 2 bushels for soybeans.

Reduced costs

Reduced costs typically include variable production costs for crop production. Variable costs change as production is changed. In this scenario there are no discernible reduced costs.

Reduced returns

Reduced returns include those items that will decrease the landowner's revenue. They normally consist of any reduced yields that may occur through a change in a cropping practice. In this scenario there are no discernible reduced returns.

Added costs

Added costs include those items that increase the cost to the landowner and consist of the certified crop consultant's management fees.

Conclusion

This analysis indicates integrated pest management will reduce onfarm pest infestations, increase yields, alleviate drinking water concerns, and address offsite water quality concerns. This can be accomplished for an added cost of about $3,369. Revenues would increase by $5,964. This represents a net increase of nearly $2,600, or $4.08 per acre for the 636 acres in production. See table 6-2.

Table 6–2 Data for economic evaluation of integrated pest management for weed and pest control

Added return calculation

Crop	Yield w/o IPM (bu/ac)	Yield with IPM (bu/ac)	Price ($/ac)	Added revenue per acre ($/ac)	Number of acres	Total revenue
Corn	140.00	145.00	2.08	10.40	280	2,912.00
Soybeans	37.00	39.00	5.45	10.90	280	3,052.00
	Subtotal					$5,964.00

Added cost calculation

Crop consultant fee for scouting	$6 per acre
Number of acres in corn and soybeans	560
Total cost	$3,360

Reduced costs (+)

None

Reduced returns (–)

None

Partial budget summary

Added returns	$5,964
Reduced costs	0
Reduced returns	0
Added costs	$3,369
Net change for operation	$2,595

Chapter 7 Summary

Pest management should be implemented in conjunction with crop residue management, nutrient management, conservation buffers, and other conservation practices to address natural resource concerns and to maximize economic returns by enhancing the quantity and quality of agricultural commodities. Pest management conservation planning assistance should be targeted at agricultural areas that are known contributors to existing resource impairments or have the potential for impairing resource quality in the future. The potential for impairments can be identified with screening tools. This evaluation can then be used in conjunction with resource sensitivity information to target pest management mitigation measures.

Pest management should consider site features that influence the potential for offsite pesticide movement and water quality impairment. Current pesticide recommendations are acceptable when they perform adequately from efficacy, economic, and environmental standpoints. When they have significant potential to negatively impact the environment, NRCS should work closely with Extension, certified crop advisors, crop consultants, and other pest management advisors to identify viable alternatives that will protect our natural resources.

NRCS policy does not originate specific pesticide recommendations, but we can communicate Extension's pesticide recommendations to our customers and supplement them with natural resource data and environmental risk information. The goal is to develop a suite of environmentally acceptable conservation management alternatives for producers to select from in their conservation plans.

Successful implementation of pest management requires us to partner in all facets of this effort with Extension, certified crop advisors, crop consultants, and farmers. We must strive to leverage our efforts by influencing other farm advisors to consider environmental risks in their recommendations and document the benefits of these efforts during the conservation planning process.

Appendix A WIN_PST Reports

Soil Sensitivity to Pesticide Loss Rating Report

```
COOPERATOR: USDA-NRCS Cooperator data: Name, address, etc.
TRACT: Number   FIELD: Identifier

                                WIN-PST SPISP II
                SOIL SENSITIVITY TO PESTICIDE LOSS RATING REPORT
================================================================================

Soils Data Table: SOIL_IL  Sort Order: MUSYM

--------------------------------------------------------------------------------

KANE COUNTY, ILLINOIS: IL89

                                                            SPISP II Ratings
                                              SURFACE       --------------------
MUSYM/SEQ# COMPONENT/TEXTURE/MU%    HYD KFACT  DEPTH   % OM SLP    SSRP   SARP
========== ======================== === ===== ======= ===== ====== ====== ======
531B 1     Markham SIL 100%          C  0.37    7"     2.5% L      H      H
--------------------------------------------------------------------------------

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================================================================================

Ratings Legend:
       Ratings:
           H -- HIGH
           I -- INTERMEDIATE
           L -- LOW
           V -- VERY LOW

       Conditions that affect ratings:
           m    -- There are macropores or cracks in the surface horizon deeper
                   than 24". +1 SLP
           w    -- The high water table comes within 24" of the surface during
                   the growing season. SLP = HIGH
           s    -- The slope is greater than 15%. +1 SARP

       SPISP II S-Ratings:
           SLP  -- Soil Leaching Potential.
           SSRP -- Soil Solution Runoff Potential.
           SARP -- Soil Adsorbed Runoff Potential.
```

Pesticide Active Ingredient Rating Rport

COOPERATOR: USDA-NRCS Cooperator data: Name, address, etc.
TRACT: Number   FIELD: Identifier

WIN-PST SPISP II
PESTICIDE ACTIVE INGREDIENT RATING REPORT

AIS Data Table Sort Order: NAME

Active Ingredient Common Name	pH	Solubility In Water (ppm)	Half-Life (days)	KOC (mL/g)	Human Toxicity (ppb)	Fish Toxicity MATC* (ppb)	Fish Toxicity STV	SPISP II Ratings PLP	SPISP II Ratings PSRP	SPISP II Ratings PARP	Relative Toxicity Category Water Human	Relative Toxicity Category Water Fish	Relative Toxicity Category Sediment Fish
Atrazine (ANSI) PC_CODE: 080803 CAS_NO: 0001912249		33	60	100	3 MCL	88	8831.8	I (f)	I (fr)	L (fr)	H	I	L
Dicamba (ANSI) PC_CODE: 029801 CAS_NO: 0001918009		400000	14	2	200 HA	4919	9837.9	I (f)	L (fr)	L (fr)	V	V	L
Glyphosate, isopropylamine salt PC_CODE: 103601 CAS_NO: 0038641940		900000	47	24000	700 MCL	>25700	620,000,000	V (f)	I (fr)	I (fr)	V	V	V

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```
Ratings Legend:
       Ratings:
           H -- HIGH
           I -- INTERMEDIATE
           L -- LOW
           V -- VERY LOW

       Conditions that affect ratings:                        Effect on ratings:
           i    -- Soil Incorporated.                  +1 PLP, -1 PSRP, -1 PARP
           r    -- High Residue/CT.                            -1 PSRP, -1 PARP
           f    -- Foliar Application.                 -1 PLP, -1 PSRP, -1 PARP
           b    -- Banded Application.                 -1 PLP, -1 PSRP, -1 PARP
           l    -- Low Rate of Application.
                   1/4 - 1/10 lb/acre (280 - 112 g/ha)  -1 PLP, -1 PSRP, -1 PARP
           <ul> -- Ultralow Rate of Application.
                   1/10 lb./acre (112 g/ha) or less.    -2 PLP, -1 PSRP, -1 PARP

       SPISP II P-Ratings:
           PLP  -- Pesticide Leaching Potential.
           PSRP -- Pesticide Solution Runoff Potential.
           PARP -- Pesticide Adsorbed Runoff Potential.
```

Soil/Pesticide Interaction Loss Potential and Hazaard Ratings Report

```
COOPERATOR: USDA-NRCS Cooperator data: Name, address, etc.
TRACT: Number   FIELD: Identifier

                                                 WIN-PST SOIL / PESTICIDE INTERACTION
                                               LOSS POTENTIAL and HAZARD RATINGS REPORT
=======================================================================================================

Soils Data Table: SOIL_IL  Sort Order: MUSYM
Pesticide Data Table Sort Order: NAME

                                                                  SOILS
                                   531B:  Markham SIL 100%
                                   HYDRO: C
PESTICIDES                                KANE COUNTY,
                                          ILLINOIS: IL89
_______________________________________________________________
Atrazine (ANSI)  PC_CODE: 080803
                                   Loss           Human  Fish  |
     CAS_NO: 0001912249            Potential      Hazard Hazard|
                                   ----------------------------|
              Leaching  (ILP):     L (f)            I      L   |
         Solution Runoff (ISRP):   H (fr)           H      I   |
         Adsorbed Runoff (IARP):   I (fr)                  L   |
_______________________________________________________________
Dicamba (ANSI)  PC_CODE: 029801
                                   Loss           Human  Fish  |
     CAS_NO: 0001918009            Potential      Hazard Hazard|
                                   ----------------------------|
              Leaching  (ILP):     L (f)            V      V   |
         Solution Runoff (ISRP):   I (fr)           V      V   |
         Adsorbed Runoff (IARP):   I (fr)                  L   |
_______________________________________________________________
Glyphosate, isopropylamine salt  PC_CODE: 103601
                                   Loss           Human  Fish  |
     CAS_NO: 0038641940            Potential      Hazard Hazard|
                                   ----------------------------|
              Leaching  (ILP):     V (f)            V      V   |
         Solution Runoff (ISRP):   H (fr)           L      L   |
         Adsorbed Runoff (IARP):   H (fr)                  L   |
_______________________________________________________________

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=======================================================================================================

Ratings Legend:
       Ratings:
          H -- HIGH
          I -- INTERMEDIATE
          L -- LOW
          V -- VERY LOW

       Conditions that affect ratings:                        Effect on ratings:
           i    -- Soil Incorporated.                  +1 PLP, -1 PSRP, -1 PARP
           r    -- High Residue/CT.                            -1 PSRP, -1 PARP
           f    -- Foliar Application.                 -1 PLP, -1 PSRP, -1 PARP
           b    -- Banded Application.                 -1 PLP, -1 PSRP, -1 PARP
           l    -- Low Rate of Application.
                   1/4 - 1/10 lb/acre (280 - 112 g/ha)  -1 PLP, -1 PSRP, -1 PARP
          <ul> -- Ultralow Rate of Application.
                   1/10 lb./acre (112 g/ha) or less.    -2 PLP, -1 PSRP, -1 PARP
```

Soil/Pesticide Interaction Loss Potential and Hazaard Ratings Report—Continued

```
m    -- There are macropores or cracks in
        the surface horizon deeper than 24". +1 SLP
w    -- The high water table comes within
        24" of the surface during the
        growing season.                        SLP = HIGH
s    -- The slope is greater than 15%.                       +1 SARP

<ln> -- Low probability of rain,
        No irrigation.                      -1 ILP, -1 ISRP, -1 IARP
<lh> -- Low probability of rain,
        High efficiency irrigation.         -1 ILP, -1 ISRP, -1 IARP
<hl> -- High probability of rain,
        Low efficiency irrigation.          +1 ILP, +1 ISRP, +1 IARP
```

Glossary

% OM
Default soil organic matter value or a user-supplied value that represents percent organic matter in the first soil horizon. Organic matter is used to compute the SLP rating.

*****
Indicates value is calculated.

<hl>
High probability of rain, low efficiency irrigation. +1 ILP, +1 ISRP, +1 IARP

<lh>
Low probability of rain, high efficiency irrigation. –1 ILP, –1 ISRP, –1 IARP

<ln>
Low probability of rain, no irrigation. –1 ILP, –1 ISRP, –1 IARP

Active ingredient common name
Common name associated with an active ingredient. Common name followed by (ANSI) indicates acceptance of name by American National Standards Institute.

Banded application
Pesticide application over less than 50 percent of the field. This typically reduces pesticide application over the rows. Banding pesticide application can reduce the P-ratings by one class because it reduces pesticide application to the field by 50 percent.

CANCERGRP
EPA cancer class (synonymous with EPA cancer group). Affects the way an HA* is computed from an RFD. See HA*. A field in the human toxicity data table. Current EPA categories (EPA is revising the cancer guidelines) :

> Group A: Human carcinogen—Sufficient evidence in epidemiological studies to support causal association between exposure and cancer.
> Group B: Probable human carcinogen—Limited evidence in epidemiological studies (group B1) and/or sufficient evidence from animal studies (group B2).
> Group C: Possible human carcinogen—Limited evidence from animal studies and inadequate or no data in humans.
> Group D: Not classifiable—Inadequate or no human and animal evidence of carcinogenicity.
> Group E: No evidence of carcinogenicity for humans—No evidence of carcinogenicity in at least two adequate animal tests in different species or in adequate epidemiological and animal studies.

(Reference: United States Environmental Protection Agency, Office of Water. 1996. Drinking Water Regulations and Health Advisories. Washington, DC.)

Cancer slope
See QSTAR.

CAS_NO
Chemical abstract service registration number for an active ingredient. Format: XXXXXXXYYZ. 10 digits, no dashes, with leading zeroes as necessary. Matches the CAS_NO field in the EPA REG DB. CASRN represents the same information as the CAS_NO except that the format of the digits is different.

CASRN
Chemical abstract service registration number for an active ingredient. Format: XXXXXXX-YY-Z. 7 digits with no leading zeroes, a dash, then 2 digits with possible leading zeroes, a dash, then 1 digit. This is the most common form of the CAS_NO. CASRN represents the same information as the CAS_NO except that the format of the digits is different.

CHCL*
Chronic human carcinogen level, calculated. The concentration at which there is a 1/100,000 probability of contracting cancer calculated by using the EPA algorithm based on QSTAR from animal studies. This probability level provides a concentration comparable to the MCL. Algorithm: CHCL* = (70 Kg x 10^-5) / (2 L/day * QSTAR) 10^-5 represents a 1/100,000 chance of contracting cancer. 70 Kg represents the average weight of an adult. 2 L/day represents average consumption of water each day by an adult. (Reference: United States Environmental Protection Agency, Office of Drinking Water Health Advisories. 1994. Drinking Water Health Advisory: Pesticides. Lewis Publishers, pp viii – xiii)

Component/texture/MU%
Component name and texture of a soil, plus the percent of this component in the current soil map unit (MU%).

Conditions that affect SPISP II Pesticide Loss Potential Ratings

Different management techniques may increase or decrease the initial P-Ratings. WIN-PST allows the user to select one of the following management techniques if they exist onsite. The adjusted rating is then carried forward to the appropriate interaction matrix.

WIN-PST pesticide report management techniques, abbreviations, and effects:

i Soil incorporated. +1 PLP, -1 PSRP, -1 PARP
r High residue/CT. -1 PSRP, -1 PARP
f Foliar application. -1 PLP, -1 PSRP, -1 PARP
b Banded application. -1 PLP, -1 PSRP, -1 PARP
l Low rate of application. 1/4 - 1/10 lb/acre (280 - 112 g/ha) -1 PLP, -1 PSRP, -1 PARP
 Ultralow rate of application. 1/10 lb./acre (112 g/ha) or less. -2 PLP, -1 PSRP, -1 PARP

Conditions that affect SPISP II soil / pesticide interaction ratings

Differing environmental conditions or management techniques may increase or decrease the I-ratings. WIN-PST allows the user to select one of the following conditions if they exist onsite. The adjusted rating is then either used in the evaluation or carried forward to be used in the ITOX rating matrix. Environmental Conditions or Management Techniques:

- High Probability of Rainfall, No Irrigation—No effect on ratings.
- High Probability of Rainfall, High Efficiency Irrigation—No effect on ratings.
- High Probability of Rainfall, Low Efficiency Irrigation—Increases ILP, ISLP, and IARP by one class.
- Low Probability of Rainfall, No Irrigation—Decreases ILP, ISLP, and IARP by one class.
- Low Probability of Rainfall, High Efficiency Irrigation—Decreases ILP, ISLP, and IARP by one class.
- Low Probability of Rainfall, Low Efficiency Irrigation—No effect on ratings.

WIN-PST soil / pesticide interaction report site conditions and management techniques, abbreviations, and effects:

i Soil incorporated. +1 PLP, -1 PSRP, -1 PARP
r High residue/CT. -1 PSRP, -1 PARP
f Foliar application. -1 PLP, -1 PSRP, -1 PARP
b Banded application. -1 PLP, -1 PSRP, -1 PARP
l Low rate of application. 1/4 - 1/10 lb/acre (280 - 112 g/ha). -1 PLP, -1 PSRP, -1 PARP
 Ultralow rate of application. 1/10 lb./acre (112 g/ha) or less. -2 PLP, -1 PSRP, -1 PARP
m Nacropores or cracks in the surface horizon are deeper than 24". +1 SLP
w High water table comes within 24" of the surface during the growing season. SLP = HIGH
s Slope is greater than 15%. +1 SARP
<ln> Low probability of rain; mo irrigation. -1 ILP, -1 ISRP, -1 IARP
<lh> Low probability of rain; high efficiency irrigation. -1 ILP, -1 ISRP, -1 IARP
<hl> High probability of rain; low efficiency irrigation. +1 ILP, +1 ISRP, +1 IARP

Conditions that affect SPISP II soil sensitivity ratings

Certain site conditions may increase or decrease the initial S-ratings. WIN-PST allows the user to select one of the following site conditions if they exist onsite. The adjusted rating is then carried forward to the appropriate interaction matrix. WIN-PST soil report site conditions, abbreviations, and effects:

m Macropores or cracks in the surface horizon are deeper than 24". +1 SLP
w High water table comes within 24" of the surface during the growing season. SLP = HIGH
s Slope is greater than 15%. +1 SARP

Effect of management and site conditions on SPISP II ratings

Ratings on the WIN-PST reports are not necessarily SPISP II ratings. These ratings may have been adjusted for management or site characteristics. See Conditions that affect soil sensitivity ratings, Conditions that affect SPISP II pesticide loss potential ratings, and Conditions that affect SPISP II soil / pesticide interaction ratings, for more information.

The legend on each of the WIN-PST reports contains a list of abbreviations that may have been used in the body of the report. These represent site conditions or management. Each of these conditions has an effect on the SPISP II ratings, as explained in the definition for each abbreviation. For example, in the legend on the Pesticide Loss Report, you see the notation -1 PLP next to the condition *Low rate of application*. This means that the effect of using a low rate of application can reduce your pesticide loss potential rating by one class. WIN-PST evaluates the cumulative effect of these conditions on the ratings as follows:

1 All of the conditions for a given loss category are assessed collectively. Each condition contributes an incremental (+ = increased risk/sensitivity) or decremental (– = decreased risk/sensitivity) effect on the ratings. The sum of all of these conditions is used in 2.

2a If the sum of all of the conditions is negative, the rating is reduced by one class. If the sum of all the conditions is positive, the rating is increased by one class. Thus, two or more incremental or detrimental conditions only change the original SPISP II rating by one class.

2b The only exceptions to rule 2a are for an ultralow rate of pesticide application, which can reduce the PLP by two classes; or the presence of a high water table during the growing season, which makes the SLP HIGH, no matter what.

EPA REG DB

EPA registration data base. Updated monthly. This data base can be accessed online at http://www.epa.gov/opppmsd1/PPISdata/index.html.

Fish hazard

I-ratings combined with fish relative toxicity categories. Only combine the ILP with a fish toxicity when using tile drainage. Only combine the ILP or ISRP with an MATC*. Only combine the IARP with an STV.

Fish toxicity

Fish toxicity threshold for an active ingredient in parts per billion (ppb). Fish toxicity types: LOC*, MATC, MATC*.

Fish toxicity categories

Ratings based on long-term MATC* fish toxicity ranges. Used to determine relative hazard. These ratings combined with the I-Ratings in the ITOX matrix evaluate the relative risk to the environment of a pesticide active ingredient. These thresholds were based on extrapolation and simplification of short-term (acute) thresholds established by EPA. Fish long-term (chronic) toxicity categories are:

High	100 ppb	> X (MATC*)
Intermediate	1,500 ppb	> X (MATC*) ≥ 100 ppb
Low	5,000 ppb	> X (MATC*) ≥ 1,500 ppb
Very low	X (MATC*)	≥ 5,000 ppb

Fish toxicity rating based on MATC*

Soluble pesticide toxicity level for fish. Compare the MATC to the following thresholds to compute the MATC fish toxicity rating:

MATC < 100 ppb	High
MATC < 1,500 ppb	Intermediate
MATC < 5,000 ppb	Low
MATC > 5,000 ppb	Very low

Fish toxicity rating based on STV

Pesticide adsorbed to sediment toxicity level for fish. Compare the STV to the following thresholds to compute the STV fish toxicity rating:

STV < 100 ppb	High
STV < 1,500 ppb	Intermediate
STV < 5,000 ppb	Low
STV > 5,000 ppb	Very low

Foliar application

Foliar pesticide application using a directed spray when the crop and/or weed are at nearly full canopy. This increases interception of pesticide by the plant and decreases contact with the soil. Foliar application allows reduction of the P-ratings by one class.

G/E

The G/E field in the NAPRA PPD indicates the quality of the representative value. NAPRA PPD pesticide property data (KOC, solubility in water, and field half-life) is comprised from a variety of sources:

- Pesticide properties in the environment; Wauchope et al., 1996. (PPE)
- Personal communications with Dr. Wauchope.
- EPA OPP EFGWB One Liner Data Base. Version 3.04; data table dated 3-18-98.
- Personal communications with chemical companies.

All of the values in the NAPRA PPD were selected from literature with the intent that these values would be used in pesticide models, which requires the use of a *representative value* rather than a range of values, which more correctly describes the range of values each property could take for each chemical. The values in the G/E field indicate the quality of each data element:

G—A "guess" value from PPE and subsequent personal communication with Dr. Wauchope (ARS):

- Indicates that some degree of uncertainty exists in the value. **G** is used when no value is known to exist, but the authors of PPE believe that the parameter can be estimated by a similar compound. (PPE, p. 23); i.e., **G** denotes a guess value; neither an experimental value nor a good estimation procedure was available (PPE, p. 33).
- Solubilities marked with a **G** are expected to be accurate within a factor of 10. A total guess was required only for petroleum oil, a mixture of hydrocarbons (PPE, p. 9, section 3.3.1).

E—An "estimate" value from PPE and subsequent personal communication with Dr. Wauchope (ARS):

- Indicates that some degree of uncertainty exists in the value. **E** is used to indicate that existing data are so diverse that selection of a representative value is a matter of scientific judgment by the authors of PPE or that the value is calculated from some more fundamental property. (PPE Pg. 23) i.e. 'E' denotes that a value is an 'estimate', meaning either: (a) an unusually wide range of values have been reported and we (the authors of PPE) had no reason to select any one value as a 'best' value, or (b) no experimental value is available but a reasonable estimation was possible. (PPE Pg. 33)
- Solubilities marked with an **E** are expected to be accurate within a factor of 2. About 10 percent of the solubilities in PPE were estimated. In some cases the solubility of a similar compound was used as an estimate (PPE, p. 9, section 3.3.1).

n—A NAPRA selected value. Equates to a <BLANK>. (These values have not been peer reviewed.)

g—A "guess" value developed by the NAPRA team using Dr. Wauchope's guess methodology. (These values have not been peer reviewed.)

e—An "estimate" value developed by the NAPRA team using Dr. Wauchope's estimate methodology. (These values have not been peer reviewed.)

<BLANK>—A value from PPE and subsequent personal communication with Dr. Wauchope (ARS). The set of all pesticides that are not designated by a G, E, n, g, or e.

HA

Health advisory determined by EPA's Office of Water. The concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects over a lifetime exposure with a margin of safety. HA is compared to the PLP or PSRP for humans.

HA*

Health advisory calculated using the EPA method for calculating HA based on Reference Dose (RFD). RFD values are from the EPA Office of Pesticide Programs (OPP), EPA or World Health Organization (WHO). The EPA OPP RFD is updated regularly and when available is used to determine HA*. If the RFD from EPA OPP is not available, then the EPA RFD is used. EPA RFD is an agencywide value that is not updated as regularly or as often as the OPP RFD. If neither of these values are available, then the WHO RFD is used. In accordance with EPA's Office of Water policy, health advisories are not calculated for chemicals that are known or probable human carcinogens (EPA Cancer Class A and B):

- If the EPA Cancer Class is C: HA* = RFD * 700
- If the EPA Cancer Class is D, E, or unclassified: HA* = RFD * 7000
- If EPA Cancer Class is A or B: MCL is used if available from EPA OW. CHCL* is determined in lieu of MCL when MCL is not available.

(References: United States Environmental Protection Agency, Office of Water, 1996, Drinking Water Regulations and Health Advisories, EPA 822-B-96-002; United States Environmental Protection Agency, Office of Pesticide Programs, 1997, EPA Office of Pesticide Programs reference dose tracking report.)

Half-life (HL)

Soil half-life of an active ingredient under field conditions, in days. Sometimes referred to as field dissipation half life. Used to compute the P-ratings. Half-life is the time required for a pesticide to degrade to one-half of its previous concentration. Each successive elapsed half-life will decrease the pesticide concentration by half. For example, a period of two half-lives will reduce a pesticide concentration to one-fourth of the initial amount. Half-life can vary by a factor of three or more from reported values depending on soil moisture, temperature, oxygen status, soil microbial population, and other factors. Additionally, resistance to degradation can change as the initial concentration of a chemical decreases. It may take longer to decrease the last one-fourth of a chemical to one-eighth than it took to decrease the initial concentration to one-half. In general, the longer the half-life, the greater the potential for pesticide movement.

Hazard

Pesticide toxicity combined with potential exposure.

High residue/CT

High residue management and conservation tillage leaves crop residue on the field. High residue is defined as greater than 30 percent residue. Residue decreases field soil loss with adsorbed pesticide. Residue can reduce the PSRP and PARP by one class.

High water table (HWT)

The water table comes within 24 inches of the surface during the growing season. Increases the SLP to HIGH, no matter what other conditions exist.

Human hazard
I-ratings combined with human relative toxicity categories. Combine the ILP or ISRP with an MCL, HA, HA*, or CHCL. IARP cannot be combined with a human toxicity.

Human toxicity
Long-term human toxicity of an active ingredient in parts per billion (ppb). Toxicities are based on availability in the priority order: MCL, HA, HA* (HA and HA* are used for Cancer Groups C, D, E and unclassified), and CHCL*. MCL is used whenever available by the EPA Office of Water. HA and HA* are used for Cancer Groups C, D, E and unclassified. CHCL* is used for Cancer Groups A, B1 and B2 when MCL is unavailable.

Human toxicity categories
The long-term human toxicity ranges based on MCL, HA, HA* or CHCL*. Ranges are used to determine relative hazard. These toxicity ratings combined with I-Ratings in the ITOX Matrix to evaluate the relative risk to the environment of a pesticide active ingredient. These chronic ranges were based on acute ranges established by EPA. Human relative toxicity categories:

HIGH	10 ppb > X
INTERMEDIATE	100 ppb > X >= 10 ppb
LOW	300 ppb > X >= 100 ppb
VERY LOW	X >= 300 ppb

Human toxicity rating
Rating that determines soluble pesticide toxicity level for humans. Compare the long-term human toxicity value to the following thresholds to compute the human toxicity rating:

tox_ppb < 10 ppb	HIGH
tox_ppb < 100 ppb	INTERMEDIATE
tox_ppb < 300 ppb	LOW

Hydrologic Group (HYD)
Soil hydrologic group. HYDRO group is designated by a character from A to D.
A low runoff, high percolation (infiltration).
B moderate runoff and percolation.
C a less permeable soil that tends to have high runoff and low percolation.
D high runoff, very low or no percolation.

Dual hydro group soils are listed twice: Once for the drained condition, and again for the undrained condition. HYDRO is used to compute the S-Ratings. Soil Hydrologic Group is a group of soils having similar runoff potential under similar storm and cover conditions. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to a seasonal high water table, intake rate and permeability after prolonged wetting, and depth to a very slow permeable layer.

I-Ratings
SPISP II Soil vulnerability / pesticide loss interaction ratings: ILP, ISRP, and IARP. I-Ratings combine a pesticide's runoff or leaching rating with a soil rating developed for individual soil mapping units. The individual soil and pesticide ratings are found in Section II (Water Quality) of the USDA-NRCS Technical Guide for your state. Combining the pesticide rating and the soil rating simulates the interaction of pesticide properties and soil properties and results in a relative rating for a soil/pesticide combination. Soil/pesticide interaction ratings are developed for both pesticide movement below the root zone and pesticide movement in runoff in solution or with sediment transported to the field's edge.

IARP
SPISP II Soil / Pesticide Interaction Adsorbed Runoff Potential. Compute the IARP based on the PARP and the SARP, according to the matrix below, then adjust for rainfall and irrigation.

	PARP		
SARP	High	Intermediate	Low
High	High	High	Intermediate
Intermediate	High	Intermediate	Low
Low	Intermediate	Low	Low

If there is a high probability of rain, and you are using low efficiency irrigation, increase the IARP by one class. If there is a low probability of rain, and you are not irrigating the field or you are using a highly efficient irrigation system, decrease the IARP by one class.

ILP
SPISP II Soil / Pesticide Interaction Leaching Potential. Compute the ILP based on the PLP and the SLP, according to the matrix below, then adjust for rainfall and irrigation (H=high, I=Intermediate, L=Low, VL=Very Low).

	PLP			
SLP	H	I	L	VL
H	H	H	I	L
I	H	I	L	VL
L	I	L	L	VL
VL	L	L	VL	VL

If there is a high probability of rain, and you are using low efficiency irrigation, increase the ILP by one class.

If there is a low probability of rain, and you are not irrigating the field or you are using a highly efficient irrigation system, decrease the ILP by one class.

Irrigation

Crop irrigation:

NONE—No irrigation within 7-10 days of pesticide application.

HIGH—High efficiency system / management with insignificant runoff or deep percolation.

LOW —Low efficiency system / management with significant runoff or deep percolation.

Affects the I-ratings.

ISRP

SPISP II Soil / Pesticide Interaction Solution Runoff Potential. Compute the ISRP based on the PSRP and the SSRP, according to the matrix below, then adjust for rainfall and irrigation (H=High, I=Intermediate, L=Low). If there is a high probability of rain, and you are using low efficiency irrigation, increase the ISRP by one class. If there is a low probability of rain, and you are not irrigating the field or you are using a highly efficient irrigation system, decrease the ISRP by one class.

	PSLP		
SSLP	H	I	L
H	H	H	I
I	H	I	L
L	I	L	L

ITOX Rating Matrix

ITOX Ratings are I-Ratings combined with toxicity ratings. The ITOX Rating matrix below combines a pesticide's I-Ratings with its potential toxicity or risk to the environment. Individual pesticide toxicity ratings are found in Section II (Water Quality) of the USDA-NRCS Technical Guide for each state. Combining pesticide long-term toxicity ratings and I-Ratings in the ITOX Rating Matrix below evaluates relative risk to the environment by a pesticide. ITOX ratings are developed for both pesticide movement below the root zone and in runoff in solution or with sediment transported beyond the edge of the field. The soil / pesticide / toxicity interaction ratings are approximations of pesticide movement and risk potential and should not by themselves be used to make pest management recommendations. ITOX Rating Matrix:

Toxicity rating	I-rating	ITOX rating
HIGH	+ HIGH	—> HIGH
HIGH	+ INTMED.	—> HIGH
HIGH	+ LOW	—> INTMED.
HIGH	+ VERY LOW (ILP only)	—> LOW
INTMED.	+ HIGH	—> HIGH
INTMED.	+ INTMED.	—> INTMED.
INTMED.	+ LOW	—> LOW
INTMED.	+ VERY LOW (ILP only)	—> LOW
LOW	+ HIGH	—> INTMED.
LOW	+ INTMED.	—> LOW
LOW	+ LOW	—> LOW
LOW	+ VERY LOW (ILP only)	—> VERY LOW
VERY LOW	+ HIGH	—> LOW
VERY LOW	+ INTMED.	—> VERY LOW
VERY LOW	+ LOW	—> VERY LOW
VERY LOW	+ VERY LOW (ILP only)	—> VERY LOW

Kd

The ratio of sorbed to solution pesticide concentrations after equilibrium of pesticide in a water/soil slurry. Kd x 100 can be used to approximate unknown Koc's. See Koc for relationship between Koc and Kd.

KFACT

Soil Erodability factor (K). Used to compute the SLP and SARP ratings. Valid range: 0.02 - 0.69. Soil Erodibility Factor (K) is the rate of soil loss per rainfall erosion index unit [ton x acre x h(hundreds of acre x ft-ton x in) -1] as measured on a unit plot. The unit plot is 72.6 ft. long, 6 ft. in width, has a 9 percent slope, and is continuously in a clean-tilled fallow condition with tillage performed upslope and downslope. The soil properties that influence assigned K factor values to specific soils are soil texture, organic matter content, structure, and permeability.

If the soil hydrologic group is D and KFACT is 0, a KFACT of 0.02, the lowest valid KFACT, is used in the SPISP II Ratings algorithms. A KFACT of 0 is OK in the database if you have a D hydro group because if erosivity is a non-issue, a KFACT was purposely not computed. This is an indication of a field that has virtually no erosion; i.e., A nonerosive soil.

For more information on KFACT, see page 8-11 of the USDA Agriculture Handbook # 537 "Predicting Rainfall Erosion Losses—A guide to conservation planning." December 1978.

Koc
Soil organic carbon sorption coefficient of this active ingredient in mL/g. Used to compute the P-ratings. Pesticides vary in how tightly they are adsorbed to soil particles. The higher the KOC value, the stronger the tendency to attach to and move with soil. A pesticide with ionic properties would have a KOC set low to account for that pesticide's inability to sorb to soil particles. Pesticide KOC values greater than 1,000 indicate strong adsorption to soil. Pesticides with lower KOC values (less than 500) tend to move more with water than adsorbed to sediment.

LOC*
Level of Concern. Acute fish toxicity value determined by dividing 96-hour LC50 by two. LOC is used by EPA for risk assessment.

Reference: "Hazard Evaluation Division Standard Evaluation Procedure, Ecological Risk Assessment." EPA-540/9-85-001. Published June, 1986. EPA Office of Pesticide Programs, Washington, DC 20460.

Loss Potential
Potential for pesticide to move off the edge of the field and/or percolate below the root zone. Determined from soil/pesticide interaction ratings (I-Ratings) that result from combining soil ratings and pesticide ratings.

Low Rate
A pesticide application rate of one-tenth to one-quarter of a pound of active ingredient per acre. (112 to 280 grams per hectare.) A low application rate can reduce the P-Ratings by one class.

Macropores
Holes or cracks at the soil surface. If there are macropores or cracks deeper than 24 inches in the surface horizon then SLP can be increased by one class.

MATC*
Calculated Maximum Acceptable Toxicant Concentration (MATC*) in ppb. MATC* is the long-term toxicity value for fish. Because MATC's are not currently available for most pesticides, all MATC's are calculated. This value is combined with the PLP or PSRP. MATC* is used in WIN-PST as a long-term acceptable toxicity value for fish. Pesticide concentration below MATC will not compromise a species population over the long-term. An MATC can be determined empirically by performing lifetime or long-term toxicity tests including sensitive early life stages. Alternatively, an MATC* can be calculated from 96-hour LC50's using the method of Barnthouse, Suter, and Rosen (1990).

Reference: Barnthouse, L.W., G.W. Suter II and A.E. Rosen, 1990. "Risks of Toxic Contaminants to Exploited Fish Populations: Influence of Life History, Data Uncertainty and Exploitation Intensity." Environmental Toxicology and Chemistry. 9:297-311.

MCL
EPA's Maximum Contaminant Level. Maximum permissible long-term pesticide concentration allowed in a public water source. MCL is used in WIN-PST for any pesticide for which EPA has an assigned value. In the absence of an MCL, an HA, HA* or CHCL* is used in WIN-PST.

MUSYM/SEQ#
Map unit symbol and sequence number associated with a soil.

Organic Matter (OM[1])
Organic matter content of the surface horizon of the soil. By default, this is the average of the high and low values stored in the soils data table. The user can vary this parameter based on site characteristics. Used to compute the SLP. Soil organic matter is the organic fraction of the soil that includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population.

P-Ratings
SPISP II Pesticide loss ratings: PLP, PSRP, PARP.

PARP
SPISP II Pesticide Adsorbed Runoff Potential. PARP indicates the tendency of a pesticide to move in surface runoff attached to soil particles. A low rating indicates minimal potential for pesticide movement adsorbed to sediment, and no mitigation is required. Compute the PARP according to the following algorithm, then adjust for management.
HL—Half-life in the soil in days
SOL—Solubility in water in mg/L (ppm)
KOC—Soil organic carbon sorption coefficient in mL/g

```
If  ((HL >= 40) and (KOC >= 1000)) or
    ((HL >= 40) and (KOC >= 500) and
    (SOL <= 0.5))
    PARP = HIGH
Otherwise, if
    (HL <= 1)  or
    ((HL <= 2)  and (KOC <= 500)) or
    ((HL <= 4)  and (KOC <= 900) and (SOL >= 0.5)) or
    ((HL <= 40) and (KOC <= 500) and (SOL >= 0.5)) or
    ((HL <= 40) and (KOC <= 900) and (SOL >= 2))
         PARP = LOW
```

Otherwise
PARP = INTERMEDIATE

Adjust the PARP according to management. See 'Effect of management and site conditions on SPISP II Ratings' for how to adjust the ratings for these conditions:
Soil Incorporated: -1
High residue or conservation tillage management strategy: -1
Foliar: -1
Banded: -1
Low or ultra-low rate of application: -1

PC_CODE
EPA active ingredient registration number. (AKA Shaughnessy Code)

Pesticide Properties in the Environment (PPE)
Pesticide Properties in the Environment, Arthur G. Hornsby, R. Don Wauchope, Albert E. Herner, Springer-Verlag, 1996. ISBN (Disk) 0-387-94353-6. ISBN (Without Disk) 0-540-94353-6. This book provides the basis for the pesticide property data in the NAPRA PPD.

pH
pH value at which pesticide properties are valid. When determining P-Ratings or I-Ratings, appropriate properties are selected based on field soil pH. If pH designation is blank, pesticide properties are insensitive to pH and therefore properties are valid at any soil pH.

PLP
SPISP II Pesticide Leaching Potential. PLP indicates the tendency of a pesticide to move in solution with water and leach below the root zone. A low rating indicates minimal movement and no need for mitigation. Compute the PLP according to the following algorithm, then adjust for management.
HL—Half-life in the soil in days
SOL—Solubility in water in mg/L (ppm)
KOC—Soil organic carbon sorption coefficient in mL/g

Please note: The log() function used below is log, base 10.

First, compute a log value:
log_val = log(HL) * (4-log(KOC))

Second, use log_val in the following algorithm:
If (log_val >= 2.8). PLP = HIGH
Otherwise,if ((log_val < 0.0) or ((SOL < 1) and (HL <= 1))), then: PLP = VERY LOW
Otherwise, if (log_val <= 1.8)
PLP = LOW
Otherwise
PLP = INTERMEDIATE

Third, adjust the PLP according to management. See 'Effect of management and site conditions on SPISP II Ratings for how to adjust the ratings for these conditions:
Soil Incorporated: +1
Foliar: -1
Banded: -1
Low rate of application: -1
Ultralow rate of application: -2 (The only condition, other than HWT, that can adjust ratings by more than one class.)

PSRP
SPISP II Pesticide Solution Runoff Potential. PSRP indicates the tendency of a pesticide to move in surface runoff in the solution phase. A high rating indicates the greatest potential for pesticide loss in solution runoff. Compute the PSRP according to the following algorithm, then adjust for management.
HL—Half-life in the soil in days
SOL—Solubility in water in mg/L (ppm)
KOC—Soil organic carbon sorption coefficient in mL/g

If ((SOL >= 1) and (HL > 35) and (KOC < 100000)) or ((SOL >= 10) and (SOL < 100) and (KOC <= 700))
PSRP = HIGH
Otherwise, if (KOC >= 100000) or ((KOC >= 1000) and (HL <= 1)) or ((SOL < 0.5) and (HL < 35))
PSRP = LOW
Otherwise
PSRP = INTERMEDIATE

Adjust the PSRP according to management. See Effect of management and site conditions on SPISP II Ratings for how to adjust the ratings for these conditions:
Soil Incorporated: -1
High residue or conservation tillage management strategy: -1
Foliar: -1
Banded: -1
Low or ultra-low rate of application: -1

QSTAR
EPA OPP Cancer Slope Value. Determined from animal studies; QSTAR values are assigned by EPA and used to estimate the probability of contracting cancer from a pesticide. Used to determine CHCL*. QSTAR is a field in the human toxicity data table.

Rainfall
Probability of precipitation (affects the I-ratings):

NONE No precipitation within 7-10 days of pesticide application.
LOW Low probability of rainfall causing runoff or deep percolation in 7-10 days.
HIGH High probability of rainfall causing runoff or deep percolation in 7-10 days.

S-Ratings
SPISP II Soil vulnerability ratings: SLP, SSRP, SARP.

SARP
Soil Adsorbed Runoff Potential. Represents sensitivity of a soil to pesticide loss adsorbed to sediment and organic matter that leaves the edge of the field. SARP characterizes those soil properties that would increase or decrease the tendency of a pesticide to move in surface runoff attached to soil particles. A high rating indicates the greatest potential for sediment/pesticide transport. Compute the SARP according to the following algorithm, then adjust for site conditions.

HYD — Hydrologic Group.
KFACT — Soil K factor.

If (HYD == D) and (KFACT == 0) use a KFACT of 0.02 in the algorithm below. See the definition for KFACT.

If ((HYD == C) and (KFACT >= 0.21)) or
((HYD == D) and (KFACT >= 0.10))
SARP = HIGH
Otherwise, if (HYD == A) or
((HYD == B) and (KFACT <= 0.10)) or
((HYD == C) and (KFACT <= 0.07)) or
((HYD == D) and (KFACT <= 0.02))
SARP = LOW
Otherwise
SARP = INTERMEDIATE

Adjust the SARP according to management. See Effect of management and site conditions on SPISP II Ratings for how to adjust the ratings for these conditions. If a slope on the field is greater than 15 percent, increase the rating by one class.

Slope
Field slope. SARP is increased one class where a slope is greater than 15 percent.

SLP
SPISP II Soil Leaching Potential. The sensitivity of a given soil to pesticide leaching below the root zone. SLP characterizes those soil properties that would increase or decrease the tendency of a pesticide to move in solution with water and leach below the root zone. A high rating indicates the greatest potential for leaching. Compute the SLP according to the following algorithm, then adjust for site conditions.

HYD—Hydrologic group
KFACT—Soil K factor
OM —% surface horizon organic matter content
Horiz_1_Depth—Depth of the first soil horizon, in inches

If (HYD == D) and (KFACT == 0) use a KFACT of 0.02 in the algorithm below. See the definition for KFACT.

If ((HYD == A) and ((OM1 * Horiz_1_Depth) ≤ 30))
or
((HYD == B) and ((OM1 * Horiz_1_Depth) ≤ 9) and (KFACT <= 0.48)) or
((HYD == B) and ((OM1 * Horiz_1_Depth) ≤ 15) and (KFACT <= 0.26))
SLP = HIGH

Otherwise, if ((HYD == B) and ((OM1 * Horiz_1Depth) ≥ 35) and (KFACT ≥ 0.40)) or
((HYD == B) and ((OM1 * Horiz_1_Depth) ≥ 45) and (KFACT ≥ 0.20)) or
((HYD == C) and ((OM1 * Horiz_1_Depth) ≤ 10) and (KFACT ≥0.28)) or
((HYD == C) and ((OM1 * Horiz_1_Depth) ≥ 10))
SLP = LOW
Otherwise, if (HYD == D)
SLP = VERY LOW
Otherwise
SLP = INTERMEDIATE

Adjust the SLP according to management. See Effect of management and site conditions on SPISP II Ratings for how to adjust the ratings for these conditions: If there are cracks or macropores in the surface horizon of the soil greater than 24 inches, then increase the SLP by one class. If the high water table comes within 24 inches of the surface during the growing season, change the SLP to HIGH, no matter what, and do not adjust the rating in any other way.

Soil Incorporated
Pesticide incorporated into soil. Incorporation decreases pesticide runoff but increases percolation. PLP is increased one class while PSRP and PARP are reduced one class.

Soil / Pesticide Interaction Ratings
See I-Ratings.

Soils Data
The current WIN-PST soils data tables primarily derive from the national NRCS State Soil Survey Database (SSSD) that was held in Ames, IA. Additionally, a limited amount of data was also acquired from the USDA-NRCS Soil Survey Division: National MUIR Database Download found online at http://www.statlab.iastate.edu/cgi-bin/dmuir.cgi?-F

The WIN-PST soils data base will be replaced with NASIS data after the import/export procedure from NASIS to WIN-PST is refined.

Solubility (SOL)
Solubility of an active ingredient in water at room temperature, in mg/L (ppm). Used to compute P-Ratings. Solubility is a fundamental physical property of a chemical and affects the ease of wash off and leaching through soil. In general, the higher the solubility value, the greater the likelihood for movement.

SPISP II
Soil / Pesticide Interaction Screening Procedure version II. (References: The SCS/ARS/CES Pesticide Properties Database: II, Using it with soils data in a screening procedure. Don Goss and R. Don Wauchope. Pesticides in the Next Decade: The Challenges Ahead, Proceedings of the Third National Research Conference On Pesticides, November 8-9, 1990. Diana L. Weigmann, Editor, Virginia Water Resources Research Center, Virginia Polytechnic Institute & State University. Pg. 471-487

SPISP II Ratings
Ratings of pesticides, soils and pesticide/soil interaction that indicate potential for pesticide movement. Rating class abbreviations used in the WIN-PST reports include:

H — HIGH
I — INTERMEDIATE
L — LOW
V — VERY LOW (Leaching Only)

Ratings on the WIN-PST reports are SPISP II ratings modified for management. See Conditions that affect SPISP II Pesticide Loss Potential Ratings, Conditions that affect SPISP II Soil / Pesticide Interaction Ratings, Conditions that affect SPISP II Soil Sensitivity Ratings, and Effect of management and site conditions on SPISP II Ratings.

SSRP
SPISP II Soil Solution Runoff Potential. The sensitivity of a given soil to pesticide loss dissolved in surface runoff that leaves the edge of the field. A high rating indicates the greatest potential for solution surface loss. Compute the SSRP according to the following algorithm.

HYD — Hydrologic Group

```
If ((HYD == C) or (HYD == D))
    SSRP = HIGH
Otherwise, if (HYD == A)
    SSRP = LOW
Otherwise, if (HYD == B)
    SSRP = INTERMEDIATE
```

STSSAID
State Soil Survey Area ID.

STV
Sediment Toxicity Value. STV = MATC x KOC. Compared to the PARP when the species of concern are fish. STV provides toxicity of pesticide sorbed to detached soil leaving the field. KOC is used in STV determination to estimate pesticide concentration in sediment pore water. Fish MATC is used in lieu of toxicity data to sediment dwelling animals for which test data are rare. STV threshold ratings are the same as those used for MATC evaluation. The method for sediment short-term toxicity of nonionic pesticides (Di Torro et al., 1991), was modified to determine long-term toxicity. STV is also used to evaluate ionic pesticide which account for about 25% of pesticides. This is achieved by use of an adjusted KOC in the NAPRA PPD, which accounts for pesticide ionic properties. References: Di Torro, D.M., C.S. Zarba, D.J. Hansen, W.J. Berry, R.C. Swartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, N.A. Thomas, P.R. Paquin. 1991. Technical Basis for Establishing Sediment Quality Criteria for Nonionic Organic Chemicals Using Equilibrium Partitioning. Environmental Toxicology and Chemistry. 10:1541-1583

Surface Depth
Depth of the soil surface horizon. Used to compute the SLP. This can be a default (average of the range in the USDA-NRCS soils database) or user-supplied value (field condition).

Texture

Soil texture class designations:

	Texture modifiers
BY	Bouldery
BYV	Very bouldery
BYX	Extremely bouldery
CB	Cobbly
CBA	Angular cobbly
CBV	Very cobbly
CBX	Extremely cobbly
CN	Channery
CNV	Very channery
CNX	Extremely channery
FL	Flaggy
FLV	Very flaggy
FLX	Extremely flaggy
GR	Gravelly
GRC	Coarse gravelly
GRF	Fine gravelly
GRV	Very gravelly
GRX	Extremely gravelly
MK	Mucky
PT	Peaty
RB	Rubbly
SR	Stratified
ST	Stony
STV	Very stony
STX	Extremely stony

	Texture terms
COS	Coarse sand
S	Sand
FS	Fine sand
VFS	Very fine sand
LCOS	Loamy coarse sand
LS	Loamy sand
LFS	Loamy fine sand
LVFS	Loamy very fine sand
COSL	Coarse sandy loam
SL	Sandy loam
FSL	Fine sandy loam
VFSL	Very fine sandy loam
L	Loam
SIL	Silt loam
SI	Silt
SCL	Sandy clay loam
CL	Clay loam
SICL	Silty clay loam
SC	Sandy clay
SIC	Silty clay
C	Clay

	Terms used in lieu of texture
CE	Coprogenous earth
CEM	Cemented
CIND	Cinders
DE	Diotomaceous earth
FB	Fibric material
FRAG	Fragmental material
G	Gravel
GYP	Gypsiferous material
HM	Hemic material
ICE	Ice or frozen soil
IND	Indurated
MARL	Marl
MPT	Mucky-peat
MUCK	Muck
PEAT	Peat
SG	Sand and gravel
SP	Sapric material
UWB	Unweathered bedrock
VAR	Variable
WB	Weathered bedrock

TOX_PPB

Toxic concentration of pesticide in parts per billion (ppb).

TOX_TIME

Timeframe associated with a toxicity.
WIN-PST PPD, Fish: {MATC—long-term | LOC—4-Day}.
WIN-PST PPD, Human: {Lifetime}.

TOX_TYPE

Toxicity type that applies to an animal, fish or humans.

FISH: Toxicity types in the WIN-PST fish toxicity data table: 96-hour LC50, LOC, MATC*, and STV.

HUMAN: Toxicity types in the WIN-PST human toxicity data table: MCL, HA, HA*, and CHCL. Based on availability, usage priority in this data base is: MCL, HA, HA* and CHCL. This order was determined by considering:

1. MCL is EPA's drinking water regulation of choice.
2. HA has been determined by the EPA Office of Water (OW).
3. HA* is calculated by the same method used by the OW for noncarcinogens and possible human carcinogens as determined by OW.
4. CHCL is determined for probable and known carcinogens. It is comparable to the MCL.

Ultralow Rate
A pesticide application rate of one-tenth of a pound or less of active ingredient per acre. (112 grams per hectare.) An ultra low rate of application allows reduction of the PLP by two classes, and the PSRP and PARP by one class.

WIN-PST / WIN_PST()
Windows Pesticide Screening Tool. WIN-PST was developed by the NAPRA Team, Amherst, Massachusetts. WIN-PST replaces NPURG. WIN-PST is based on the SPISP II algorithms, but allows a user to modify the ratings based on site conditions or management. WIN-PST can be used to help determine the potential for agricultural pesticides to move towards water resources. WIN-PST allows the user to combine the effect of pesticide and soils properties to determine potential environmental risk from pesticide movement below the rootzone and beyond the edge of the field.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

PEST MANAGEMENT

(Acre)

CODE 595

DEFINITION

Managing pests including weeds, insects, diseases and animals.

PURPOSES

This practice may be applied as part of a conservation management system to support one or more of the following purposes:

- Enhance quantity and quality of agricultural commodities
- Minimize negative impacts of pest control on soil resources
- Minimize negative impacts of pest control on water resources
- Minimize negative impacts of pest control on air resources
- Minimize negative impacts of pest control on plant resources
- Minimize negative impacts of pest control on animal resources

CONDITIONS WHERE PRACTICE APPLIES

Wherever pest management is needed.

CRITERIA

General Criteria Applicable to All Purposes

A pest management component of a conservation plan will be developed. Methods of pest management must comply with Federal, State, and local regulations.Integrated Pest Management (IPM) programs that strive to balance economics, efficacy and environmental risks will be utilized where available. (IPM is an approach to pest control that combines biological, cultural and other alternatives to chemical controls with the judicious use of pesticides. The objective of IPM is to maintain pest levels below economically damaging levels while minimizing harmful effects of pest control on human health and environmental resources.)

An appropriate set of mitigation techniques must be implemented to address the environmental risks of pest management activities in order to adequately treat identified resource concerns. Mitigation techniques include practices like filter strips and crop rotation, and management techniques like application timing and method.

Cultural and mechanical methods of pest management must comply with the rest of the conservation plan.

This practice has the potential to affect National Registered listed or eligible (significant) cultural resources. Follow NRCS State policy for considering cultural resources during planning, application and maintenance.

When developing alternatives and applying chemical controls of pest management, the following will apply:

- Both label instructions and Extension recommendations (where available) will be followed when developing chemical control alternatives. Pay special attention to environmental hazards and site-specific application criteria.
- Compliance with Federal, State and local laws is required (e.g., Food Quality Protection Act (FQPA), Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), Worker Protection Standard (WPS) and Interim Endangered Species Protection Program (H7506C)).

Additional Criteria to Protect Quantity and Quality of Agricultural Commodities

IPM will be used where available, however, if IPM programs are not available, the level of pest control must be the minimum necessary to meet the producer's objectives for commodity quantity and quality. [State Standards will identify their commodity-specific IPM programs.]

Additional Criteria to Protect Soil Resources

In conjunction with other conservation practices, the number, sequence and timing of tillage operations shall be managed to maintain soil quality and maintain soil loss below or equal to the soil loss tolerance (T) or any other planned soil loss objective.
Label restrictions shall be followed for pesticides that can carry over in the soil and harm subsequent crops.

Additional Criteria to Protect Water Resources

Pesticide environmental risks, including the impacts of pesticides in ground and surface water on non-target plants, animals and humans, must be evaluated for all identified water resource concerns. [State Standards will include approved evaluation procedures such as NRCS' Soil/Pesticide Interaction Screening Procedure (SPISP), Windows Pesticide Screening Tool (WIN-PST) and National Agricultural Pesticide Risk Analysis (NAPRA).]

When a chosen alternative has significant potential to negatively impact important water resources, (for example: SPISP "High" and "Intermediate" soil/ pesticide combinations in the drainage area of a drinking water reservoir), an appropriate set of mitigating practices must be put in place to address risks to humans and non-target aquatic and terrestrial plants and wildlife. [State Standards will identify appropriate mitigation practices by pesticide loss pathway and resource concern. For example: for pesticide sorbed to eroded soil in a surface water concern area, residue management, water management and filter strips may be appropriate mitigation practices.]

Open mixing of chemicals will not occur in the application field within a minimum of 100 feet from a well or surface water body. Open mixing should be performed down gradient of wells (State or local regulations may be more restrictive).

The number, sequence and timing of tillage operations shall be managed in conjunction with other sediment control tactics and practices, in order to minimize sediment losses to nearby surface water bodies.

Additional Criteria to Protect Air Resources

Follow pesticide label instructions for minimizing volatilization and drift that may impact non-target plants, animals and humans.

Additional Criteria to Protect Plant Resources

Prevent misdirected pest management control measures that negatively impact plants (e.g., removing pesticide residues from sprayers before moving to next crop and properly adjusting cultivator teeth and flame burners).

Follow pesticide label directions specific to the appropriate climatic conditions, crop stage, soil moisture, pH, and organic matter in order to protect plant health.

Additional Criteria to Protect Animal Resources

Follow pesticide label instructions for minimizing negative impacts to both target and non-target animals.

CONSIDERATIONS

When IPM programs are not available, basic IPM principles should be strongly encouraged. [State Standards should include all appropriate IPM principles such as using mechanical, biological, and cultural control methods in lieu of chemical controls, scouting pest populations to avoid routine preventative pest control measures, and the utilization of spot treatments.]

Adequate plant nutrients and soil moisture, including favorable pH and soil conditions, should be provided to reduce plant stress, improve plant vigor and increase the plant's overall ability to tolerate pests.

PLANS AND SPECIFICATIONS

The pest management component of a conservation plan shall be prepared in accordance with the criteria of this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

As a minimum, the pest management component of a conservation plan will include:

- plan and soil map of managed fields
- location of sensitive resources and setbacks
- crop sequence and rotation if applicable

- identification of target pests (and IPM scheme for monitoring pest pressure when available)
- recommended methods of pest management (biological, cultural, mechanical or chemical), including rates, product and form, timing, and method of applying pest management
- results of pest management environmental assessments (SPISP, WIN-PST, NAPRA, RUSLE etc.) and a narrative describing potential impacts on non-target plants and animals, through soil, water and air resources as appropriate
- operation and maintenance instructions

OPERATION AND MAINTENANCE

The pest management component of a conservation plan will include the following operation and maintenance items:

- A safety plan complete with telephone numbers and addresses for emergency treatment centers for personnel exposed to chemicals. For human exposure questions, the telephone number for the nearest poison control center should be provided. The telephone number for the national hotline in Corvallis, Oregon may also be given:

  1-800-424-7378
  Monday - Friday
  6:30 a.m. to 4:30 p.m. Pacific Time

  For advice and assistance with emergency spills that involve agrichemicals, the local emergency telephone number should be provided. The national CHEMTREC telephone number may also be given:

  1-800-424-9300
- Posting of signs according to label directions and/or Federal, State, and local laws around fields that have been treated. Follow re-entry times.
- Disposal of pesticides and pesticide containers must be in accordance with label directions and adhere to Federal, State, and local regulations.
- The requirement that pesticide users must read and follow label directions, maintain appropriate Material Safety Data Sheets (MSDS), and become certified to apply restricted use pesticides.
- Calibration of application equipment according to Extension Service recommendations before each seasonal use and with each major chemical change.
- The requirement that worn nozzle tips, cracked hoses, and faulty gauges must be replaced.
- The requirement that the producer will maintain records of pest management for at least two years. Pesticide application records will be in accordance with USDA Agricultural Marketing Service's Pesticide Record Keeping Program and state specific requirements. [State Standards will describe record keeping requirements.]

CORE4 Key Conservation Practices

Part 4 Buffer Practices

Chapter 1 Conservation Buffers—Overview

What are conservation buffers?

Conservation buffers are areas or strips of land maintained in permanent vegetation to help control pollutants and manage other environmental problems. Conservation buffers are common sense conservation!

Buffers are strategically located on the landscape to accomplish many objectives. Ten conservation practices are commonly thought of as buffers.

Alley cropping

Alley cropping is the planting of trees or shrubs in two or more sets of single or multiple rows with agronomic, horticultural, or forage crops cultivated in the alleys between the rows of woody plants. Alley cropping is used to enhance or diversify farm products, reduce surface water runoff and erosion, improve utilization of nutrients, reduce wind erosion, modify the microclimate for improved crop production, add diversity for wildlife habitat, and enhance the aesthetics of the area.

Contour buffer strips

Contour buffer strips are strips of perennial vegetation alternated with wider cultivated strips that are farmed on the contour. Contour buffer strips slow runoff and trap sediment. They help reduce sediment, nutrients, pesticides, and other contaminants in runoff as they pass through the buffer strip. Vegetative strips can also be designed to provide food and cover for wildlife.

Cross wind trap strips

Cross wind trap strips are areas of herbaceous vegetation that are resistant to wind erosion and grown as nearly as possible perpendicular to the prevailing wind direction. These strips catch wind-borne sediment and other pollutants, such as nutrients and pesticides, from the eroded material before it reaches waterbodies or other sensitive areas. They are filter strips for wind-borne material.

Field border

A field border is a band or strip of perennial vegetation established on the edge of a cropland field. It reduces sheet, rill, and gully erosion at the edge of fields; traps sediment, chemical, and other pollutants; provides turning areas for farm equipment; and provides habitat for wildlife.

Filter strip

A filter strip is an area of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants from runoff and to maintain or improve water quality. It slows the velocity of water, filters suspended soil particles, and increases infiltration of runoff and soluble pollutants and adsorption of pollutants on soil and plant surfaces. Filter strips also can be designed to enhance wildlife habitat.

Grassed waterways with vegetated filter

A grassed waterway/vegetated filter system is a natural or constructed vegetated channel that is shaped and graded to carry surface water at a nonerosive velocity to a stable outlet that spreads the flow of water before it enters a vegetated filter.

Herbaceous wind barriers

Herbaceous wind barriers are tall grass and other nonwoody plants established in one- to two-row, narrow strips spaced across the field perpendicular to the normal wind direction. These barriers reduce wind velocity across the field and intercept wind-borne soil particles.

Riparian forest buffer

A riparian forest buffer is an area of trees and shrubs located adjacent to streams, lakes, ponds, and wetlands. It intercepts contaminants from surface runoff and shallow subsurface waterflow. The buffer also can be designed to enhance wildlife habitat, impact water temperature, and aid in streambank stability.

Vegetative barriers

Vegetated barriers are narrow, permanent strips of stiff stemmed, erect, tall, dense perennial vegetation established in parallel rows and perpendicular to the dominant slope of the field. The barriers provide water erosion control on cropland and offer an alternative to terraces where the soil might be degraded by terrace construction.

Windbreak/shelterbelt

A windbreak or shelterbelt is a single or multiple row of trees or shrubs that protects the soil from wind erosion, protects sensitive plants, manages snow, improves irrigation efficiency, protects livestock and structures, and creates or enhances wildlife habitat.

Why conservation buffers?

Conservation buffers are put into landscapes to achieve conditions that landowners and other stakeholders want. By achieving those conditions, buffers increase the value society derives from the land. Value to society is also expressed in other terms, such as, objectives, concerns, problems, issues, goals, benefits, and products. Conservation buffers are used to achieve these.

A broad goal of the Natural Resources Conservation Service (NRCS) is to maintain healthy and productive land that

- sustains food and fiber production,
- sustains functioning watersheds and natural systems,
- enhances the environment, and
- improves urban and rural landscapes (USDA Strategic Plan 1997).

In a general way, this goal identifies the condition of agricultural landscapes that the public wants—productive and ecologically healthy. Similar public desires have been formally expressed through legislative action, such as the Clean Water Act, Endangered Species Act, and the Farm Bill. They are informally expressed through public support of other conservation agencies, organizations, and public initiatives (e.g., Northwest Salmon Initiative, Chesapeake Bay Program). Conservation buffers can be used to achieve this Agency goal.

Public concern for conservation is based on observations of decline of water quality, wildlife, and other ecological health-related conditions. Many of these problems are direct consequences of extensive land conversion to intensive agricultural production. Well-planned conservation buffers can play a role in reversing this trend.

National Conservation Buffer Initiative

In a 1993 report, the National Research Council recommended the increased use of buffers for soil and water quality. As a result NRCS organized several focus groups and determined that buffers were an acceptable practice with the farm community and received support from the environmental community. In the fall of 1996, NRCS Chief Paul Johnson proposed the National Conservation Buffer Initiative (NCBI). Today, the NCBI involves over 100 conservation agencies, agribusiness firms, and agricultural and environmental organizations partnering to promote conservation buffers. Seven major agribusiness firms (Cargill, ConAgra, Farmland Industries, Monsanto, Novartis Crop Protection, Pioneer Hi-bred International, and Terra Industries) along with the National Corn Growers Association and the National Council of Farm Cooperatives form the leadership core for the NCBI. In 1997, USDA Secretary Dan Glickman made the buffer initiative a priority of the Department.

How conservation buffers work

Conservation buffers achieve desired conditions by enhancing ecological functions that produce them. Buffers use permanent vegetation to enhance specific ecological functions. For example, the roots of plants stabilize soil and the plant foliage, block ,or provide shade. Buffers can vary widely in their vegetation and location on the landscape in order to enhance specific ecological functions that achieve conditions landowners and other stakeholders want.

Ecological function, as we define it here, refers to a collection of physical, chemical, and biological processes that act to create a landscape condition. A convenient way to organize a description of ecological functions of buffers is to associate them with important desired conditions that they help achieve. Some examples of desired conditions include:

- stable and productive soils
- cleaner water
- enhanced wildlife populations (aquatic and terrestrial)
- protected crops, livestock, and structures
- alternative farm income
- enhanced aesthetics and recreation opportunities
- sustainable landscapes

Typical causes of degradation for each of these broad desired conditions and the ecological functions of buffers that improve conditions are described in the following sections.

Stable and productive soils

Wind and water flowing across bare soil mobilize and remove fertile topsoil from fields. Flowing water and wave action of streams and lakes erode soil from their banks. Onsite soil loss can lead to lower soil productivity and land loss. Offsite problems caused by sediment in waterways include damaged aquatic habitat, degraded drinking water quality, and sediment-filled lakes, wetlands, and reservoirs. Blowing soil degrades air quality.

Ecological functions

Buffers function to stabilize soil with plant roots that bind soil particles together and shoots that protect soil from mobilizing forces by absorbing the energy of wind, flowing water, and raindrop impact.

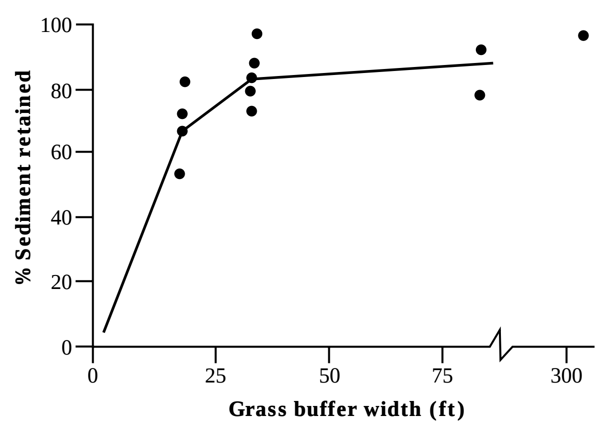
Cleaner water

Sediment in a watercourse damages aquatic habitat, degrades drinking water quality, and fills wetlands, lakes, and reservoirs. High levels of nutrients, pesticides, and animal wastes degrade drinking water quality, aquatic habitat, and recreational quality of watercourses. Specifically, nitrate, ammonia nitrogen, and pesticides can be toxic to humans and aquatic organisms; fecal bacteria and other microbes in animal wastes can cause disease; phosphate can promote algae blooms, which suffocate fish and other aquatic organisms, and turbidity that adds undesirable color, taste, and odor to drinking water.

Ecological functions

- Plant stems slow and disperse flow of surface runoff and promote settling of sediment (fig. 1–1).
- Roots stabilize the trapped sediment and hold soil in place.
- Particulates and sediment-attached pollutants are trapped along with the sediment. Improved infiltration of surface runoff and vigorous growth of vegetation promote uptake and transformation of dissolved contaminants by plants and soil microbes.
- Dissolved contaminants may be similarly removed from shallow ground water and used in production of plants and biomass.

Figure 1–1 Sediment retention by a filter strip in relation to its width



Enhanced wildlife populations

Bare, unshaded, sediment-laden streams provide poor habitat for fish and other aquatic organisms. Extensively cultivated cropland provides insufficient cover, food, and suitable migration routes for upland wildlife at critical times of the year.

Ecological functions

- Buffer vegetation adjacent to aquatic systems provides shade that reduces light intensity and water temperature in streams.
- Plant litter as well as insects and other invertebrates on plants are food for fish. Larger plant debris and roots can form stable shelter for aquatic organisms and provide carbon energy for micro-organisms.
- Perennial vegetation supplies diversity of cover and food for terrestrial wildlife.
- Buffers can also provide suitable migration routes for larger animals, they are extensive enough and have the proper vegetative structure.

Protected crops, livestock, and structures

Dry summer winds and blowing soil can stress crop plants, reduce production, and increase need for irrigation. Cold winter winds can stress crops and livestock causing reduced production or death; draw heat out of barns, workplaces, and homes; and promote drifting of snow. Flooding caused by larger storm runoff events can erode soil and damage crops, deposit debris in fields, and damage buildings, bridges, and other structures.

Ecological functions

- Plant stems block and absorb wind energy to reduce wind velocity near the ground, providing protected environments for crops and livestock (fig. 1–2).
- By controlling wind velocity buffers can also influence snow deposition either by encouraging deposition on crop fields and pastures or by discouraging deposition around structures and along roadways.
- On flood plains, plant stems can reduce floodwater velocity and erosive power, filter out sediment, and block stream debris from entering crop fields and pastures.
- Extensive buffers in a watershed may reduce peak flood level by encouraging greater infiltration of rainfall and slowing the movement of runoff.

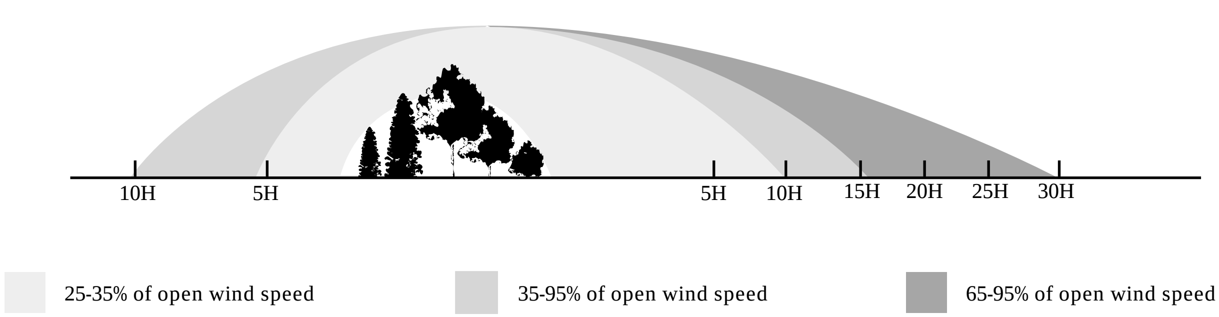
Alternative farm income

Reliance on a few crop species exposes farmers to risk of crop or market failure and income instability. Buffers may take land out of cultivated crop production and require additional cost to install.

Ecological functions

- Buffer vegetation may produce alternative commodities to diversify farm income, such as lumber, fuel wood, fiber, hay, seeds, and ornamental, medicinal, and food products.
- Increased wild game and fish populations resulting from habitat improvement may produce income from hunting and fishing fees.
- Conservation buffer systems often enhance property values.

Figure 1–2 Wind speed profile around a windbreak



Enhanced aesthetics and recreation opportunities

Extensive cultivated cropland and pasture have low visual diversity. Noise from or views of roads and industry or other human activities reduce aesthetic values and recreational experiences of people. Exposure to intense summer sun can create undesirable conditions for outdoor activities.

Ecological functions

- Shoots of perennial vegetation (especially trees and shrubs) create visual diversity to a crop- or forage-dominated landscape.
- They can filter noise, block undesirable views, and separate human activities to create a more pleasant aesthetic and recreational environment.
- Tree canopies provide shade that can create a more desirable microenvironment in which to work and recreate.

Enhancing sustainability

Based on current scientific knowledge, sustainability of highly valued agricultural landscapes is achieved when the diversity and integrity of natural ecological processes and patterns is restored.

Sustainable landscapes

Landscapes dominated by a few intensively managed species have lower diversity of plants and animals than a natural ecosystem. Fewer species, higher rates of soil erosion, and increased need for fertilizer and pesticide inputs to maintain production indicate declining ecological health and natural productivity. Agricultural landscapes are typically partitioned into independent land management units that fragment habitats and disrupt natural patterns of drainage and related ecological processes. Reduced integration of ecological processes in agricultural landscapes is thought to play an important role in declining biological diversity, ecological health, and sustainability of agricultural landscapes.

Ecological functions

Buffers can increase biological diversity by creating more habitat for perennial plant species and associated animals and by arranging composition and location on the landscape to provide diverse habitat characteristics. Sustainability can be improved by:

- planting locally adopted species that create improved habitat for wildlife,
- stabilizing soil from loss by erosion, and
- recycling nutrients in the agroecosystem.

Developing buffers across land ownership boundaries can help to reconnect habitats and create wildlife corridors. Ecological integrity is enhanced by restoring natural ecological processes and patterns.

Chapter 2 Planning

An integrated approach

Conservation buffers are used to achieve conditions people want. Application of a buffer is straight forward if only one desired condition (such as crop protection from wind) can be achieved by a buffer (such as a windbreak). Most situations are more complex, however, because conservation measures have other ecological consequences that may be important to the landowner or other stakeholders. For example, a windbreak for crop protection can harbor game animals and weeds or change the visual aesthetics of an area.

Often desired conditions can only be achieved by addressing ecological function both on and off the site. For example, cleaner water at a site may also require attention to runoff problems farther up on the watershed, or enhanced wildlife populations at a site may require habitat connection to offsite areas to allow wildlife to migrate to that site. Still other conditions, such as sustainability, may require simultaneous enhancement of several ecological functions.

Conservation planners need to consider the full range of desired conditions and ecological functions when applying conservation buffers. An integrated approach is a means to identify, blend, and balance all the desired conditions of the landowner and other stakeholders into a buffer design. Through this approach, conservation buffers can be designed to achieve a higher level of social value from agricultural lands. It helps managers consider and account for multiple desired conditions and the ecological functions that affect each condition.

Accomplishing an integrated approach

Planning is a widely accepted method for managing complex natural resource issues. It is also a logical process that promotes effective decisionmaking.

The Natural Resources Conservation Service (NRCS) uses a nine-step Conservation Planning Process to assist clients in solving resource problems and making wise resource management decisions. The planning process integrates ecological, economic, and social considerations to meet private and public needs. This process provides the framework to determine if buffers are an appropriate conservation treatment and how they may be used to address multiple objectives.

NPPH nine-step conservation planning process

- Step 1: Identify problems and opportunities
- Step 2: Determine objectives
- Step 3: Inventory resources
- Step 4: Analyze resource data
- Step 5: Formulate alternatives
- Step 6: Evaluate alternatives
- Step 7: Make decisions
- Step 8: Implement plan
- Step 9: Evaluate plan

This workbook is not intended to teach the Conservation Planning Process, but rather to explain its use as an integrated approach to applying conservation buffers. For more information on the process, refer to the National Planning Procedures Handbook (NPPH).

To identify, blend, and balance all the desired conditions of the landowner and other stakeholders into a site design, several questions need to be answered during the planning process:

- What conditions do the landowner and other stakeholders desire?
- What ecological functions of buffers can contribute to those conditions?
- How can buffers be designed to enhance the functions that achieve those conditions?

Identify desired conditions

One of the first tasks done in conservation planning is to define what landowners and other stakeholders want. Landowner goals are commonly site- and farm-focused and usually take the form of problems the landowner wants to solve (“stop the erosion”) or conditions the landowner wants to create (“more wildlife”). Having a landowner prioritize his/her short- and long-term goals may help later on if conflicting goals are identified.

Goals of other stakeholders are usually concerned with offsite and larger-scale issues. A buffer may contribute to solving a larger scale problem and/or have negative offsite consequences. To determine public goals, relevant stakeholders must be identified and their opinions solicited. This may already have been done and reported in an Areawide Conservation Plan, or it can be accomplished by interviewing neighbors, community board members, and representatives of special interest organizations and government agencies.

Assessment of site and areawide conditions is necessary to confirm resource problems expressed by a landowner and other stakeholders. An assessment also identifies any other existing resource concerns and helps estimate the potential for a buffer to achieve desired conditions. For some of these issues, field indicators or other tools (e.g., RUSLE, HSI, REMM, and GAP analysis) are often used to quantify resource conditions relative to an accepted standard. A thorough assessment at this stage should also provide the necessary detail on resource problems and causal factors to facilitate later stages in the planning process.

A synthesis of the information on existing and desired conditions produces a list of *achievable* desired conditions (or objectives) for which a buffer can be designed. Educating landowners and other stakeholders on the results of an assessment helps refine the list of desired conditions. For example, there may be site conditions a buffer cannot address or that would limit its effectiveness, or additional problems posing opportunities to create more value with a buffer. The landowner and other stakeholders may need to adjust their goals to accommodate this new information. Prioritizing these goals can help reconcile conflicts in both balancing multiple desired conditions and in gaining voluntary acceptance by a landowner. This process produces the desired conditions needing to be achieved with the design of a conservation buffer.

Areawide Conservation Plan

The NRCS calls a plan or assessment developed for a large area an Areawide Conservation Plan. The process of developing the plan is a locally led effort that involves landowners and other stakeholders. They identify public goals and make decisions regarding conservation activities. The plan is used to address conservation issues encompassing watersheds or other large geographical areas that have multiple landowners. This process produces valuable information that cannot be acquired by talking with individual landowners about their site.

Identify ecological functions of buffers that will achieve desired conditions

Achievable desired conditions (objectives) need to be translated into the ecological functions that buffers perform to create those conditions. Those functions are produced by the structure of the buffer vegetation and its arrangement on the landscape. Several examples were given in chapter 1.

Usually, specific causes of an existing undesired condition must be identified to correctly design a buffer that improves that condition. For example, a desired condition may be expressed as “better water quality,” which could mean either greater fish populations or cleaner drinking water (among other possibilities). Furthermore, low fish populations may be caused by low structural debris or high water temperature. Poor drinking water could be caused by sediment from eroding streambanks or nutrients in agricultural runoff. Identification of specific problems allows more accurate identification of the functions buffers must perform to achieve the desired condition of “better water quality.” In this example, the buffer must function to produce large, woody debris or shade to increase fish populations, to stabilize the streambank, or to filter agricultural runoff to improve drinking water quality. The resource assessment conducted should produce information that will help identify the specific functions that buffers must perform.

The scale of controlling functions must also be determined. Some desired conditions can be achieved by buffer functions acting at the site (e.g., soil stabilization against rill erosion). Other conditions, however, must also be addressed by functions that exist beyond the site scale. In the previous example of fish populations, watershed-wide riparian buffers may be necessary to provide adequate shade to moderate stream water temperature. Plans to enhance a larger scale function should show how multiple sites contribute to that function.

Finally, the context (or location) of the site within the larger landscape must be considered. Different ecological functions may achieve the same desired condition depending on location. For example, to increase fish populations, buffers in the upper stream reaches may need to function to keep sediment from spawning areas and provide shade to reduce the temperature in shallow water. Along lower reaches, it may be more important for buffers to provide woody debris for cover and to control bank erosion to maintain channel capacity.

Design a buffer that enhances functions to achieve desired conditions

During steps 5 and 6 of the planning process, alternative conservation treatments that achieve the desired conditions are developed and evaluated. Alternative conservation treatments may involve one or several conservation practices, management measures, and/or works of improvement. If desired conditions can be achieved using permanent vegetation in a strip or area, then buffers need to be considered in the conservation treatment.

The goal in designing a buffer is to place the appropriate vegetation in the right location to enhance the functions that will achieve the identified desired conditions. When designing a buffer, criteria need to be developed that define those characteristics (e.g., location, vegetative composition and density, area, and width) that enhance the appropriate ecological functions to the required level.

Planners well versed in these methods can design buffer systems to meet any combination of objectives by using the specific design criteria identified during planning. Those less familiar with buffer design methods need to use conservation buffer practices.

Purposes of Conservation Buffer Practices

Each conservation buffer practice strives to achieve a high level of effectiveness for a few specific ecological functions, called purposes. For example, the purposes of Contour Buffer Strips are to slow runoff, reduce erosion, trap sediment and other pollutants in runoff water, and/or provide food and cover for wildlife. These purposes help achieve desired conditions including stable and productive soils, cleaner water, and enhanced wildlife populations.

There are 10 conservation buffer practices. Each practice is a general type of buffer (vegetation, size, location, among other design criteria) that is intended to enhance specific ecologic functions. Those target functions are called *purposes* and are listed for each practice. Standards for the design of each practice are intended to assure a high degree of effectiveness for those targeted purposes. Practices can also enhance secondary and incidental purposes. Guidance to achieve these may also be provided in the practice standard.

While practices do not provide the full range of flexibility to address any combination of purposes and desired conditions, they do address the more common ones and simplify the task of designing a buffer to achieve them. Multiple objectives can be accommodated by modifying the practice, within a limit that the primary purpose(s) is not compromised, or by combining different conservation practices on the site.

Table 2–1 illustrates the relationship among broad desired conditions, general ecological functions and purposes of conservation buffers.

Practice selection

Conservation buffer practices have been developed that enhance specific ecological functions on agricultural and other lands. Each practice is designed to enhance only a few target purposes. There may be more than one buffer practice that can enhance a given purpose.

Planners often need to incorporate several functions into a buffer design, and one practice may not be able to address all of them. In such cases two or more practices may be used together to enhance all of the functions required to achieve the planning objectives.

To select a buffer practice that is most appropriate for a specific situation, the planner must understand how each practice functions and how the design can be modified to suit conservation needs. Chapter 3 describes each buffer practice in detail and provides information on how they can be modified to achieve conservation objectives.

See the Practice Selection Decision Key on this page.

Resource Management System

Conservation buffers are most effective in protecting and enhancing natural resources when they are used with other appropriate conservation practices in a system. Conservation buffers are not intended to be stand-alone practices, but rather a component of a resource management system for a field, farm or watershed. A resource management system uses a combination of conservation practices and management to prevent resource degradation and permit sustained use. For example, when designing a system for erosion and water quality on cropland, buffers need to be combined with conservation tillage, nutrient and pest management.

Additional reading

United States Department of Agriculture, Natural Resources Conservation Service. 1988. National Planning Procedures Handbook (NPPH), 180-vi-NPPH, Amend. 2. Washington, DC.

Practice Selection Decision Key

A decision key has been developed to facilitate the identification of conservation buffer practices that may be appropriate for a given situation. The key asks for:

- Landscape position where a buffer would likely be installed
- Primary desired condition or general function requiring enhancement to achieve a desired condition
- Various other characteristics of the situation (often specific ecological functions) that help differentiate practices

The key guides the user to an appropriate practice generally by matching the situation with a purpose for which a practice is intended. In some cases more than one practice is identified. A decision between two or more practices is made based on which one best achieves secondary conservation or other objectives.

Where multiple primary concerns or functions occur, use the key separately for each one. Decide among those practices identified which one or combination of them best addresses all the objectives.

This key is also on the internet at:

www.ftw.nrcs.usda.gov./tpham/buffer/akey.htm

Table 2–1 Relationship among some broad desired conditions, general ecological functions, and specific ecological functions (purposes) of conservation buffer practices. Code numbers for the applicable buffer practice(s) are listed in parentheses.

Broad desired condition	General ecological function	Specific ecological function (purpose) of conservation buffer practice*
Stable and productive soils	**Reduce soil erosion:**	
	• Reduce water runoff energy	• Retard surface water runoff (VB, 332) • Reduce surface water runoff (311, VB) • Convey water to a stable outlet (412) • Control erosion (VB) • Reduce water erosion (311, 393, 386) • Reduce sheet and rill erosion (332) • Disperse concentrated flow to reduce gully erosion (VII) • Divert runoff water to a stable outlet (VII) • Slow out-of-bank flood flow (391)
	• Reduce wind erosive energy	• Reduce wind erosion (311, 422A, 380)
	• Stabilize soil particles	• Protect banks from water erosion (391)
Cleaner water	**Reduce erosion of sediment, nutrients, and other potential contaminants:**	
	• Reduce water runoff energy	• Retard surface water runoff (VB) • Reduce surface water runoff (311, VB) • Convey water to a stable outlet (412) • Divert runoff water to a stable outlet (VB) • Control erosion (VB) • Reduce water erosion (311) • Reduce sheet and rill erosion (332) • Disperse concentrated flow to reduce ephemeral gully erosion (VB)
	• Stabilize soil particles	• Protect banks from water erosion (391)
	• Sequester nutrients	• Improve nutrient utilization (311)
	Remove contaminants from water runoff and wind:	
	• Trap and transform contaminants in water runoff	• Remove contaminants from runoff (393, 332, 386, 412) • Intercept contaminants in surface runoff and shallow ground water (391) • Trap contaminants and facilitate their transformations (VB)
	• Trap wind-borne contaminants	• Catch wind-borne sediment and associated contaminants (589C)
Enhanced wildlife populations	**Enhance aquatic habitat**	• Lower water temperature (391) • Provide debris (391)
	Enhance terrestrial habitat	• Provide or improve wildlife habitat (311, VII, 393, 380, 386) • Provide food and cover for wildlife (589C, 422A, 332, 412, 391)

Table 2–1 Relationship among some broad desired conditions, general ecological functions, and specific ecological functions (purposes) of conservation buffer practices. Code numbers for the applicable buffer practice(s) are listed in parentheses. (cont.)

Broad desired condition	General ecological function	Specific ecological function (purpose) of conservation buffer practice*
Protection for crops, Livestock and structures	Protect from, or manage, wind	• Modify microclimate to improve crop production (311, 380) • Improve irrigation efficiency (380) • Protect crops from damage by wind-borne sediment (422A) • Provide shelter for livestock and structures (380) • Deposit or manage snow (422A, 380)
	Protect from floodwater: • Reduce floodwater levels	• Convey water to a stable outlet (412) • Retard surface water runoff (VB) • Reduce surface water runoff (311, VB)
	• Reduce erosive force of floodwater	• Slow out-of-bank flood flow (391)
Alternative farm income	**Grow marketable plant products**	• Enhance or diversify farm products (311) • Provide tree and shrub products (380, 391)
	Grow marketable wildlife	• See Enhanced wildlife populations
Aesthetics and recreation opportunities	**Reduce undesirable views and noices**	• Provide a living screen (380)
	Enhance natural area	• Enhance aesthetics of an area (311, 380, 393) • Improve aesthetics (380)
Sustainable landscape	**Reduce soil erosion**	• See Stable and productive soils
	Restore native plant species and diverse habitats	• No buffer practices explicitly identified as enhancing this function
	Restore natural ecological processes and patterns	• No buffer practices explicitly identified as enhancing this function

* Practice codes and purposes Alley cropping (311), Contour buffer strips (332), Cross wind trap strips (589), Field borders (386), Filter strips (393), Grassed waterway/vegetated filter systems (412), Herbaceous wind barriers (422A), Riparian forest buffer (391), Windbreak/shelterbeIt (380), Vegetative barriers (VB), as determined from NRCS Conservation Practice Job Sheets dated Apri1 1997.

Chapter 3a Alley Cropping

Definition of alley cropping

Alley cropping is broadly defined as the planting of trees or shrubs in two or more sets of single or multiple rows at wide spacings, creating alleyways within which agricultural, horticultural, or forage crops are cultivated (fig. 3a–1). The trees may include valuable hardwood species, such as nut trees, or trees desirable for wood products. This approach is sometimes called intercropping. The foundation for alley cropping dates back to 17th century (perhaps earlier) Europe where fruit orchards containing intercrops of cereal grains and other crops were grown between the rows of fruit trees. This concept was brought to North America where today most of the emphasis and research focuses on pecan and black walnut alley cropping or intercropping applications. However, there are numerous other potential tree, shrub, and crop combinations.

Purpose of alley cropping

Alley cropping offers a variety of potential financial and environmental benefits to a farm enterprise. These benefits include:

- Diversifies farm enterprises by providing short-term cash flow from annual crops while also providing medium to long-term products from the trees (fig. 3a–2).
- Reduces water erosion on sloping cropland through the interception of rainfall by the tree canopy and increased infiltration as a result of tree and herbaceous roots.
- Improves water quality by interception of sediment by herbaceous cover in tree rows and interception, sequestration, and decomposition of agricultural chemicals by tree and herbaceous root environment.
- Improves crop production by reducing wind erosion, modifying the microclimate, and in some cases providing shade.
- Protects crops from insect pests by reduced crop visibility, dilution of pest hosts because of plant diversity, interference with pest movement, and creation of environments less favorable to pests and more favorable to beneficial insects.

Figure 3a–1 When an agricultural crop is grown simultaneously with a long-term tree crop, the landowner receives an annual income while the tree crop matures

- Enhances wildlife habitats and travel corridors through the addition of tree and herbaceous cover.
- Improves aesthetics by adding trees to an agricultural landscape.

Although alley cropping produces some potential benefits, it also has some limitations:

- Requires a more intensive management system including specialized equipment for the tree management and additional managerial skills and training to manage multiple crops on a given site.
- Removes land from annual crop production and may not provide a financial return from the trees for several years.
- Requires a marketing infrastructure for the tree products that may not be present in some agricultural communities.

Functions

Agroforestry practices tend to be more ecologically complex compared to a monocrop mainly because of the physical and biological interactions that occur when trees or shrubs are integrated with annual crops and forage crops. Some key functions of these more ecologically complex systems include:

Figure 3a–2 Hay is harvested in between rows of maturing walnut trees. This provides supplemental livestock feed or income before the trees produce a product.

- Water management
  - — Alter the hydrologic cycle by increasing water infiltration through disruption of overland flow by the tree/grass strip.
  - — Filter more thoroughly filters water cycled through the system and gradually releases any excess.
- Nutrient cycling
  - — Provides additional nitrogen if a nitrogen-fixing tree or shrub is used.
  - — Uses more nutrients from the deeper root systems of the trees.
- Soil quality
  - — Reduces soil erosion (wind and/or water) by interrupting the soil erosion process.
  - — Adds soil organic matter from leaf drop.
- Microclimate modification
  - — Reduces wind velocity changing temperature and evapotranspiration of intercrop plants and soil.
- Pest management
  - — Provides habitat and increases populations for natural enemies for insects, diseases, or weed pests.
  - — Interrupts pest cycles.
- Waste management
  - — Intercepts, fixes, and biodegrades sediment, nutrients, pesticides, and other biological pollutants.
- Landscape diversity
  - — Adds more biological diversity through increased number of trees/shrubs.
- Economic diversity
  - — Derives products directly from tree/shrub component (wood, nuts, fruit, foliage).
  - — Increases products indirectly derived from tree/shrub component (crops enabled by tree protection).
- Wildlife habitat
  - — Provides food, cover, nesting sites, and travel lanes for a variety of wildlife species.

Not all of these functions exist with each application of alley cropping. The function is dependent upon the way the plant components are manipulated in the design process. There is a lack of understanding of all the different interactions that occur with the different combinations of tree/shrub/herbaceous (annual and perennial) plants. For example, not enough information is available to evaluate all the different pest interactions to positively show that beneficial insects will be favored and the negative pests will be reduced. As different systems are designed, the best knowledge available must be used and the systems for different interactions must monitored.

Design considerations

Location

Alley cropping can be used anywhere crops or forages are grown and adapted trees or shrubs are available to provide either economic and/or environmental benefits to the field. In some instances alley cropping can be used to convert marginal cropland to a permanent forest cover. In others, alley cropping can be designed for both long-term crop or forage production with tree production.

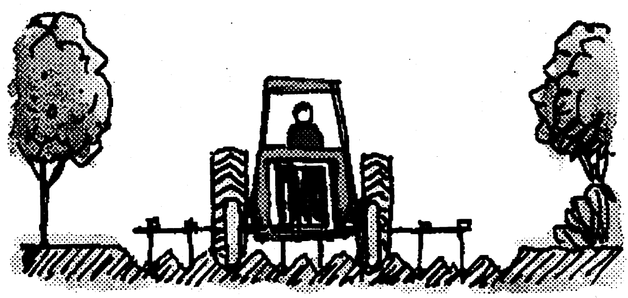
Layout

The tree and/or shrub row(s) are placed at intervals across the crop or hay field, depending on the purpose, either on the contour or perpendicular to prevailing troublesome winds or parallel to the field boundaries. Several factors used to determine the interval between the row(s) of trees or shrubs include:

- Slope length needed to reduce water erosion (similar to contour strip-cropping buffer strip interval which is the lessor of half the predominant downhill slope length or 1.5 times the critical slope length for contour stripcropping as determined from the water erosion prediction models; e.g., RUSLE).
- Field width to reduce wind erosion (derived from the allowable unsheltered distance calculations in the wind erosion models; e.g., WEQ).
- Light requirement for the crop or forage to be grown in the alleyway.
- Multiples of the widest field equipment width (fig. 3a–3).

The row(s) of trees can be either a single species or mixed species. A single species is the easiest to plant, but a mixed species with similar growth rates and site requirements may provide greater economic and environmental diversity. The tree rows can be configured as single rows or multiple rows (fig. 3a–4). The single row takes up the least amount of space, but the trees may require pruning to enhance the quality of the future wood product. Multiple rows, however, result in self pruning of the interior row(s). Conifers are a good choice as the “trainer” trees in the outside rows. The hardwood species tend to bend toward the light in the alleyway, thus reducing their wood value except for chips (fig. 3a–5). Nitrogen-fixing “nurse trees” can also be used for the outside tree rows to help increase the growth rate and improve the form of the high-value interior tree row. Care must be taken to ensure fast-growing nurse trees do not overtop the high-value crop tree in the center.

Figure 3a–3 Widths of the row crop strips are determined by machinery width, sunlight needs of the intercrop plants, and desirable slope distances to control soil erosion.



Between row spacing—If wood production is of primary importance, closer row spacing is desirable. Wider row spacing is preferred when nut production is desired. The spacing should also be adjusted based on multiples of the widest farm equipment to be used in the alleyway. The number of years that light-demanding crops are to be grown in the alleyways is another consideration:

- 40-foot spacing generally allows crop production (e.g., corn, soybeans, cereals) for 5 to 10 years.
- 80-foot spacing allows production for up to 20 years or more.

As the shade increases over the life of the trees, the companion crop being grown in the alleyway may need to be changed. Refer to the section on potential companion crops for more information.

Within-row spacing—The primary objective for the trees and the cost of the stock helps determine the within-row spacing. If erosion control reduction is desired, a closer spacing would give better results. If the tree stock is from unknown origin and quality, a closer spacing gives more opportunities to select the best quality trees during succeeding thinning. However, if expensive grafted tree stock is used for nut production, a wider spacing may be used to reduce cost.

Plant materials

Woody plant species—Desirable characteristics for trees or shrubs that will be grown in an alley cropping system include:

- Produce a commercially valuable product or multiple products (i.e. wood, fruit, chemicals)
- Fast growing

- Tolerant to a variety of soils
- Produce appropriate shade for the companion crop
- Deep-rooted with minimal roots at the soil surface
- Rapidly decomposing foliage except where erosion control is a priority
- Does not produce growth inhibitory chemicals
- Short growing season
- Produce wildlife benefits

All the listed characteristics will most likely not be exhibited by one tree species. Several tree species are either used in alley cropping or have potential for that use.

Black walnut: Markets available for wood and nuts. Produces light shade, has a short foliage period, and is deep rooted. The juglone allelochemical limits companion crop choices somewhat.

Pecan: Markets available for wood and nuts. Nuts more valuable than the wood. More shade produced than walnut, but no allelochemicals.

Figure 3a–5 Most alley cropping systems use a single row of trees in each tree/shrub strip although strips that include training trees for high-value hardwoods may have three or more rows.

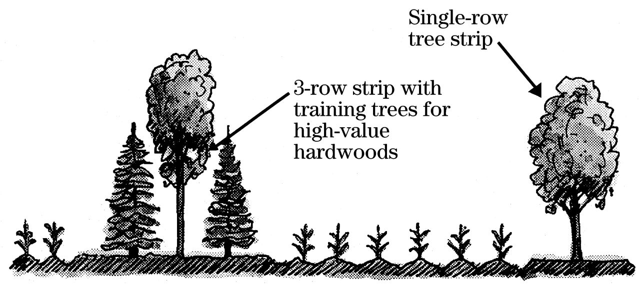
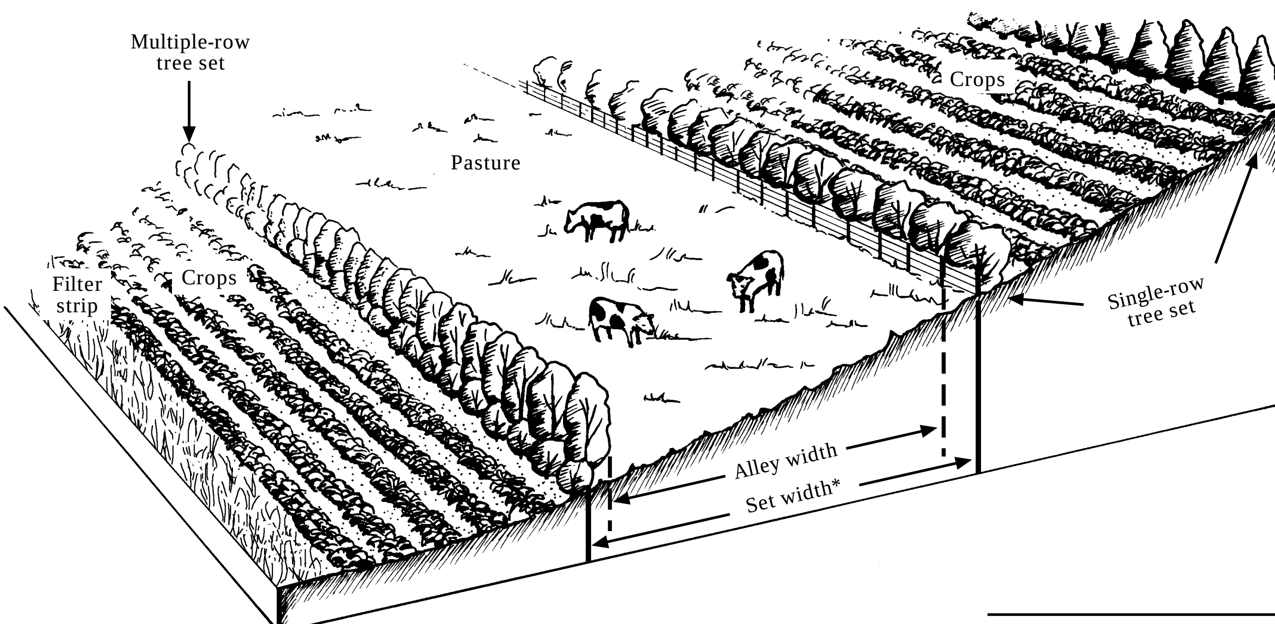


Figure 3–4 Alley width depends on purpose, tree canopy, crop sensitivity, crop rotation, and the crop or forage grown.



*Centerline–to–Centerline

Chestnuts: Chinese, Japanese, and blight-resistant hybrids with American chestnut produce valuable nuts. The value of the wood is low. Chinese chestnut is most blight resistant followed by the Japanese. Japanese is not as cold tolerant as Chinese.

Honeylocust: The seed pods have potential value for livestock feed supplement. The wood has value, but markets are poorly developed. It produces a light shade and is deep-rooted.

Oaks: The wood has a high value, and the acorns are good wildlife food. The oaks are relatively slow growing and produce fairly dense shade.

Ash: The wood is high value, but there are no other potential products. These trees are relatively fast growing and produce a light shade.

Persimmon: The fruit is edible by humans and wildlife. The heartwood is valuable, but is slow to develop.

Fast growing hardwoods (cottonwood, hybrid poplars, silver maple, birch): Markets are emerging for use in pulp/paper or oriented strand board.

Black locust: This fast-growing, nitrogen fixing tree of durable wood is used for posts and other such uses. The drawbacks include the thorns and susceptibility to borer attack.

Mesquite: This species actually has a high value wood for use in flooring and furniture because of its low shrinkage characteristic. Chips are also used for cooking meat. It is a nitrogen fixing plant, and the seed pods provide livestock fodder.

Nut or fruit bearing shrubs: The hazelnut, pawpaw, blueberries, and other nut or fruit bearing shrubs can be used as stand-alone hedgerows or in combination with other taller tree species.

> Studies in the Southeast conclude that a double-row versus a single-row configuration of slash pine (Pinus elliotti Engelm) with forages in-between is a superior design. After 13 years, double-row plantings, where within- and between-row spacing are sufficiently wide (e.g., 4 feet x 8 feet with about 40 feet between the double row sets), produce as much wood per acre as the same number of trees in single-row configuration. Moreover, double-row configurations produce more forage than single rows.

Conifers: Several suitable species are available, but the shade produced may limit the companion crops to forages, horticultural crops, or other specialty crops.

Exotics: Paulownia is a fast-growing tree that produces a valuable wood for Asian export, but no other products. It is adapted primarily to the Southeast.

Potential companion crops: Companion crops chosen for the alleyway depend on their light, moisture, and nutrient requirement as well as the growth period in relation to the woody species. Since the tree-crop interface interactions will change over the life of the woody perennial, the companion crop selection may change during different life stages of the woody plants. Some considerations for different types of companion crops follow.

Row crops—Corn, soybeans, sorghum, wheat, barley, oats, potatoes, and peas have demonstrated success in an alley cropping system. Most of these crops have high light demands. In a 40-foot wide alleyway, shade will limit their use after 5 to 10 years depending on the tree species (3 to 4 years with fast growing species). Juglone from walnut has not been reported to significantly affect row crops. Cool-season small grains can be planted close to tree rows early in the rotation since weed control space is not needed, maximizing crop production. Using corn in the first few years speeds tree growth by creating a greenhouse effect for the tree rows.

Forage crops—On more erosive slopes with droughty and/or poorer soils, forage crops may be a more suitable intercrop. Tall fescue and orchardgrass tolerate considerable shade and are productive cool-season grasses. Other potential forages that show shade tolerance include desmodium, Kentucky bluegrass, ryegrass, smooth brome, timothy, white clover, and alfalfa. Bermudagrass, a productive warm-season perennial, is the most commonly grown forage in pecan orchards, but has low shade tolerance. Winter annuals, such as cereal grains, crimson clover, and hairy vetch, must be reseeded every year. They only provide one cutting of hay, but do not compete with the trees and provide good erosion control.

Specialty crops—Landscaping plants, Christmas trees, and small fruit trees or shrubs can be grown either temporarily between the permanent in-row crop trees or in the alleyways. As the alleyways become more shaded, shade tolerant species, such as redbud, dogwood, and spruce, could be grown for landscaping if there is a nearby market. A variety of shade tolerant medicinal/ornamental/food plants (e.g., ginseng, golden seal, mushrooms) may also be an option for under the rows of trees or in alleyways that have closed canopy.

Biomass crops—Both woody and herbaceous plants for biomass production could be an option for the alleyways. Soft hardwood species, such as poplars, willow, sycamore, silver maple, and birches, could be grown for pulp, paper, or oriented strand board if markets are available. Nitrogen fixers, such as black locust and alders, might also be alternative species. Herbaceous biomass crops (e.g., switchgrass) could be another alternative.

Iowa State University produced a herbaceous energy crop in 50-foot alleyways between dual rows of hybrid poplars. The potential dry weight yields of woody biomass could be as high as 3 to 4 tons/ac/yr, while the herbaceous species, such as switchgrass, will yield 3 to 6 tons/ac/yr. This is based on a study using different application rates on municipal waste sludge.

Operation and maintenance

All buffers need to have an operation and maintenance plan to assure they continue to function as desired. The items to be included in the plan for alley cropping are described in this section.

Weed/grass control

Weed control is important for the intercrop. For rowcrops, weed control depends on the tillage system being used ranging from coventional tillage to no-till. Regardless of the method, the goal should be to have few or no weeds present when the crop emerges. This can be achieved with either tillage or herbicides. After crop emergence, weed control should target those weeds that may present the greatest economic threat using either post-emergent herbicides or tillage.

Weed control for alley cropping includes both the rows of trees and the intercrop. For the tree row(s), most weeds need to be minimized for the first 3 to 5 years in a band about 3 feet on each side of the trees. If mechanical cultivation is used (sweep, disc, spring tooth, rototiller), several cultivations may be needed each year, depending on the geographic area. If cultivation is used, the tillage depth should be shallow (2 to 4 inches) to avoid excessive damage to surface tree roots. Some specially designed implements that operate on a hydraulic arm can cultivate in the row. These implements need to be operated carefully to avoid damage to the seedlings.

Chemical weed control (pre- and/or post-emergent herbicides) can be a relatively inexpensive approach with a single treatment generally lasting longer than mechanical methods. Approved herbicides for trees come and go, so check with the county agent, state forester, or other certified/licensed herbicide specialist. The sprayer must be calibrated correctly.

A third weed control alternative for the trees is to use some type of mulch. Synthetic woven plastic weed barriers are available commercially. These synthetic mulches range from 4-foot squares to continuous rolls 6 feet wide. Most mulches biodegrade over time. The mulches not only control weeds, but also conserve moisture. Initial cost is significant, but some mulch products will not degrade for 5 years or beyond. Organic mulches, such as wood chips, can also be used if a ready supply is available. Research is being done on potential living mulches, such as clovers, to see if they could provide not only weed suppression, but also some nitrogen fixation.

Supplemental irrigation

Irrigation is not a substitute for good site preparation and weed/grass control. In the humid and semiarid regions, irrigation may be needed for the trees and/or intercrop when soil moisture conditions are extremely dry at planting time or during prolonged drought after planting. In arid regions of the country, permanent irrigation systems may need to be designed to ensure adequate survival and growth. Hand, drip, sprinkler, furrow, or flood irrigation can be used.

Where pre-emergent herbicides are used for in-row weed control for the trees, irrigation should be used sparingly to prevent leaching of herbicide into the tree root system. Irrigation should be considered only a temporary maintenance practice used to ensure survival in the humid and semiarid regions. The water source needs to be tested to assure it is not toxic to the plants. Irrigation should be discontinued in the fall to slow plant growth and allow hardening off before winter.

Routine maintenance needed on the irrigation equipment includes:

- clean filters
- clean emitters on drip systems
- repair damaged or split pipe
- repair any malfunctioning spray heads, pipes, or other components
- clean furrows for unimpeded flows

Replanting
Replant all trees or shrubs that have failed. Replant annually for at least 3 years after the initial planting and continue until full stand of trees is attained.

Fertilization
Generally, fertilization of the tree crop is not needed. A normal fertility program applied for the intercrop in the alleyway also benefits the tree crop.

Branch pruning
Pruning of the trees may be necessary, depending on the design, to improve wood quality and the microenvironment for the companion crop. A single log length (prune to about 13 feet) is generally desirable. This length allows adequate crown development if nuts are being sought and limits shade to the companion crop. Tip pruning may be necessary to allow equipment access. Hail, wind or snow storms often cause breakage of limbs and sometimes the main trunk of the trees and shrubs. Corrective pruning of broken limbs and tops is needed on these occasions.

Root pruning
The tree roots projecting into the companion crop area sometimes need pruning. Normally pruning is done to a 24-inch depth. Root pruning should be done only on one side of the tree row. Allow a 3-year interval before pruning the other side. Once root pruning is started, it probably needs to be continued on a 5- to 8-year interval. Pruning is normally done about 2 feet beyond the drip line of the trees.

Thinning
Tree rows need to be thinned to increase light in the alleyways and speed production of high value crop trees.

Protection
Firebreaks (10- to 20-foot mowed or tilled strips) around the trees may be needed if the crops grown in the alleyways present a fire hazard. If row crops are tilled annually, the need for firebreaks is less.

Trampling and browsing damage from livestock or wildlife may be a concern for the trees. The damage may occur directly on the trees or through soil compaction to the root systems. Do not graze until trees are of sufficient size. Develop and follow a grazing plan for proper utilization of forage and protection of trees or establish appropriate fencing to prevent livestock damage, and repair broken fences promptly. Consult local and state game/wildlife specialists on control of large game, small mammals, and rodents. Control measures include repellents, fencing, and seedling protectors (e.g., photodegradable vexar tubing or plastic mesh netting).

Insects and diseases can significantly reduce the health and vigor of both the tree crop and the intercrop. Periodic inspection of the crops and trees is recommended to detect and identify possible pests. These inspections and in some cases the use of pheromone traps help determine when corrective action is warranted. The corrective actions can include chemical controls and/or cultural or mechanical controls. Actions taken should minimize the impacts on beneficial insects.

Information needed to fill in job sheet

Purpose

A specifications sheet should be filled out for each alley cropping site. This sheet will be used by the landowner or manager. Indicate the landowner’s name and the field number corresponding with the conservation plan map. Check those purposes that apply to the particular site based on the objectives of the landowner.

Location and layout

Complete the planned distance for the alley width, which is the distance available to produce the companion crop in the alleyway. The spacing between tree sets is the distance from the center of one tree/shrub set to the center of the next tree/shrub set. This distance is used during layout of the system. Mark the appropriate box for the orientation of the alley cropping tree/shrub sets.

Plant materials

Complete the recommended planting date for the trees/shrubs. For each tree/shrub set shown on the sketch, list the species (including specific cultivars) for each row in the set. If only single rows are used, only the first line in each set would be completed. Explain what type of planting stock is planned using the symbols in the footnote (BA=bareroot, CO=container, CU=cutting) as well as the size of the desired stock. Record in the next column the distance between the individual plants in the row. Based on the estimated length of the row, estimate the number of plants needed for each row. In the final column, record the spacing between individual rows within a given set.

Other instructions

On the back of the specification sheet, complete a sketch for the planned alley cropping sets. This should include the number of rows in each set as well as the distances between the rows, sets, and effective alley width for the companion crop.

Under Additional specifications and notes, the type of companion crop(s) planned could be noted. Detailed information about the planting and management of the companion crop would probably be explained under the conservation crop rotation practice description in the conservation plan.

Additional Reading

Garrett, H.E., and R.L. McGraw. 1998. Alley cropping. *In* Agroforestry - An Integrated Science and Practice, American Society of Agronomy, (*In* press).

Hall, D.O., and J.I. House. 1993. Biomass as a modern fuel. *In* Proceedings IEA Bioenergy Environmental Impact Seminar, Elsinore, Denmark.

Lewis, C.E., G.W. Tanner, and W.S. Terry. 1985. Double vs. single-row pine plantations for wood and forage production. Southern Journal of Applied Forestry, 9:55-61.

Rietveld, W.J. 1997. Agroforestry for conservation, now and in the future. *In* Proceedings of Agroforestry for Sustainable Land-use: Fundamental Research and Modeling Temperate and Mediterranean Applications, Montpellier, France, pp 105-107.

United States Department of Agriculture, Natural Resources Conservation Service. 1996. Agroforestry for farms and ranches. Agroforestry technical note 1, 26 pp.

Ward, T. 1998. Alley cropping for sustainable agricultural systems. Lesson plan for the training course: Agroforestry - A Conservation Planning Opportunity. United States Department of Agriculture, Natural Resources Conservation Service, (*In* press).

Alley Cropping

Conservation Practice Job Sheet **311**

Natural Resources Conservation Service (NRCS) ***April 1997***

Landowner____

Definition

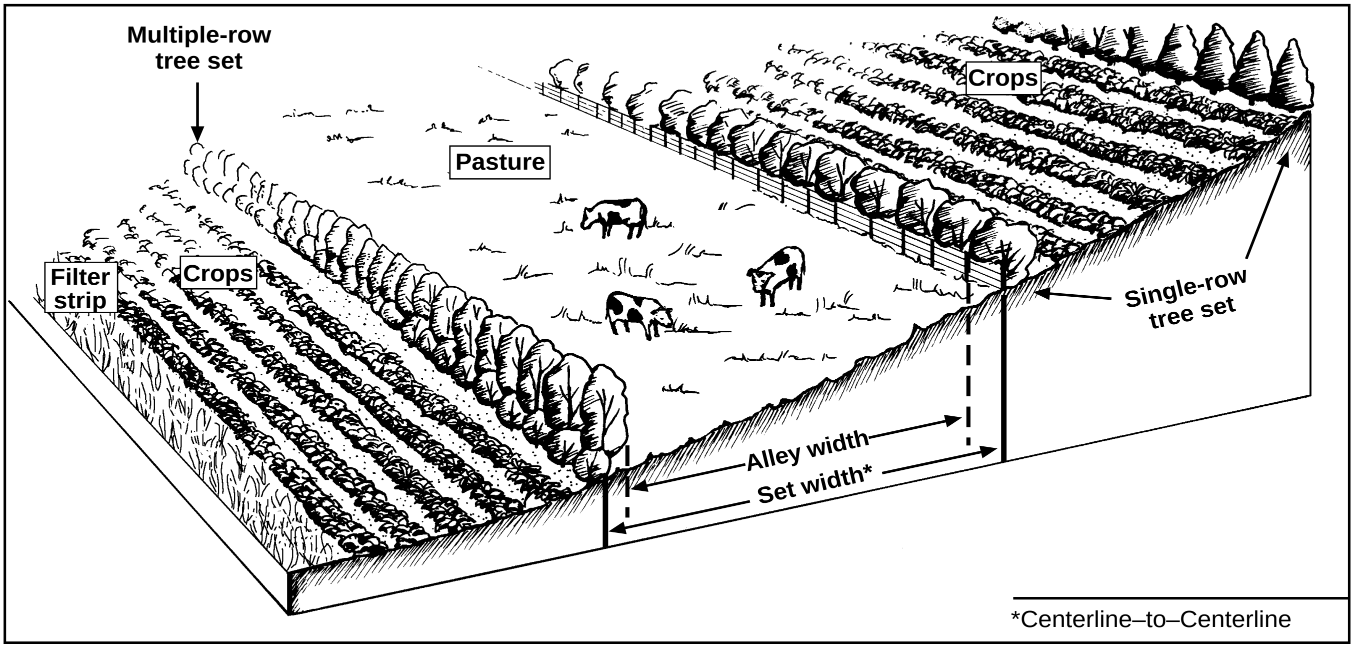
Alley cropping is the planting of trees or shrubs in two or more sets of single or multiple rows with agronomic, horticultural, or forage crops cultivated in the alleys between the rows of woody plants.

Purpose

Alley cropping is used to enhance or diversify farm products, reduce surface water runoff and erosion, improve utilization of nutrients, reduce wind erosion, modify the microclimate for improved crop production, improve wildlife habitat, and enhance the aesthetics of the area.

Trees

Trees or shrubs are generally planted in a single- or multiple-row set or series. The spacing between sets is determined by the primary purpose of the alley cropping and the agronomic, horticultural, or forage crop grown. Woody plants are typically selected for their potential value for wood, nut, or fruit crops and/or for the benefits they can provide to the crops grown in the alleys. Common tree species are black walnut, pecan, green ash, and northern red oak. There are many other compatible species, depending upon region of the country, value, and markets.



Alley width depends on purpose, tree canopy, crop sensitivity, crop rotation, crop or forage grown.

Crops

All traditional crops can be grown with alley cropping. The primary factors determining which crops can be grown are the canopy density and sunlight requirement for the agronomic, horticultural, or forage crop.

Management

When row sets are spaced at relatively close intervals (40 feet or less), row crops can be grown for several years until the tree canopy begins to compete for sunlight. Management options include:

- Change the crop grown in the alleys from row crop to small grain to forage and potentially to tree plantation as the trees mature and the canopy shades the alley crop.
- Plan for a specific crop rotation and manage the trees to keep the canopy (competition for light) within the requirements of the crops grown.

Where used

Alley cropping is used where improved economics or environmental conditions are desired over the existing farming practices. Alley cropping in addition to the tree or shrub products grown, is used with row, small grain, or specialty crop production. The sites selected must be suited to produce both the woody and herbaceous crop species desired.

Conservation management system

Alley cropping is normally established as part of a conservation management system to address the soil, water, air, plant, and animal needs and the owner's objectives. When agronomic and horticultural crops are grown, it is important to plan the conservation crop rotation, nutrient and pest management, crop residue management, and other cropland practices. Proper grazing use and other forage practices for pasture and hayland need to be applied when forage crops are used. When alley cropping is used for erosion control, trees are planted on the contour in conjunction with a contour buffer strip.

Wildlife

Alley cropping provides excellent opportunities to improve wildlife habitat for some species by creating travel lanes connecting important habitat areas or infield cover. Practices, such as wildlife upland habitat management, provide guidance for applying alley cropping to meet wildlife objectives.

Operation and maintenance

Trees must be periodically inspected and protected from damage so proper functioning is maintained. Care must be taken to utilize chemicals or chemical applications that are compatible both with the tree crop and the alley crop.

Specifications

Site-specific requirements are listed on the specifications sheet. Additional provisions are entered on the job sketch sheet. Specifications are prepared in accordance with the NRCS Field Office Technical Guide. See practice standard Alley Cropping code 311.

Landowner____ Field number___________

Purpose (check all that apply)	
☐ Diversify farm products to improve or optimize economics	☐ Regulate excess subsurface water
☐ Protect growing plants (crops, forage, other)	☐ Provide wildlife habitat
☐ Reduce water runoff and erosion	☐ Improve aesthetics
☐ Reduce wind erosion	☐ Other (specify):
☐ Decrease nutrient/chemical loss	☐

Location and Layout
Alley width (ft)[1]:
Spacing between tree sets[2]:
Tree set orientations: (See diagram job sketch) ☐ Contour ☐ East/West ☐ North/South ☐ Other (specify) ______________________________

[1]Distance available for herbaceous crop production. [2]Distance from the center of one tree/shrub set to the center of the next tree/shrub set.

Woody Plant Materials Information				
Planting dates:				
Species/cultivar by row number *Set number [1/]*	Kind of stock[2]	Plant-to-plant distance(ft) within row	Total number of plants for row	Distance (ft) between this row and next row[3]
1				
2				
3				
4				
Set number [1/]				
1				
2				
3				
4				

[1] Indicate set number as shown on sketch.
[2] BAreroot, COntainer, CUtting; include size, caliper, height, and age as applicable.
[3] Adjusted for width of maintenance equipment.

Site Preparation
Remove debris and control competing vegetation to allow enough spots or sites for planting equipment. For plantings requiring supplemental moisture, prepare and ready applicable materials for installation. Additional requirements:

Temporary Storage Instructions
Planting stock that is dormant may be stored temporarily in a cooler or protected area. For stock that is expected to begin growth before planting, dig a V-shaped trench (heeling-in bed) sufficiently deep and bury seedlings so that all roots are covered by soil. Pack the soil firmly and water thoroughly.

Planting Method(s)
For container and bareroot stock, plant stock to a depth even with the root collar in holes deep and wide enough to fully extend the roots. Pack the soil firmly around each plant. Cuttings are inserted in moist soil with at least 2 to 3 buds showing above ground. Additional requirements:

Alley Cropping Maintenance
Tree planting must be inspected periodically and protected from damage so proper function is maintained. Replace dead or dying tree and shrub stock and continue control of competing vegetation to allow proper establishment. For plantings used for water erosion, grass needs to be maintained in the single row sets. See standard maintenance requirements.

If needed, an aerial view or a side view of the alley cropping can be shown below. Other relevant information, such as complementary practices, adjacent field or tract conditions, and the positioning of multiple or single row sets across a field or tract, and additional specifications may be included.

Scale 1"=________ ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")

Additional Specifications and Notes:

Chapter 3b Contour Buffer Strips

Definition of contour buffer strips

Contour buffer strips are narrow strips of permanent, herbaceous vegetative cover established across the slope and alternated down the slope with wider cropped strips (fig. 3b–1).

Contour buffer strips are most suitable on slopes ranging from 4 to 8 percent where slope lengths are less than the critical slope length beyond which contouring loses its effectiveness. Critical slope length is determined by using the Revised Universal Soil Loss equation (RUSLE) or other approved erosion prediction technology.

The practice is not suited to long slopes where lengths exceed critical slope length by more than 1.5 times unless other practices, such as terraces or diversions, are installed to intercept the flow.

Contour buffer strips are more effective in trapping sediment and filtering pollutants and less likely to fail in areas where storm energy intensities are low to moderate and where 10-year erosion index (EI) values as used in RUSLE are less than 140.

Purpose of contour buffer strips

This practice has two primary purposes for which it can be designed and installed:

- to reduce sheet and rill erosion
- to reduce transport of sediment and other waterborne contaminants downslope, onsite, or offsite

In addition to these primary purposes, the practice may also enhance wildlife habitat.

Design considerations

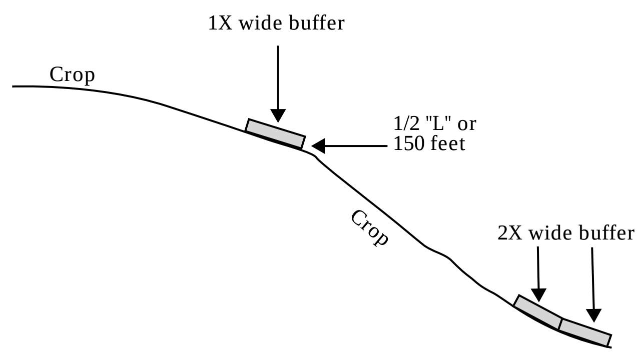
Location and layout

Buffer strip width
The actual width of the contour buffer strip is determined by the purpose or purposes identified, the type of vegetation to be established, and its effectiveness. Where more than one purpose is being served, the most restrictive criteria governs.

Minimum widths for various purposes and types of vegetation are stated in the contour buffer strip practice standard for your area. Generally, contour buffer strips are a minimum of 15 feet wide for grasses or grass legume mixtures and 30 feet for legumes alone. Experience has shown that by increasing the minimum width to 20 feet, flow velociy through the buffer is reduced even further thus reducing the risk of erosion immediately below the buffer.

Width of cultivated strips
Since contour buffer strips are established in conjunction with contour cropped strips, the spacing between buffer strips is determined by the purpose(s) being served and the criteria stated in the practice standard.

Figure 3b–1 Typical slope with contour buffer strips designed to reduce contaminants



Generally, for erosion control the criterium is the lesser of half the predominant downhill slope length or half the critical slope length for contour strip cropping as determined using RUSLE or other approved erosion prediction technology. Critical slope lengths can be increased by increasing residue cover or roughness, which changes the vegetative cover management conditions of the cropped strip.

The criterium for reducing sediment or other waterborne contaminants is generally the lesser of half the predominant downhill slope length or 150 feet (fig. 3b–1). To determine the minimum width of cultivated strips, some preliminary slope information must be collected in the field and run through RUSLE. Additionally, equipment must fit well with contour buffer strips. Not only must the strips be parallel, but they must also be planned on multiples of the working width of equipment, typically, the planter or drill used to plant the crops. This adjustment will prevent encroachment into the buffer strip or the planting of point rows. Tables 3b–1 through 3b–4 show strip widths for various planter and drill widths and row spacing.

For example, if common planting equipment is six 30-inch rows, the working width of each pass is 15 feet. If half of the downhill slope length is 125 feet, the appropriate spacing would be adjusted downward to 120 feet or eight passes (four rounds) with the 15-foot-wide 6-row planter.

Strip width is not as much of an issue with drilled or broadcast seeding methods. If other crops, such as small grains or drilled soybeans, are planted in the rotation, a spacing of 120 feet fits multiple passes of 8-, 10-, 12-, 15-, 20-, 24-, and 30-foot wide drills.

Consideration must also be given to use of other equipment, such as sprayers. For example, a sprayer with a 60-foot boom can be successfully used on a 120-foot-wide strip by making two passes or on a 90-foot strip by making one full pass and then a half pass with half of the boom shut off to avoid overlap and spraying the buffer strip.

Table 3b–1 Strip width adjustments for planters on 30-inch rows

# of	- - - - - - - 4 row - - - - - - -		- - - - - - - - 6 row - - - - - - - -		- - - - - - - 8 row - - - - - - -		- - - - - - - - 12 row - - - - - - -	
passes	# of rows	width ft	# of rows	width ft	# of rows	width ft	# of rows	width ft
1	4	10	6	15	8	20	12	30
2	8	20	12	30	16	40	24	60
3	12	30	18	45	24	60	36	90
4	16	40	24	60	32	80	48	120
5	20	50	30	75	40	100	60	150
6	24	60	36	90	48	120	72	180
7	28	70	42	105	56	140	84	210
8	32	80	48	120	64	160	96	240
9	36	90	54	135	72	180		
10	40	100	60	150	80	200		
11	44	110	66	165	88	220		
12	48	120	72	180	96	240		
13	52	130	78	195				
14	56	140	84	210				
15	60	150	90	225				
16	64	160						
17	68	170						
18	72	180						
19	76	190						
20	80	200						
21	84	210						
22	88	220						
23	92	230						

Table 3b–2 Strip width adjustments for planters on 20-inch rows

# of	4 row		6 row		8 row		12 row	
passes	# of rows	width ft	# of rows	width ft	# of rows	width ft	# of rows	width ft
1	4	6.67	6	10	8	13.33	12	20
2	8	13.34	12	20	16	26.66	24	40
3	12	20.01	18	30	24	39.99	36	60
4	16	26.68	24	40	32	53.32	48	80
5	20	33.35	30	50	40	66.65	60	100
6	24	40.02	36	60	48	79.98	72	120
7	28	46.69	42	70	56	93.31	84	140
8	32	53.36	48	80	64	106.64	96	160
9	36	60.03	54	90	72	119.97		
10	40	66.70	60	100	80	133.30		
11	44	73.37	66	110	88	146.63		
12	48	80.04	72	120	96	159.96		
13	52	86.71	78	130				
14	56	93.38	84	140				
15	60	100.05	90	150				
16	64	106.72	96	160				
17	68	113.39						
18	72	120.06						
19	76	126.73						
20	80	133.40						
21	84	140.07						
22	88	146.74						
23	92	153.41						
24	96	160.08						
25	100	166.75						

Table 3b–3 Strip width adjustments for planters on 38-inch rows

# of passes	4 row # of rows	4 row width ft	6 row # of rows	6 row width ft	8 row # of rows	8 row width ft	12 row # of rows	12 row width ft
1	4	12.67	6	19	8	25.33	12	38
2	8	25.34	12	38	16	50.66	24	76
3	12	38.01	18	57	24	75.99	36	114
4	16	50.68	24	76	32	101.32	48	152
5	20	63.35	30	95	40	126.65	60	190
6	24	76.02	36	114	48	151.98	72	228
7	28	88.69	42	133	56	177.31	84	266
8	32	101.36	48	152	64	202.64	96	304
9	36	114.03	54	171	72	227.97		
10	40	126.70	60	190	80	253.30		
11	44	139.37	66	209	88	278.63		
12	48	152.04	72	228	96	303.96		
13	52	164.71	78	247				
14	56	177.38	84	266				
15	60	190.05	90	285				
16	64	202.72	96	304				
17	68	215.39						
18	72	228.06						
19	76	240.73						
20	80	253.40						
21	84	266.07						
22	88	278.74						
23	92	291.41						
24	96	304.08						
25	100	316.75						

Table 3b–4 Strip width adjustments for drills and seeders on 15-inch rows

# of passes	4 row # of rows	4 row width ft	6 row # of rows	6 row width ft	8 row # of rows	8 row width ft	12 row # of rows	12 row width ft
1	8	10	12	13	15	20	24	30
2	16	20	24	26	30	40	48	60
3	24	30	36	39	45	60	72	90
4	32	40	48	52	60	80	96	120
5	40	50	60	65	75	100	120	150
6	48	60	72	78	90	120	144	180
7	56	70	84	91	105	140	168	210
8	64	80	96	104	120	160	192	240
9	72	90	108	117	135	180		
10	80	100	120	130	150			
11	88	110	132	143	165			
12	96	120	144	156	180			
13	104	130	156	169				
14	112	140	168	182				
15	120	150	180					
16	128	160						
17	136	170						
18	144	180						
19	152							
20	160							
21	168							
22	176							
23	184							

Alignment

Alignment is generally the most important factor in farmability of contour buffer strip systems. The tools for the traditional method of laying out a key line for establishment of a contour buffer strip system are a hand level, a measuring tape, cable, or rope equal to the maximum width of the cropped strips, an assistant, and some surveying flags.

Laying out the key line

On level ground, determine your eye height on the assistant by sighting through the hand level to a point on your assistant the same level as your eye.

Walk to the top of the slope where the buffer strips are to be installed. Measure downhill the width of the crop strip as previously calculated and place a surveying flag in the ground. If two prominent hills are joined by a somewhat lower ridge or saddle, measure down from the seat of the saddle rather than the top of either of the hills (fig. 3b–2). If this condition exists, one or more contours may be needed above the key line to fully protect the top of the slope.

Position the assistant at the survey flag. Taking flags and the hand level, pace about 50 feet across the slope at approximately the same elevation and sight back on the same spot on your assistant that was identified on level ground. Move up or down slope until the hand level bubble is centered on the spot on your assistant. Put a flag in the ground at your feet at this spot. Pace another 50 feet around the slope while the assistant moves to the second flag. Repeat the process.

Continue setting flags on the contour until you reach the field edge. Return to the beginning flag and repeat the process in the opposite direction until you reach the other field edge. The line you have staked is the key contour line and the upper border of the first grass strip. Drive a pickup or tractor along the line to make sure there are no curves too sharp to maneuver machinery. Straighten any curves by adjusting one or more flags. Varying the grade along the line is a useful technique to increase farmability by straightening curves.

Laying out the contour buffer strip

Find the steepest part of the slope along the contour line and measure downhill the minimum width of the grassed strip. This contour line will be the lower border of the grass strip (fig. 3b–2). Place a different colored flag at that point and lay out another contour line using the procedure described above. Unless the topography is uniform, the grass strip will not be a uniform width. It should not be narrower than the minimum buffer width at any point.

Laying out the second crop strip

From the line representing the lower border of the grass strip just staked, extend a tape or cable downhill the width of the cropped strip (fig. 3b–3). One person walks along the line just staked while the other person stretches the cable perpendicular to that line and places flags at 50-foot intervals along a new line parallel to the bottom edge of the grass strip. The cable should always be stretched perpendicular to the previously staked line to ensure that the cropped strip is of uniform width.

Figure 3b–2 Staking key line and buffer widths

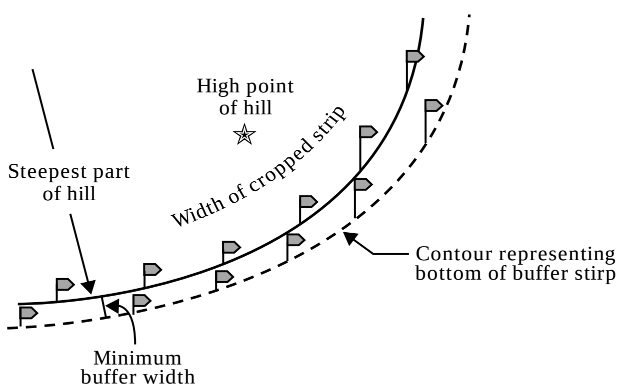
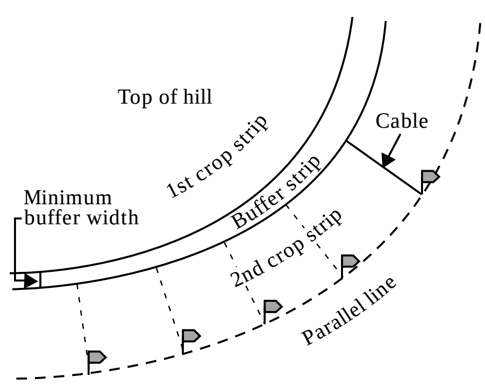


Figure 3b–3 Staking width of cropped strip below buffer strips



One helpful method of ensuring that measurements are made perpendicular to the lower edge of the preceding grass strip involves the use of a pickup truck. Attach the cable to the front corner of the pickup bed in the gap next to the pickup cab (fig. 3b–4). One person drives the truck along the contour line while the other stretches the cable down hill the width of the crop strip. At points around the slope, the person at the end of the cable places flags at 50 foot intervals by first aligning himself or herself such that daylight can be seen through the gap between the truck bed and cab. This ensures that the crop strip is parallel to the bottom of the grass strip above, and is of uniform width.

If the topography is uniform, additional strips may be established parallel to the first by simply staking parallel lines using the cable and truck. However, if the topography is not uniform, additional grass strips should be staked by finding the steepest point along the lower border of the crop strip just staked, measuring down the width of the grass strip, and staking a new contour line representing the lower border of the grass strip. The crop strip width is flagged using the truck and cable or other means to ensure uniform width.

This procedure avoids point rows, but may result in more area comprising grass buffers. The procedure can be reversed to establish even width grass strips that minimize the amount of the field in grass, but point rows and a less farmable system result.

An alternate method for layout of contour buffer strips can be used in irregular topography to ensure that the leading edge of each buffer strip is on, or close to the contour. In this method the key line is staked in the same fashion as described previously. Next, at the steepest part of the slope, a point is staked downslope from the keyline equaling the minimum width of the buffer strip plus the adjusted crop strip width. From this point another contour line is staked representing the leading edge of the second contour buffer strip. This line is then adjusted for farmability. Next, using the cable or rope representing the adjusted crop strip width, the crop strip is staked between the two buffers. The line staked is the lower edge of the first contour buffer. Irregularities in the two contour lines are contained the variable width of the buffer strip.

Opportunities exist to enhance wildlife habitat in the irregular shaped contour buffers. Trees and shrubs may be established in areas where sharp corners are avoided if they do not interfere with normal equipment operation.

Reverse curves

Reverse curves should be avoided in contour buffer strip layout. A reverse curve is two circular curves on the opposite side of a common tangent (fig. 3b–5). As an example, the line may first curve to the right and then to the left. Each of the curves has a radius point, so as rows are planted parallel to the line they can only be parallel as far away as the radius point of each curve. Each curve becomes more gradual and more farmable as rows are planted parallel to the line as the length of the radius increases. However, the curve

Figure 3b–4 Buffer strip layout using a pickup truck and cable

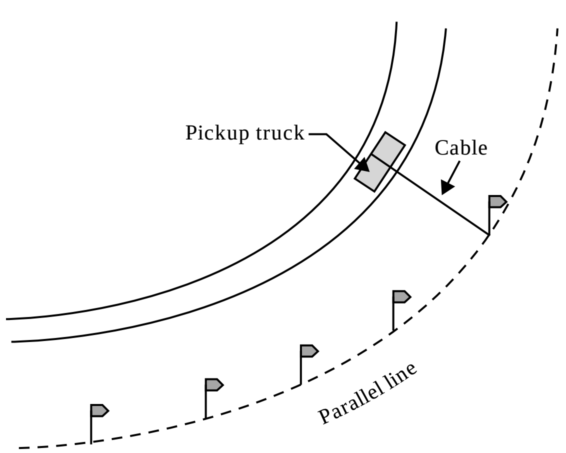
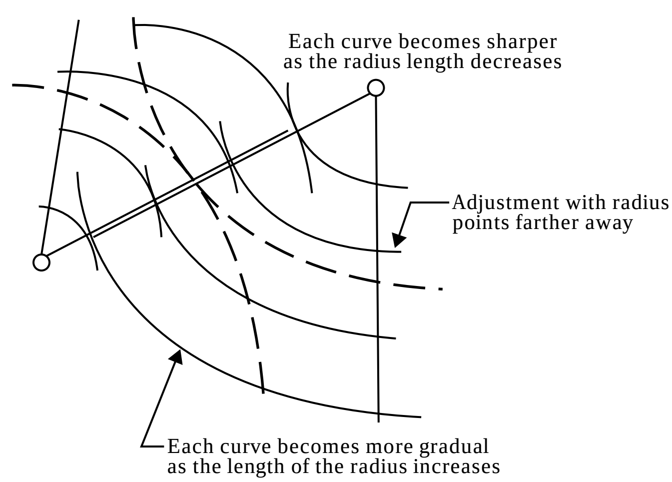


Figure 3b–5 Contour line adjustment for reverse curves



becomes sharper as the length of the radius becomes shorter. At some point, depending on the size of equipment, the curved rows become too sharp to be farmable. This can be avoided by making the curves more gradual, by moving the radius point farther away, or by putting some grade in the buffer boundary.

Buffer strips should be parallel to the extent possible. Where topography is irregular, each buffer strip should have a parallel crop strip above it with the correction made by varying the width of the buffer strip by re-aligning the lower boundary instead of planting point rows in the cropped strip.

Although, farmability is important in the acceptance of a contour buffer strip system, the flattening of curves should not result in grades along the edges of the buffer or crop rows exceeding the lesser of half the downhill slope grade or 2 percent (fig. 3b–6). Up to 3 percent row grade may be permissible for distances of less than 150 feet as rows approach a stable outlet, such as a grassed waterway. Maximum effectiveness of the buffer is achieved when overland flows are broad and not concentrated as they enter the buffer.

Layout at field edges

Contour buffer strip systems are more farmable when they approach the ends of the field at right angles (fig. 3b–7). This facilitates the turning of equipment. In other cases buffer strips may be laid out parallel to field edges with slight adjustments in grade and alignment to avoid point rows. In either case, opportunities may exist to establish field borders to facilitate equipment operation and enhance the effectiveness of the entire system.

Plant materials information

The state contour buffer strip practice standard contains minimum requirements for locally adapted vegetation for the buffer strips to be established for various purposes. Generally, contour buffer strips are established to either legumes, grasses, or grass-legume mixtures when erosion control is the primary purpose. Permanent sod-forming grasses alone are used when filtering of sediment or other water-borne contaminants is the primary purpose. If both purposes are served, then the more stringent criteria for sod forming grasses should be used.

Stem densities of mature stands should be greater than 50 stems per square foot for grasses and greater than 30 stems per square foot for legumes depending on the purpose of the buffer and the species seeded. Species should be adapted to the climate and soil conditions of the site. If the state standard does not contain specific plant materials criteria, suitable seeding mixtures meeting the requirements for buffer purposes may be selected from other vegetative practice standards, such as Grassed Waterways, Critical Area Planting, or Pasture and Hayland Planting. Generally, the grass mixtures and seeding rates from the

Figure 3b–6 Buffer boundary grade

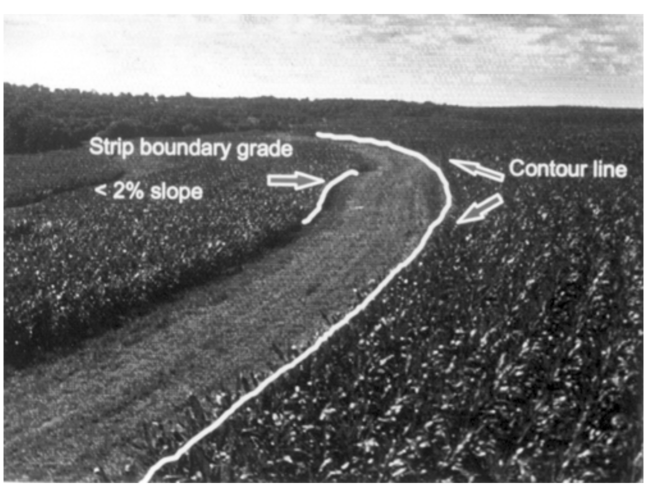
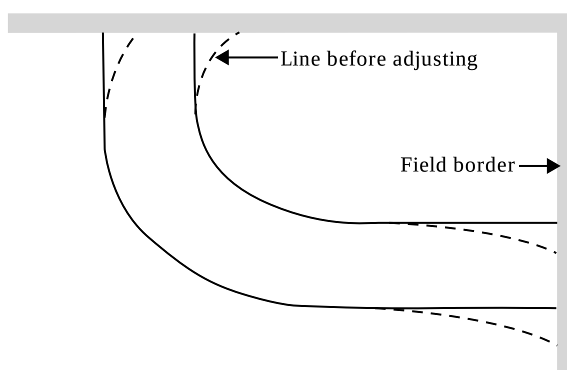


Figure 3b–7 Buffer alignment adjusted to meet field edges at right angles



Grassed Waterway or Critical Area Planting standards are more suitable for purposes of filtering pollutants when used for buffers. The grass-legume mixtures from Pasture and Hayland Planting standards may be adequate for erosion reduction purposes.

The effectiveness, longevity, and maintenance of the buffer strip can be enhanced by planting and maintaining a narrow 2- to 3-foot strip of tall, stiff stemmed grass along the upper edge of the buffer strip. This tends to pool the runoff before it enters the buffer strip, and sediment is dropped in the adjacent cultivated area where it can be removed without destroying and reseeding the buffer strip. Figure 3b–8 shows vegetative barrier enhancement. See chapter 3i for information on vegetative barrier.

Site preparation

The flow entering the contour buffer strip must be diffused and uniform. Small gullies or channels that exist on the slope should be smoothed and seeded before the buffer strip is established. This will provide a stable outlet for concentrated flows. Noxious weeds should be eliminated along with any debris, stones, or other obstructions that will affect either the establishment, function, or maintenance of the buffer strip.

Planting methods

A new seeding generally is the preferred method to establish buffer strips. In some cases if land is coming out of setaside or CRP, the existing vegetation is left in the areas designated as the buffer strips. Lime and fertilizer should be applied according to soil test recommendations before seedbed preparation. A firm seedbed about 4 inches deep should be prepared, and the seed drilled or broadcast and lightly covered. In some cases a no-till drill or direct seeder is used to seed buffer strips.

Operation and maintenance

The establishment period is critical to the success of the buffer strip. Weed competition should be controlled by mowing during the establishment period.

All field operations should be conducted parallel to the strip boundaries. Tillage, planting, spraying, and harvesting operations should be kept off the buffer strips. Even wheel tracks from incidental vehicular traffic can lead to concentrated flows, gullies, and failure of the buffer strip. Traffic should especially be kept from the upper few feet of the buffer strip because this area does trap more sediment and filter more contaminants than any other area. By maintaining a thick, stiff, tall stand of grass, the buffer tends to pool water in front of it and actually deposits most of the sediment on the adjacent cropped area. This sediment is much easier to remove and place back on the cultivated strip if it is not allowed to be deposited within the buffer itself. Figure 3b–9 illustrates maintenance of the buffer strips.

Poor adjustment or improper operation of tillage equipment in the cropped strip can result in poor performance of the buffer strip. For example, if a tandem disk is not leveled from front to rear it creates ridges across the slope. The ridges often concentrate runoff and then break over forming ephemeral gullies. When operating disks and other implements next to the buffer strips, care should be taken not to form a ridge on the upslope edge of the buffer or furrow on the lower edge.

Mowing operations should be timed to maintain tall vegetation during periods of high intensity storms. If wildlife habitat enhancement is desired, mowing should be delayed until after the nesting period of

Figure 3b–8 Buffer with vegetative barrier enhancement

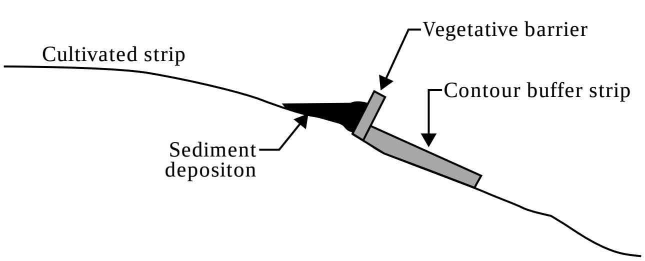
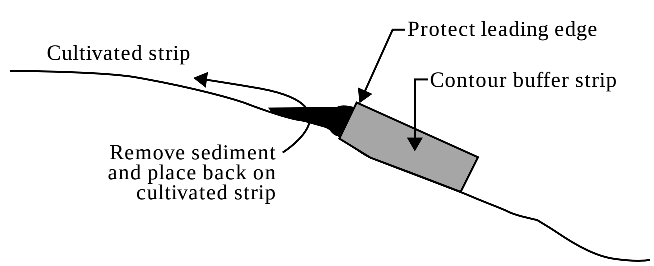


Figure 3b–9 Buffer maintenance



desired wildlife species. To maintain vigorous growth, the buffer strips should be fertilized with the rest of the field.

Inspect the buffer strips regularly, especially after major storms. Repair by reseeding or sodding any areas damaged by concentrated flow, machine operation, or herbicide application.

If renovation is eventually needed, new buffer strips should be established immediately beside existing buffer strips. On a given slope all new buffer strips should maintain the same relationship to the old strip, either all above the old strip or all below the old strip. This preserves the spacing relationships with the cropped areas. Figure 3b–10 illustrates this procedure. After a mature stand is established, destroy the original buffer, regrade the area if necessary to allow overland flows to reach the new contour buffer, and return the former buffer area to crop production.

Case study example and information needed to fill in job sheet

Setting

A 40-acre field in southeast Nebraska is composed of Pawnee clay loam and Wymore silty clay loam soils on slopes ranging from 2 to 11 percent. Typical slopes used for erosion prediction are 8 percent and 200 feet long (fig. 3b–11). Slope length is measured from the point where overland flow begins at the top of the slope and ends at the point of significant deposition or where the sheet flow enters a concentrated flow channel.

Several grassed waterways in the field drain into larger tributaries that feed a recreation lake downstream. Therefore, agricultural runoff and sediment are concerns as well as soil erosion on this field.

Step 1—On the specification sheet, place an X in the boxes designating all purposes for which contour buffer strips are being designed for the site. More than one primary purpose may be served. Use the other block for secondary purposes, such as enhancing wildlife habitat. Additional specifications may be required for design and layout to accommodate secondary purposes. Enter these on the back of the specifications sheet or on additional sheets as necessary.

In this example, reduce sheet and rill erosion and reduce pollution from runoff are checked on the specifications sheet.

Location and layout of strips

The slopes are moderately to severely eroded and have been farmed to corn or grain sorghum and soybeans for many years. This field now is leased by a producer who farms with large equipment consisting

Figure 3b–10 Maintaining spacing when reestablishing

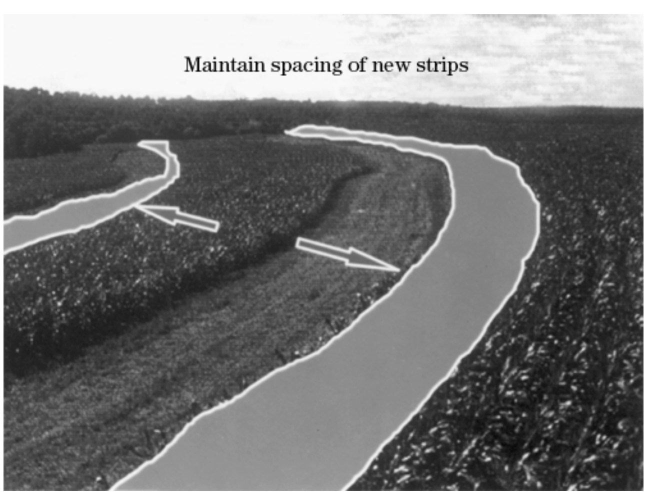
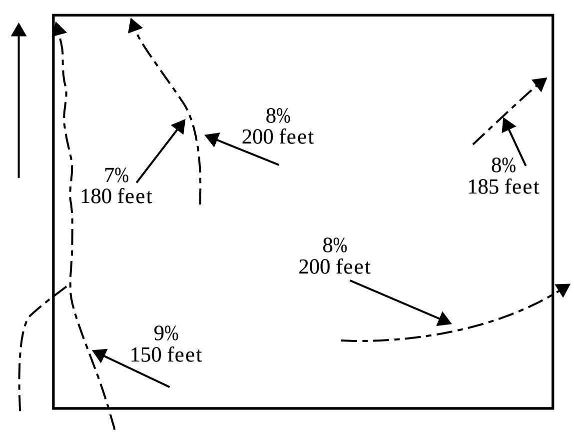


Figure 3b–11 Field sketch with slope measurements



of a 12-row, 30-inch spacing planter and a 15-foot no-till grain drill. Terraces and contouring are common in this area, but this field has not had these practices applied.

Step 2—Determine the widths of the cultivated and buffer strips in the location and layout portion of the specifications sheet. Because the buffer strip's length and width vary during layout, only an estimate of the acres in the buffer strips can be made beforehand based on sketches, an aerial photograph, or other means. This is useful in planning with the landowner. If more precise information on area comprising the buffers is needed, it may be better to delay this calculation until after layout when more precise measurements can be used.

From RUSLE it is determined that the critical slope length for contouring is 417 feet. The actual slopes in this field do not exceed 200 feet; therefore, critical slope lengths have not been exceeded and the practice itself applies to the site. Because two purposes, erosion reduction and reduction of sediment-borne pollutants, are identified, the criteria for both must be compared. Whichever is most restrictive is then used in designing the contour buffer strip system.

The criterium for width of cropped strip for the erosion control purpose is the lesser of half of **L** or half of the critical slope length for contour strip cropping. In this case half of **L** is 100 feet. The critical slope length for contour strip cropping is 1.5 times the slope length limit for contouring, or (417 feet x 1.5) = 624 feet. Half of this limit is 312 feet, so the slope length limit for contour strip cropping has not been exceeded. Therefore, for the erosion control purpose, the 100 feet or half of **L** criterium applies.

For the sediment-borne pollutant purpose, the maximum cropped strip width is half of the slope length or a maximum of 150 feet, whichever is less. In this case half of **L** is less than 150 feet, so half of **L** governs for this purpose as well. Thus the maximum cropped strip width is 100 feet.

Next, an adjustment is made to this width for multiple passes of the equipment. From table 3b–1 it is noted that three passes with the 12-row, 30-inch spacing planter covers a width of 90 feet and that 6 passes with the drill also covers 90 feet. The cropped strip width can be adjusted downward to 90 feet and will fit both machines quite well. Enter this width in the blank on the specifications sheet for strip 1 for width of the cultivated strip. See figure 3b–12.

Consideration must also be given to the use of other equipment, such as sprayers. For example, a sprayer with a 60-foot boom can be successfully used on the 90-foot strip by making one full pass and then a half pass with half of the boom shut off to avoid overlap and avoid spraying the buffer strip.

Next, the width of the buffer strips must be determined. This width depends on the purposes being served and the kind of vegetation required. Because two purposes are identified, the criterium for each must be compared. The erosion control criterium allows either a 15-foot width when grasses or grass legume mixtures are seeded or a 30-foot width when legumes alone are seeded. On the other hand the sediment borne pollutant criterium allows only the use of stiff-stemmed grasses with a minimum width of 15 feet and a double width strip at the base of the slope. (figure 3b–1). In this case the more stringent sediment-borne pollutant criteria governs.

Enter on the specifications sheet 15 feet for strip 2, 90 feet for strip 3, and 30 feet for strip 4. If during layout it is determined that more than two pairs of crop/ buffer strips are needed, only the bottom strip needs to be 30 feet wide.

Plant materials information

Step 3—For each buffer strip enter the common names of the selected species, seeding rates per acre, seeding date, and lime and fertilizer requirements.

The Nebraska practice standard for contour buffer strips specifies that for the sediment and water-borne contaminant purpose the permanent grass seeding mixture should consist of at least 60 percent stiff-stemmed sod forming grasses, such as switchgrass, big bluestem, or pubescent wheatgrass. The seeding rate criterium is a minimum of 40 pure live seeds per square foot. Using the appropriate seeding table from the Nebraska Pasture and Hayland Planting practice standard, it is determined that both big bluestem and switchgrass are adapted to this vegetative zone and to pasture and hayland suitability groups A-2 and A-4 to which the Wymore and Pawnee soils respectively are assigned. Of the cool-season grasses, smooth bromegrass and intermediate wheatgrass are also adapted to these soils. Since the buffer strip will receive herbicide-contaminated runoff, switchgrass is a good choice because it is tolerant to atrazine.

Using the procedure in the Pasture and Hayland standard, a mixture of 40 percent switchgrass, 40 percent big bluestem, and 15 percent intermediate wheatgrass is developed. Based on this mixture, it is calculated that 2 pounds of switchgrass, 4.3 pounds of big bluestem, and 4 pounds of intermediate wheatgrass per acre are needed. The seeding date for these grasses is November 1 to May 20 in this vegetative zone. This information is inserted in the plant materials information section of the Specifications Sheet for strips 2 and 4 and noted that strips 1 and 3 are cropped strips.

The field was limed 2 years ago so it is assumed that the lime requirements have been met. Since no soil test has been taken and since the soils are eroded, a standard 1,000 pounds of 12-12-12 fertilizer per acre is specified in the fertilizer column for strips 2 and 4.

Step 4:Specify details of needed site preparation in the Site Preparations section of the specifications sheet.

In this example, no special site preparation is required.

Step 5—Specify the planting method, seeding depth, and mulching requirements in the Planting Methods section of the specifications sheet.

Since the farmer has a 15-foot no-till drill with grass seed attachments, no-till is specified as the planting method. In addition, one bushel (32 pounds) of spring oats per acre is specified as a nurse crop.

Step 6—Specify the operation and maintenance requirements in the Maintenance section of the specifications sheet or on attachments.

The oats nurse crop is specified to be mowed or clipped before it heads out in the Maintenance section of the specifications sheet.

Step 7—Make a sketch of the field with approximate locations of buffer strips and supporting practices.

A sketch of the field is made on the back of the specifications sheet. In addition to approximate locations of buffer strips, the location of grassed waterways and field borders which will complement the system are also shown (fig. 3b–13).

Contour Buffer Strips

Conservation Practice Job Sheet 332

Natural Resources Conservation Service (NRCS) *April 1997*

Landowner____

Definition

Contour buffer strips are strips of perennial vegetation alternated with wider cultivated strips that are farmed on the contour.

Purpose

The benefits of farming on the contour and practicing crop residue management make contour buffer strips an effective conservation practice. This practice is further enhanced when used with other conservation practices, such as conservation tillage and crop rotation.

Contour buffer strips slow runoff and trap sediment. Grass strips established on the contour can significantly reduce sheet and rill erosion. Sediment, nutrients, pesticides, and other contaminants are removed from the runoff as they pass through the buffer strip. Grass strips also provide food and nesting cover for wildlife.

Where used

- On cropland where sheet and rill erosion are problems. Contour buffer strips are an excellent filter for runoff and will improve surface water quality.
- Where contouring is practical. Contour buffer strips are unsuitable in fields with irregular, rolling topography where contouring is impractical.

Requirements for establishing contour buffer strips

Contour buffer strip layout

Recommendations for establishing contour buffer strips include a minimum buffer strip width, with strips placed along the contour and farming operations that follow the approximate contour grade. Cultivated strip widths are determined by variables, such as slope, soil type, field conditions, climate, and erosion potential.

Other considerations in layout of contour buffer strips include:

- Cultivated strip widths may be adjusted, generally downward, to accommodate machinery widths.
- Cropping between the buffers strips, including tillage, rotation, and crop residue use, should be acceptable to the soil and site conditions.
- Buffer strips can be used as turn areas if care is taken to minimize disturbance to soil and vegetation.
- Waterways or diversions are needed where runoff concentrates and erosion is a problem.
- Contour buffer strips may be part of a wildlife habitat program.
- Contour buffer strips can be established between terraces to enhance treatment of the hill slope.
- A ratio of cultivated to buffer strip width of between 9:1 and 4:1 is desirable.

Wildlife

When planning for wildlife, adjust buffer width and plant species to meet the needs of the target wildlife species. Avoid mowing during the nesting period.

Specifications

Site-specific requirements are listed on the specifications sheet. Additional provisions are entered on the job sketch sheet. Specifications are prepared in accordance with the NRCS Field Office Technical Guide. See practice standard Contour Buffer Strips (332).

Operation and maintenance

- Mow buffer strips to maintain appropriate vegetative density and height for trapping sediment.
- Fertilize buffer strips according to soil test recommendations.
- Spot seed or renovate buffer strip area damaged by herbicides, equipment, or unusual rainfall events.
- Redistribute sediment accumulations as needed to maintain uniform sheet flow along the crop/buffer boundary.

Contour Buffer Strips – Specifications Sheet

Landowner *Bill Brown* Field number *7*

Purpose (check all that apply)	
☑ Reduce sheet and rill erosion	☐ Provide wildlife habitat
☑ Reduce pollution from runoff	☐ Other (specify)

Location and Layout	Strip 1	Strip 2	Strip 3	Strip 4
Cultivated width (ft)	*90 '*	—	*90 '*	—
Buffer strip width (ft)	—	*15 '*	—	*30*
Buffer strip length (ft)	*to be determined*	*during layout*		
Acres in buffer strip				

Plant Materials Information				
Species/cultivar *Strip #1*	Seeding rate (lb/acre)	Seeding date	Recommend lime (tons/acre)	Recommend fertilizer $N\text{-}P_2O_5\text{-}K_2O$ (lb/acre)
1 *Cultivated Crop*				
2				
3				
4				
Strip #2 *Contour Buffer Strip*				
1 *Switchgrass*	*2.0*	*Nov. 1 to*	*None*	*1,000 lb 12-12-12*
2 *Big Bluestem*	*4.3*	*May 20*		
3 *Intermediate Wheatgrass*	*4.0*			
4				
Strip #3 *Cultivated Crop*				
1				
2				
3				
4				
Strip #4 *Contour Buffer Strip*				
1 *Switchgrass*	*2.0*	*Nov. 1 to*	*None*	*1,000 lb 12-12-12*
2 *Big Bluestem*	*4.3*	*May 20*		
3 *Intermediate Wheatgrass*	*4.0*			
4				

Site Preparation

Prepare firm seedbed. Apply lime and fertilizer according to recommendations.

Planting Method(s)

Drill grass and legume seed *1/4-1/2* inches deep uniformly over area. Establish stand of vegetation according to recommended seeding rate. If necessary, mulch newly seeded area with — tons per acre of mulch material. May seed small grain as a companion crop at the rate of *32* pounds per acre, but clip or harvest before it heads out. *Spring Oats*

Maintenance

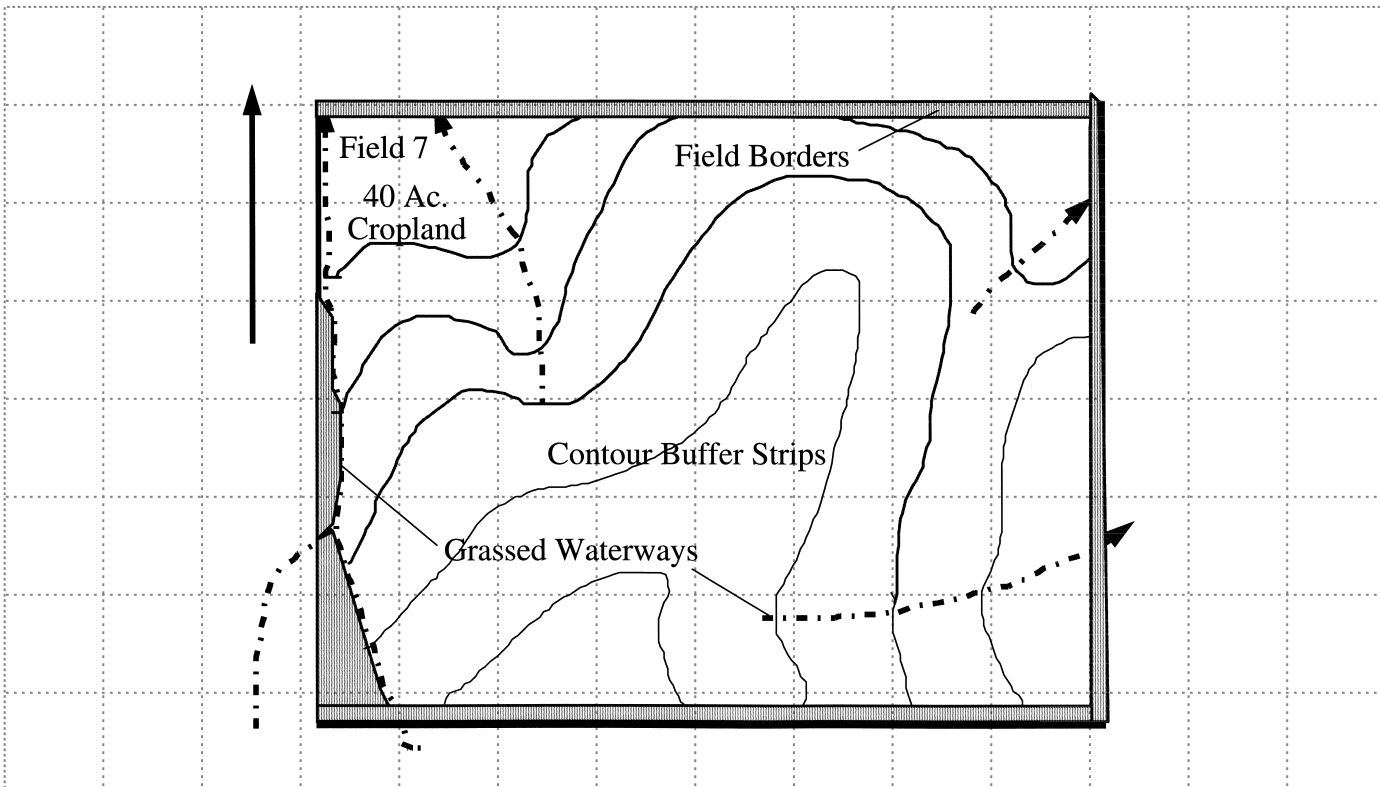
Buffer strips must be inspected periodically and protected from damage so proper function is maintained. Damaged areas should be repaired and/or revegetated. Sediment accumulations should be redistributed as needed to maintain uniform sheet flow along the crop/buffer boundary.

Mow or clip the oats before head stage

Contour Buffer Strips – Job Sketch

If needed, an aerial view or a side view of the contour buffer strips can be shown below. Other relevant information, such as complementary practices, and adjacent field or tract conditions including structures and crop types, and additional specifications may be included.

Scale 1"=__N/A__ ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")



Additional Specifications and Notes:

Chapter 3c Cross Wind Trap Strips

Definition of cross wind trap strips

Cross wind trap strips are herbaceous vegetation, resistant to wind erosion, and grown in strips as nearly as possible perpendicular to the prevailing wind erosion direction. Cross wind trap strips entrap windborne sediment and establish a stable area to resist wind erosion.

Purposes of cross wind trap strips

Cross wind trap strips catch wind-borne sediment and other pollutants, such as nutrients and pesticides. This practice as part of a conservation management system may support one or more of the following purposes:

- Reduce soil erosion from wind by establishing a stable area.
- Entrap wind-borne sediment within or near the trap strip.
- Induce soil deposition from wind erosion (saltation and surface creep) and entrap soil-bound pollutants, such as nutrients, pesticides, and organic material, before they are deposited downwind into the sensitive areas.
- Protect growing crops from damage by wind-borne soil particles.
- Provide food and cover for wildlife.

Benefits

- Reduce wind erosion on cropland when part of a planned resource management system.
- Reduce plant stress and damage from wind erosion and windblown sediment.
- Prevent topsoil from leaving the field.
- Benefit fish and other stream invertebrates from less suspended sediment and less pesticides, nutrients, and organics in surface water.
- Benefit drainage ditches by extending the time between clean-out maintenance that is required for removing wind deposited sediment.
- Benefit wildlife by having more cover, food sources, and travel corridors.

Negative impacts

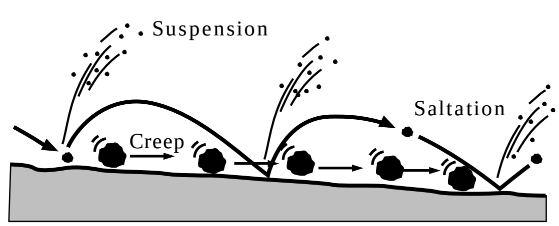
Trap strips may become a haven for burrowing rodents, such as groundhogs (woodchucks), that can create an economic crop loss by eating the adjacent crop before it matures. Such burrows, when discovered, should be managed by trapping, hunting, or poisoning the pests before they do excessive damage to the planted crop. Burrowing rodents can also damage banks and dikes along drainageways and watercourses.

Weeds and other pests can proliferate in cross wind trap strips if they are improperly maintained. Mowing and scouting for pests must become part of the operation and maintenance of the practice.

Functions

Since the primary function of cross wind trap strips is to capture saltating and creeping windblown soil particles, they should be designed to match the local landscape. When properly designed, trap strips capture about 50 to 80 percent of the predicted Wind Erosion Sediment. This range is provided in the National Agronomy Manual or the wind erosion prediction section in the Field Office Technical Guide. (Approximately 50 to 80 percent of the wind erosion occurs by saltation and surface creep of soil particles along the soil surface.) Figure 3c–1 shows the wind erosion process.

Figure 3c–1 The wind erosion process



Design considerations

Planning considerations

The effectiveness of cross wind trap strips is maximized when strips are oriented as close to perpendicular as possible to the prevailing wind erosion direction for the period for which the system is designed.

Additional trap strips may be placed in the field to reduce the in-field wind erosion rate.

Some plants are damaged by blowing wind as well as by wind-borne sediment. In such cases the spacing between trap strips may need to be reduced from that obtained using wind erosion prediction technology.

When trap strips are designed to enhance wildlife, plant species diversity within the strip should be encouraged. Trap strips that result in various plant heights within the strips maximizes wildlife use. For example, adding wildflowers to warm-season grass trap strips would add plant diversity.

Drifting snow or grazing by wildlife may reduce the trapping capability of trap strips. Other conservation practices, such as residue management, cover crops, windbreaks, and herbaceous wind barriers, may be used with trap strips to achieve the conservation objective.

Planting of annual wind strips upwind of the cross wind trap strip helps accumulate wind-borne sediment where it can be spread and leveled annually or as needed. This will extend the design life of the permanent cross wind trap strips.

Trap strips need to be designed to create a stable condition (fig. 3c–2). A stable condition is an area with sufficient vegetation to trap and hold expected saltation and surface creep from the upwind contributing area. For a grassed area to be stable, it must meet the following criteria:

- Width of 12 to 15 feet
- Height of 1 to 2 feet
- 50 percent or greater vegetated cover
- 50 to 75 per square foot stem density

Trap strip width must be 12 feet or wider when vegetation or stubble in the strips is normally 1 foot or more in height during periods when wind erosion is expected to occur.

The minimum width of the strip must be at least 25 feet when the effective height of the vegetation or stubble in the strip is normally less than 1 foot during periods when wind erosion is expected to occur. However, annually seeded and harvested trap strips of small grain should be adjusted to match the farmer's combine header width. Annual trap strips, such as rye, have proven beneficial for protecting sensitive crops, such as sugar beets.

As part of a Resource Management System on a cropland field, cross wind trap strips can be planned and spaced across a field to reduce wind erosion. Determine trap strip design width and spacing by:

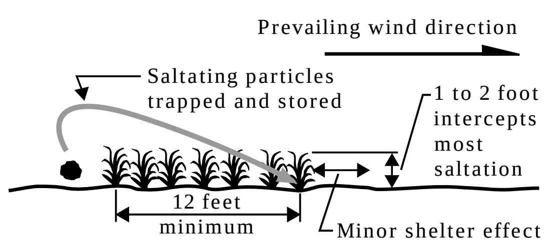
1. Determining the contributing area of **L**.
2. Estimating the wind erosion rate in tons per acres from the contributing area.
3. Selecting a trap strip width based on length and deposition depth less than or equal to 2.4 inches per year.

If the design accumulated deposition depth in the trap strips is 2.4 inches per year, this could accumulate up to about 2 feet in 10 years. In some regions of the country, more restrictive guidelines for deposition may be required depending on local observations and needs.

Locate trap strips for this purpose as follows:

- at the windward edge of fields
- immediately upwind from areas within fields to be protected from erosion or deposition
- in recurring patterns interspersed between erosion-susceptible and/or cropped strips

Figure 3c–2 Stable condition with a trap strip



Direction and width of erosion-susceptible strips

When trap strips are installed in patterns alternated with erosion-susceptible crop strips, and the direction of the strips deviates from perpendicular to the prevailing wind erosion direction, the width of the erosion-susceptible strips shall be correspondingly reduced.

The effective distance between strips is measured along the prevailing wind erosion direction during those periods when wind erosion is expected to occur. That distance shall not exceed the width permitted by the soil loss tolerance (T) of the predominate soil used in planning the Conservation Management System.

The width of the strips is determined using the current wind erosion prediction method. Calculations must account for the effect of other practices in the Conservation Management System.

Direction and width of strips planted in sensitive areas

Reduce the trap strip width when the predominant wind direction differs from perpendicular to the trap strip.

Measure the effective width along the prevailing wind erosion direction during those periods when sensitive crops are susceptible to wind erosion damage. Base strip width on the Crop Tolerance to Wind Erosion Table which is in the Wind Erosion Prediction Section of the NRCS Field Office Technical Guide (FOTG), or on other acceptable references. Crop tolerance to wind erosion is the maximum rate of soil blowing that crop plants can tolerate without significant damage by abrasion, burial, or desiccation.

Width of trap strips to improve water quality

The width of the strips is determined using the current wind erosion prediction method. Calculations must account for the effect of other practices in the Conservation Management System.

As part of a Resource Management System plan for a farm, trap strips can also improve water quality by entrapping contaminant-enriched soil blown into surface water, especially from tilled land on flat, open landscapes. These areas may be eroding at or slightly below **T**, yet significantly contributing to nonpoint source pollution. Trapping blowing soil in the vegetation also reduces sediment deposition, eutrophication, and algal blooms in the ditches.

To reduce sediment in drainage ditches and improve water quality in flat, open areas, select the level of soil loss reduction desired. However, if the contributing area is really large or eroding above the tolerable soil loss **T**, then a Resource Management System must be planned. Where necessary, additional erosion control measures, such as residue management, annual trap strips, and cover crops, may be necessary to prevent inundation of the trap strip.

The contributing area could potentially be eroding below **T**, but still contributing soil and sediment to a stream, creating a water quality problem. The planner needs to be careful not to design a trap strip too narrow as it could be buried by incoming saltation before it serves its useful life. It should be designed using the locally accepted wind erosion prediction methods according to the NRCS Field Office Technical Guide.

A planting of a locally adapted annual species next to the windward edge of the permanent trap strip can also entrap sediment. In the Cross Wind Trap Strip standard (589C), this option is offered to extend the life of the designed strip. This may prevent the trap strip from being buried in one large wind storm event.

Plant materials information

Select grass species with stiff, erect stems capable of maintaining the desired characteristic during the wind erosion period when the effect of filtering prevents sediment pollution of surface water. This effect varies depending on the local climate, tillage practices, crop grown, and other contributing area characteristics.

Seeding methods and dates should match the Critical Area Treatment standard (342).

A final stem density of 50 to 75 stems per square foot and 50 percent vegetative cover in the trap strip area is desired to achieve the entrapment of saltating soil.

Selection of plants for use in trap strips should favor species tolerant to herbicides used on adjacent crops or other land uses.

Select plant species for trap strips on the following criteria:

- Ability to withstand snow drifting
- Ability to remain erect during wind erosion periods
- Tolerance to annual predicted sediment deposition
- Adaptation to the soil condition onsite

Follow the local Critical Area Treatment standard (342) for seeding establishment guidelines.

Vegetation or its residue will be 1 foot or more in height during periods when wind erosion is expected to occur.

Designing for wildlife habitat

Cross wind trap strips are important in providing cover and food for pheasants, quail, and other game birds. For wildlife purposes trap strips should be at least 30 feet wide and are generally located next to wetlands, drainage ditches, or road ditches for maximum benefit. Narrower trap strips (less than 30 feet wide) planned for wind erosion control still have many wildlife benefits, such as travel corridors, cover, and nesting depending on the wildlife species using them.

An annual planting of grain crops or regionally adapted species of small grain at the trap strip upwind leading edge can

- provide additional food and cover for wildlife,
- protect permanent trap strips, such as switchgrass, from being totally buried by soil or snow,
- create habitat diversity, and
- allow the farmer to annually till next to the permanent trap strip and level accumulated soil that has been deposited by the wind.

Example design of cross wind trap strips

Step one–Estimate how much soil is blowing annually from the contributing area or a field. For those familiar with the USDA wind erosion prediction equation (WEQ), the contributing area is described by **L**, or the unsheltered distance along the prevailing wind erosion direction for the field or area to be evaluated. **L** represents the distance from a point upwind where no saltation or surface creep occurs to a point downwind where an edge of field or other stable occurs.

Figures 3c–3, 3c–4, 3c–5, and 3c–6, show how to determine **L**. Use the soil survey, aerial photo, or other means to determine the stable border or the area describing **L**.

Figure 3c–3 Determining L on an isolated field

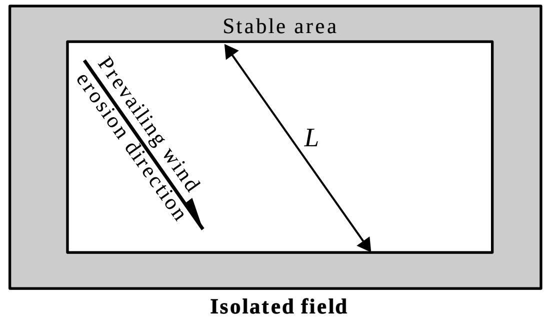


Figure 3c–4 Determining L on a field that is not isolated

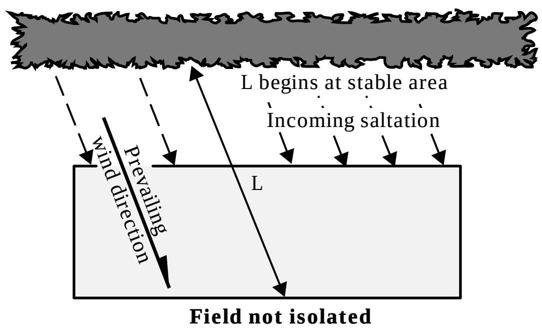


Figure 3c–5 Determining L in wind strip cropping field

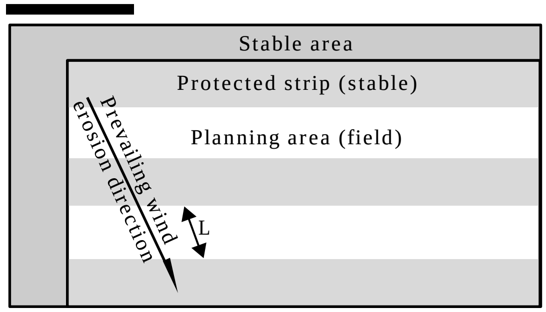
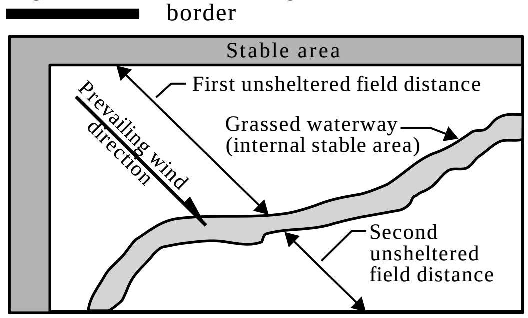


Figure 3c–6 Determining L in a field with internal stable border



Step two—Review the local soil survey and record the predominant soil type(s) in the contributing area. Then using the NRCS SOI-5 data base, soil survey, or local NRCS FOTG wind erosion prediction tables, determine the Wind Erodibility Groups (WEG) for the contributing area. Select the predominant soil WEG upwind of the planned trap strip, or if another soil WEG is close to the same size with a higher Wind Erodibility Group, then use the most erosive group to make the soil loss prediction and to design the trap strip width.

Step three—Use the current USDA wind erosion equation to estimate the wind erosion (in tons per acre per year) from the contributing area. Currently in the Eastern states, the annual wind erosion prediction method most accurately predicts the soil losses observed.

However, in the Western states that have a higher wind erodibility, the crop period wind erosion prediction method is used to determine the tons per acre per year and Resource Management System needs. Follow your local Field Office Technical Guide Wind Erosion Prediction Section when designing trap strips.

In all cases, to prevent inundation of the trap strips by too much soil, the width must accommodate the incoming sedimentation. Too high a soil rate could bury the vegetation in a year's wind erosion season or by a big wind storm, making the trap strips less effective in future wind storms. Therefore, soil loss tolerance **T** (or soil loss less than **T**), may be used to design the width between trap strips. Select additional practices, such as residue management, wind stripcropping, windbreaks, to achieve **T** or below in the contributing area.

Once the RMS is planned to achieve **T**, then the width as a trap strip is selected for its desired effects. Generally, as the contributing area increases, the trap strip width also widens to accommodate the incoming saltation.

Cross wind trap strips need to be planted to a species capable of maintaining a 12-inch or greater height, a stem density of 50 to 75 stems per square foot, and a 50 percent vegetative cover during wind erosion events to function properly. A design table placed in a spreadsheet was created (appendix 3c–A) to estimate the width of trap strips needed to entrap all of the saltation and surface creep. The percentage of the total wind erosion present in the saltation and surface creep is referred to as the *saltation factor*. This example table for 25-foot design width for trap strips was developed using a spreadsheet assuming 80 percent of the total erosion in the form of saltation and surface creep is entrapped in the trap strip. If desired, adjust the design table to match local conditions or use a higher or lower saltation factor. A spreadsheet using the formulas can be programmed to recreate the design table for easily adjusting the results obtained.

A 10-year design life with an annual accumulation of 2.4 inches of deposition from an annual wind erosion prediction level of any soil loss rate is possible.

Cross wind trap strip design for water quality improvement could depend on the desired reduction of sedimentation or contaminant reduction requirements to meet local, state, or federal water quality nonpoint source standards or goals.

Because of sediment accumulation along the leading edge of trap strips, a narrow row planting of upright grass may be needed to protect the practice from the overloading and shortening of the normal 10-year-life expectancy. This option will require leveling the sediment hump annually and reestablishing the narrow protective strip.

Orientation of the field and the beginning point for wind erodibility prediction is critical to the design width of the trap strips. The larger the contributing area, the wider the trap strip width is needed to keep from burying the planned trap strip species. So trap strip design width is also a function of the area described by **L,** which may or may not be at the upper field edge. (See the NRCS National Agronomy Manual wind erosion prediction section or the local NRCS Field Office Technical Guide wind erosion prediction section.) See previous figures for determining **L**.

The design of a cross wind trap strip is based on the following formulas:

1. Determine the contributing area through **L**, the distance downwind from a point of stable area to a point where no saltation or surface creep occurs. Area is measured in acres.
   Example: 20 acres

2. Estimate the wind erosion rate of the contributing area using current wind erosion prediction methods.
   Example: 5 tons/acre/year

3. Sum the total erosion from the contributing area.
   Total tons = (acres)(erosion rate)
   $$(20 \text{ acres})(5 \text{ tons / ac / yr}) = 100 \text{ tons / yr}$$

4. Estimate the percent of saltation and surface creep trapped in the cross wind trap strip.

   Saltation factor ranges from 0.5 to 0.8 (50 to 80 percent) of the total wind erosion sediment that is transported as saltation and surface creep.
   Example: 80 percent

5. Total sediment that can be potentially trapped in the strip.

   Soil trapped in trap strip = (Total tons/ac from contributing area)(saltation factor)
   Example: (100 tons / yr)(80%) = 80 tons / yr

6. Find the bulk density value for the soil used in the soil loss prediction. From table 3c–1 select the depth in a ton of soil with that bulk density.
   Example: Soil has a bulk density of 1.3.
   Depth in 1 ton of soil from table 3c–1 is 0.007 inch.

7. Select trap strip width: 15, 20, 25, or 30 feet.
   Example: 15 feet.

   Calculate:

$$\text{trap strip acres} = \frac{(\text{strip width - ft})(\text{trap strip length - ft})}{(43,560\ \text{ft}^2/\text{ac})}$$

   For a 20-acre rectangular field (1,320 ft by 660 ft) the calculation for a 15-foot trap strip is:

$$\frac{15\ \text{ft} \times 1,320\ \text{ft}}{43,560\ \text{ft}^2/\text{ac}} = \frac{19,800\ \text{ft}^2}{43,560\ \text{ft}^2/\text{ac}} = 0.45\ \text{ac}$$

Table 3c–1 Soil bulk density in relation to depth in inches-per-ton of soil

Soil bulk density (g/cc)	Weight (lb/ft^3)	Depth / ton (in)
0.5	31.2	0.018
0.6	37.44	0.015
0.7	43.68	0.013
0.8	49.9	0.011
0.9	56.16	0.010
1.00	62.4	0.009
1.1	68.64	0.008
1.2	74.88	0.007
1.3	81.12	0.007
1.4	87.36	0.006
1.5	93.6	0.006
1.6	99.84	0.005
1.7	106.08	0.005
1.8	112.32	0.005
1.9	118.56	0.005
2	124.8	0.004

8. Calculate deposition depth as follows

$$\frac{(\text{soil trapped in tons/ac})(0.007\ \text{in/ton of soil/ac})}{(\text{trap strip acres})}$$

$$\text{Example: } \frac{(80\ \text{tons})(0.007\ \text{in/ton})}{.045\text{ac}} = 1.24\ \text{in/yr}$$

An alternative calculation can be made to determine the width of a cross wind trap strip if the annual depth of sediment deposition is known or predicted. Steps 1 through 6 are the same as the first method.

7. Weight of cubic foot of soil, lb/ft^3:
   Water = 62.4 lb/ft^3.

$$(\text{Bulk density})(62.4) = \text{Wt. soil } (\text{lb/ft}^3)$$

   Example: Soil with a bulk density of 1.28 cc weighs 80 lb/ft^3 (1.28 x 62.4 = 80)

8. Determine the cubic feet per ton of sediment:

$$\text{Cubic feet} = \frac{2,000\ \text{lb/ton}}{\text{lb/ft}^3}$$

$$\frac{2,000\ \text{lb/ton}}{80\ \text{lb/ft}^3} = 25\ \text{ft}^3/\text{ton}$$

9. Volume of sediment trapped in trap strip

$$\text{ft}^3 = \text{tons of sediment entrapped} \times \text{ft}^3/\text{ton}$$

$$\text{ft}^3 = 80\ \text{tons} \times 25\ \text{ft}^3/\text{ton} = 2,000\ \text{ft}^3$$

10. Length of cross wind trap strip or length of field perpendicular to wind direction, in feet:
    Example: 1,320 feet

11. Depth of annual deposition to be permitted in the cross wind trap strip, in feet:
    Example: 0.2 feet =2.4 inches

12. Width of cross wind trap strip required to entrap transported sediment:

$$\text{Width} = \frac{\text{Volume of sediment entrapped } (\text{ft}^3)}{\text{length of trap strip } (\text{ft}^3) \times \text{depth of annual accumulation } (\text{ft})}$$

$$\frac{2,000\ \text{ft}^3}{(1,320\ \text{ft} \times 2\ \text{ft})} = 7.5\ \text{ft}$$

80 tons sediment spread over a trap strip 7.5 feet wide and 1,320 feet long would be equivalent to 2.4 inches of soil on about a quarter acre. The minimum width for the trap strip, 15 feet, would accumulate an annual deposition of 1.2 inches on about a half acre.

In this example: a 15-foot-wide trap strip along the drainage area or field edge should catch most of the wind erosion below **T**, which is contributing sediment and phosphorus that is polluting the nearby stream. A water quality concern has been identified. The annual deposition is less than 2.4 inches per year, so a 15-foot-wide trap strip should catch the soil without being totally buried (fig. 3c–7).

Phosphorus entrapment estimate

The following procedure for estimating pounds of phosphorus (P) delivered to the trap strip from the contributing area on an annual basis is based on the soil loss prediction, contributing area erosion rate, soil test phosphorus levels, and the total phosphorus enrichment ratio (PER). The data are from observation and local soil test P in both field and wind sediment from a wind study. This procedure may be applicable to areas where eroded sediment is deposited directly into a surface drainage ditch.

To estimate the pounds of phosphorus contributed to a waterbody by wind erosion and sedimentation, use the following formulas for contributing areas with a soil phosphorus test:

1. Soil phosphorus test level, in ppm, derived from laboratory analysis:
   Example: 250 ppm soil phosphorus, or 0.025%

2. Total PER is the ratio of total P found in the sediment to soil test P found in the contributing area. The ratios shown in table 3c–2 are based on field sampling for different WEG soils in the contributing area. These ratios can be used as guidance until local information is collected and made available.

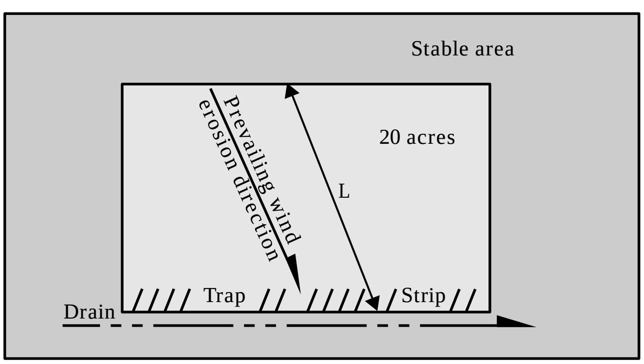
3. Phosphorus entrapment estimate procedure using the previous example for a soil sith WEG=3:

$$\text{Total P} = (\text{Soil trapped tons / ac / yr}) \times (\text{Soil test P}[\text{ppm}]) \times (\text{PER for WEG}) \times (2{,}000 \text{ lb / ton})$$

$$(80 \text{ tons / ac / yr})(0.0025)(5)(2{,}000) = 200 \text{ lb P / yr}$$

80 tons of sediment entrapped in a cross wind trap strip will also entrap 200 pounds of phosphorus.

Figure 3c–7 Trap strips protecting drainage ditch



Isolated field with drainage ditch catching wind erosion
Assume: soil loss at 5 tons/acre/year

Table 3c–2 Phosphorus enrichment ratio per wind erodibility group *

Wind erodibility group	P enrichment ratio
1, 2, 3	5
5, 7	7.5
4, 4L, 6	10

* The P enrichment ratio has not been validated by research and is based on NRCS field trial soil test analysis at one location in the Midwest and on NRCS judgment and observation. It may be different by WEG for other locations. Check with the land grant university.

Operation and maintenance

Established vegetation in the trap strip or plant residue is managed at a height of at least 12 inches, a minimum stem density of 50 to 75 stems per square foot, and more than 50 percent ground cover during those periods in which wind erosion is expected to occur. Trap strips should be mowed in time to allow for new growth to the planned height before periods when wind erosion or crop damage is expected to occur.

Spot spray or mow perennial weeds to meet state noxious weed laws for weed control.

Trap strips should not be used as travel lanes. Flattened grass is not as effective as erect grass in trapping saltating soil.

Remove entrapped soil sediment from the trap strip area and spread onto the adjacent field when the depth of the sediment begins to impede the ability of the established vegetation to trap additional sediment. This should occur before the sediment reaches a depth of 6 inches in the trap strip area.

If wildlife habitat is a purpose, the vegetation species should be mowed to promote the desired species and plant density. Avoid mowing, harvesting, or burning during critical nesting and brooding periods.

A headland or end row, where needed for turning, is required to prevent the loss of trap strip function and design.

After establishment, fertilize trap strips with nitrogen as needed to maintain plant vigor.

Establish and relocate trap strips as needed to maintain plant density and height.

Burning of warm-season grasses is not allowed unless new growth will obtain the minimum height criterium during the critical period when wind erosion, crop damage, or water quality impairment is expected to occur.

Install surface drainage outlets where required to prevent concentrated flow from flushing out sediment in trap strip area.

Fertilizing the cross wind trap strip vegetation
Fertilizer is to be applied according to a current soil test taken from the trap strip area. All phosphorus is to be incorporated to prevent phosphorus movement into the nearby surface water (except in no-till seeding). Nitrogen applications are delayed until after plant emergence and establishment to minimize nitrogen losses from leaching or runoff to the adjacent surface waterbody.

Information needed to fill in job sheet

The job sheet provides information for the design of a cross wind trap strip. The following is guidance in how to complete the specification sheet for the landowner's use.

Landowner

Enter the name of the landowner planning the cross wind trap strip.

Field number

Enter the field number or numbers from the conservation plan, job sketch, or plan map. A field name is sometimes more commonly used. Correspond the field identification with the job sketch on the back of the job specification sheet.

Purpose

Check the appropriate purpose or purposes that the cross wind trap strip will serve.

Location and layout

Cultivated width (feet)
This is the distance across the cropped field that contributes to the sediment load being deposited at the cross wind trap strip. It is the width in the direction of the **L** unsheltered distance.

Grass strip width (feet)

The case example gives two ways of determining the width of the cross wind trap strip. The first is to select from a series of predesigned trap strip width (see table for 15 feet width in appendix 3c–A) and use these precalculated tables to determine the deposition depth that would occur each year. The second method is to select the sediment deposition depth that the trap strip can tolerate each year and calculate the cross wind trap strip width using the cubic feet of sediment predicted to be entrapped.

Grassed strip length (feet)

Determine the length of the field across the landscape. Length is measured perpendicular to the flow direction of wind across the field. Some cross wind trap strips may be placed across the entire length of the field while others may traverse only a partial distance.

Acres in buffer strip

Calculate the total acreage established in cross wind trap strips. This is the width of each individual trap strip multiplied by the length of that strip. Total trap strip acres will determine seeding requirement.

Plant material information

Provide the vegetation species and/or cultivar planned to be planted in each cross wind trap strip. Cross wind trap strips need to stand upright during wind events and have a density of 50 stems per square feet. Acceptable species adapted to the location are listed in the Field Office Technical Guide. The seeding rate or transplanting distance, planting date, and any recommendations for soil amendments and fertilizer are also given. Fertilizer and soil ammendments are applied according to a soil test or following guidance from conservation practice standard for Critical Area Treatment (342). Follow recommended timings of soil and fertilizer amendments.

Site preparation

Site preparations follow normal seeding and transplanting guidelines from conservation practice standard Critical Area Treatment (342). Additional guidance can be given in Additional Specifications and Notes on the back page.

Planting method

Specify the seeding depth or transplant spacing. Generally grass seeds are planted shallow (top 0.25 inch) in a firm seedbed. Give the amount and placement of mulch material, if used. Guidance is available from conservation practice standard Critical Area Treatment (342). Use same guidance to recommend planting small grain cover or nurse crop.

Operation and maintenance

In this section provide guidance for any routine operations that are necessary to maintain the function of the cross wind trap strips. Provide weed control methods based on vegetation tolerance to herbicides, tillage, mowing, and/or burning. Program mowing to maintain plant height. Recommend fertilizer according to crop and trap strip needs. Give reminders to repair weak vegetation in the trap strips and where to obtain seedling for repair. Caution against using herbicides in cropped areas that will damage the vegetation in the trap strip. Use the section Additional Specifications and Notes to provide the information to the landowner.

Job sketch

Draw a sketch on the back page that will show field locations of each cross wind trap strip. Number each trap strip. Show all drainageways where the trap strips may be required. Show field boundaries, trap strip widths, and wind direction. Also show any other conservation buffer practices that may be planned for the field.

Appendix 3c

Cross Wind Trap Strip
15-foot design table
for a soil with 1.3 g/cc bulk density
wind erosion contributing area

Erosion rate (tons/ac/yr)	Acres 20	40	80	160	320	640
	(total tons)					
5	100	200	400	800	1600	3,200
4	80	160	320	640	1280	2,560
3	60	120	240	480	960	1,920
2	40	80	160	320	640	1,280
1	20	40	80	160	320	640

80.0% soil trapped by filter

Salt factor=0.8 erosion rate (tons/ac/yr)	Acres 20	40	80	160	320	640
	(total tons)					
5	80	160	320	640	1280	2,560
4	64	128	256	512	1024	2,048
3	48	96	192	384	768	1,536
2	32	64	128	256	512	1,024
1	16	32	64	128	256	512

Trap strip width - 15 ft

	Acres 20	40	80	160	320	640
Trap strip length (ft)	660	1,320	1,320	2,640	2,640	5,280
	1,320	2,640	2,640	5,280	5,280	

Trap strip acres

	20	40	80	160	320	640
	0.23	0.45	0.45	0.91	0.91	1.82
	0.45	0.91	0.91	1.82	1.82	

Deposition depth in trap strip

Erosion rate (tons/ac/yr)	20	40	80	160	320	640
	(in/yr)					
5	2.5	2.5	4.9	4.9	9.9	9.9
	1.2	1.2	2.5	2.5	4.9	
4	2.0	2.0	3.9	3.9	7.9	7.9
	1.0	1.0	2.0	2.0	3.9	
3	1.5	1.5	3.0	3.0	5.9	5.9
	0.7	0.7	1.5	1.5	3.0	
2	1.0	1.0	2.0	2.0	3.9	3.9
	0.5	0.5	1.0	1.0	2.0	
1	0.5	0.5	1.0	1.0	2.0	2.0
	0.2	0.2	0.5	0.5	1.0	

Additional Reading

Bensley, R.P. 1974. Erosion and sediment pollution control. Chapter 3 (Wind Erosion) Iowa State University Press, Third Ed.

Robertson, L.S. Crops and soils newsletter. Michigan State Cooperative Extension Service, E. Lansing, MI.

United States Department of Agriculture, Natural Resources Conservation Service, Field Office Technical Guide, Section IV, Cross Wind Trap Strips 589C, Field and Filter Standards.

United States Department of Agriculture, Natural Resources Conservation Service, National agronomy manual, Subpart B, Wind Erosion.

United States Department of Agriculture, Natural Resources Conservation Service, 1997. Wind erosion process, prediction, and control manual, Wind Erosion Workshop, Ft. Collins, CO.

Cross Wind Trap Strips

Conservation Practice Job Sheet **589C**

Natural Resources Conservation Service (NRCS) ***January 1998***

Landowner____

Definition

A cross wind trap strip is an area of herbaceous vegetation, resistant to wind erosion, and grown in strips perpendicular to the prevailing wind direction. As the name implies, cross wind trap strips entrap wind-borne sediment.

Purpose

Cross wind trap strips catch wind-borne sediment and other pollutants, such as nutrients and pesticides, from the eroded material before it reaches waterbodies or other sensitive areas.

Where used

Cross wind trap strips can be used along watercourses, drainage ditches, waterbodies, and other sensitive areas adjacent to agricultural fields susceptible to wind erosion or wind erosion damage.

Conservation management systems

Cross wind trap strips are recommended as part of a resource management system that addresses all natural resource concerns and the objectives of the landowner or operator. For this practice to be fully effective, crop rotation, nutrient and pest management, crop residue management, and other cropland practices should be considered.

Wildlife

Cross wind trap strips provide excellent opportunities to improve wildlife habitat by creating travel lanes that connect important habitat areas or infield escape cover. For wildlife habitat benefits, select native or other adapted species that provide wildlife food and cover.

Operation and maintenance

Trap strips must be inspected periodically. Weeds must be controlled to allow proper establishment and maintenance of the desirable species. Fertilizer will be applied as needed to maintain plant vigor. Mowing or grazing will be scheduled to accommodate wildlife species and to allow regrowth to planned height before the critical wind period or crop damage is expected to occur. Trapped material will be removed and vegetation reestablished as necessary to maintain adequate efficiency of the practice.

Specifications

Site-specific requirements are listed on the specifications sheet. Additional provisions are illustrated on the job sketch sheet. Spacing of the erosion-susceptible strips is determined using the NRCS erosion prediction technology. Specifications included in this job sheet are based on guidance contained in the local Field Office Technical Guide.

Cross Wind Trap Strips – Specifications Sheet

Landowner C.W. Strip Field number 6

Purpose (check all that apply)	
☐ Reduce soil erosion from wind	☐ Provide wildlife habitat
☑ Reduce pollution from wind-borne material	☐ Other (specify)
☐ Protect crops from wind-borne soil	

Location and Layout	Strip 1	Strip 2	Strip 3	Strip 4
Cultivated width (ft)	660			
Grassed strip width (ft)	15			
Grassed strip length (ft)	1320			
Acres in buffer strip	0.45			

Plant Materials Information				
Species/cultivar by row number	Seeding rate (lb/acre)	Seeding date	Recommend lime (tons/acre)	Recommend fertilizer $N\text{-}P_2O_5\text{-}K_2O$ (lb/acre)
Strip #1				
1 Indiangrass	9	April 10	0	30-50-80
2				
3				
Strip #2				
1				
2				
3				
Strip #3				
1				
2				
3				
Strip #4				
1				
2				
3				

Site Preparation

Prepare firm seedbed. Apply lime and fertilizer according to recommendations.

Planting Method(s)

Drill grass and/or legumes seed 0.25 inches deep uniformly. Establish stand of vegetation according to recommended seeding rate. If necessary, mulch newly seeded area with Ø tons per acre of mulch material. May seed small grain as a companion crop at the rate of Ø pounds per acre, but clip or harvest before it heads out.

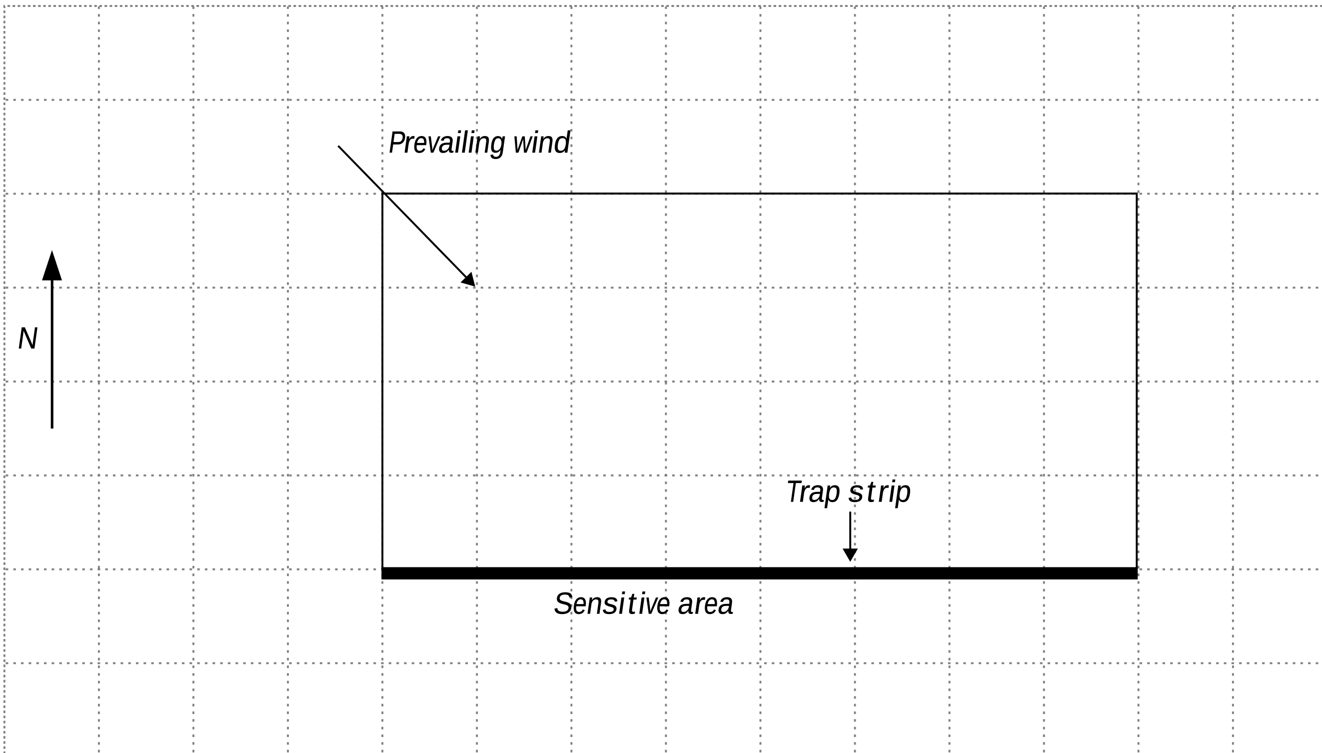
Operation and Maintenance

Trap strips must be inspected periodically. Weeds must be controlled to allow proper establishment and maintenance of the desirable species. Fertilizer will be applied as needed to maintain plant vigor. Mowing or grazing will be scheduled to accommodate wildlife species and to allow regrowth to planned height before critical wind period or crop damage is expected to occur. Trapped material will be removed and vegetation reestablished as necessary to maintain adequate efficiency of the practice.

Cross wind trap strips—Job sketch

If needed, an aerial view or a side view of the windbreak/shelterbelt shown below. Other relevant information, such as complementary practices and adjacent field or tract conditions including structures and crop types, and additional specifications may be included.

Scale 1"=________ ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")



Additional Specifications and Notes:
Prepare seedbed an additonal width for drilled sorghum on the field side of the trap strip.

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Chapter 3d Field Borders

Definition of field borders

Field borders are a strip or band of permanent vegetation established on the edge of a cropland field.

Purposes of field borders

Field borders can be used to:
- connect grassed waterways, filter strips, and other vegetative practices for ease of maintenance or harvest
- develop setbacks from sensitive areas when applying pesticides or fertilizers
- serve as turn and travel areas for equipment
- provide loafing areas for livestock
- enhance wildlife habitat
- assist with wind or water erosion control by trapping soil and organic sediment
- serve as a nursery area for beneficial insects or trap areas for pests
- reduce competition to the crop from adjacent wooded areas
- provide additional forage or crops grown for seed production
- provide setback areas from utility rights-of-way

Benefits

Field borders can be a cost-effective method to reduce erosion and sedimentation, provide better access to the field, and enhance wildlife habitat. This makes them attractive to producers, such as tenant farmers, who may not control the land for long periods, and are thus unwilling to make large investments in conservation practices.

Function

Field borders can be the "picture frame" for a combination of good conservation practices (fig. 3d–1). They provide a readily distinguishable buffer or safety zone around the edge of the field. The width can be varied and may eliminate point rows and end row planting.

Field borders differ from filter strips in a number of ways. First, filter strips are placed downgradient from areas that contribute contaminants to entrap these pollutants. Field borders are placed around perimeter areas of cropland that may or may not contribute off-site contaminants. Second, field borders need to be only wide enough to accommodate turning equipment. Filter strips are required to be designed to meet soil, climate, slope, and contributing area criteria. Third, field border vegetation is selected to tolerate equipment traffic and soil compaction. Filter strip vegetation must be stiff-stemmed and upright to retard water flow and trap contaminants.

To some degree field borders can:
- trap sediment in runoff
- filter storm water
- infiltrate storm water
- adsorb and decompose organic material and/or pollutants
- serve to enhance wildlife food, nesting, or escape cover if the proper plant species and management are used
- serves as an area to harbor beneficial and pest insects.

Figure 3d–1 Field borders and grassed waterways are among buffer options

Design considerations

Field borders must be at least 20 feet wide. The designed width will depend on the intended purposes. This often is the only conservation practice the general public can identify on some fields. Hunters and wildlife biologists will look upon it as travel lanes and nesting cover or food plots for some species. Neighboring producers will see it as an economical method for you to keep your soil from washing or blowing onto their property. Field borders may also diversify the operation if enough acres are used for forage or seed production.

When other purposes or functions of the vegetation on the edge of the cropland field is necessary, the criteria for that practice meeting the purpose or function must be followed. For example, if the field border is to become a filter strip, then the criteria of the filter strip standard will be followed.

Location

The practice is intended to link other vegetative practices together and provide the producer travel lanes to manage those practices without getting into the crop area.

Field borders are established at the perimeter of cropland fields or to connect other vegetative buffer practices, such as grassed waterways, filter strips, or contour buffer strips, so that maintenance can be performed during the crop growing season. Field borders can also be placed in strategic areas that could serve as nursery areas for beneficial insects or trap strip areas for pests. Turnrow areas or headlands can be established as a field border.

Layout

Field borders should be established wide enough to accommodate turning equipment and harvesting. They are generally more than 20 feet wide. Local design criteria should be developed for border widths that provide wildlife enhancement. Field border widths and vegetation selection should be based on the habitat requirement of the desired wildlife species. Generally, the purpose of wildlife enhancement will not be the sole reason for selecting this conservation buffer practice. Other wildlife conservation practices would be more appropriate. For field borders, wildlife enhancement comes in conjunction with any of the previously stated purposes for field borders.

Application setback distances for biosolid and chemicals follow local regulations and label requirements. For example, field borders can be used as the setback area required for pesticide application near waterbodies. Label requirements are 66 feet for atrazine.

Plant materials information

Vegetation established within a field border should be selected to meet the functional objectives of the border and the objectives of the landowner.

For turnrows or headlands, the vegetation must withstand equipment traffic and soil compaction. Consider the soils' texture, moisture conditions, and chemical properties when selecting vegetation species and mixtures. Legumes and other forbs are desirable vegetation if forage harvesting is an objective of maintaining the field border. Specific forbs and grasses may be used to harbor beneficial insects. When the field border becomes a filter strip on the downgradient side of the field, then stiff, upright stemmed vegetation is required.

Where woody field borders are desired, see Chapter 3j, Windbreak/Shelterbelt.

Operation and maintenance

Field borders can require maintenance to repair storm damage. Maintenance may also be necessary to reseed areas disturbed by tillage or traffic. Address the need for fertility, mowing or harvest schedules, and weed control. If the timing is critical to a certain operation, this can be noted. Limit the application of farm chemicals by shutting off sprayers before entering the field border.

Information needed to fill in job sheet

First, the purpose or purposes need to be agreed upon.

Species selection is the most critical issue. The field border may need to have more than one species planted in a mixture or in alternating strips to accomplish the desired purpose. Species that tolerate traffic are needed where intensive travel lanes are located. Generally those species have low growing points. For more details on differences in plant morphology, see the NRCS National Range and Pasture Handbook, chapter 5-2. Another important resource for salt tolerance and plant nutrient uptake is the NRCS Agricultural Waste Management Field Handbook, chapter 6.

The species as well as the total pounds of pure live seed required for each species can be recorded. If the seeding is a mixture, the percentage of each species should be recorded.

The width can be tailored to the field as long as the minimum design distance is obtained. An overlay of the field may be helpful for irregular fields.

The length is to be determined as well as the acres for the practice.

The slope of the border can be recorded.

Soil amendments for establishment can be recorded. This information generally comes from the soil test.

Enter the details of seedbed preparation and planting methods. This could include methods of tillage, planting depth, and the necessity for special considerations, such as mulching.

> A field border is probably the easiest of all conservation practices to apply. "Apparently soil conservation is at odds with food production because the worker of the land always has more immediate problems to solve than conserving the soil. The proper management of the soil, which also needs urgent attention, is left in second place."
> Carlos Crovetto "Stubble Over the Soil" 1996

Anticipated harvest and maintenance work can be entered in the notes section of the job specifications sheet. If wildlife habitat is a purpose of the practice, then a schedule of mowing and spraying operations acceptable for the target wildlife species should be given.

Case example

A producer in central Texas installed several grassed waterways and terraces on the erodible slopes of a field. On the part of the field that was not terraced, the producer installed contour buffer strips. After considering the maintenance requirements of the waterways and contour buffers, the producer elected to install a network of field borders to connect the vegetated areas for equipment travel and to maintain the vegetation. This vegetation also will enhance habitat for bob white quail and other birds. Bermudagrass was planted in the heavy traffic areas, but the remainder was established to a native mix of switchgrass, sideoats grama, and little bluestem to enhance habitat for the quail. This mixture will complement the existing habitat around the field and will not spread out of the border area as quickly as bermudagrass. Weed control will consist of spot treatment for johnson grass. Mowing for hay or shredding will not be done before June 15 each year to protect the nesting of quail.

Additional reading

Crovetto, Carlos L. 1996. Stubble over the soil - the vital role of plant residue in soil management to improve soil quality. American Society of Agronomy.

Heidenriech, Lynn King, Y. Zhou and T. Prato. Watershed scale water quality impacts of alternative farming systems.

United States Department of Agriculture, Natural Resources Conservation Service. National Range and pasture handbook. Chapter 5-2.

United States Department of Agriculture, Natural Resources Conservation Service. Agriculture waste management field handbook. Chapter 6.

Field Borders

Conservation Practice Job Sheet *386*

Natural Resources Conservation Service (NRCS) ***April 1997***

Landowner____

Definition

A field border is a band or strip of perennial vegetation established on the edge of a cropland field.

Purpose

A field border reduces sheet, rill, and gully erosion at the edge of fields; protects water quality by trapping sediment, chemical and other pollutants; provides a turning area for farm equipment; and provides wildlife habitat.

Where used

- On the outside edges of fields.
- Complementary to a conservation management system.

Requirements for establishing field borders

Field borders should be a minimum of 20 feet wide and should be wide enough to allow turning of farm equipment.

Conservation management system

Field borders are normally established as part of a conservation management system to address the soil, water, air, plant, and animal needs and the owner's objectives. A field border used with contouring, contour stripcropping, cross-slope farming patterns, or terraces eliminates the normal planting of end rows or headlands in uphill and downhill directions. It also provides a turning area for farm equipment, which reduces sheet, rill, and gully erosion. Field borders can also provide forage production and improve farm aesthetics. They are most effective when used in combination with other agronomic or structural practices to provide conservation benefits.

Operation and maintenance

Inspect and repair field borders after storms to fill in gullies, remove sediment, reseed disturbed areas, and take other measures to ensure the effectiveness of the border. Mow (and harvest if possible) field border vegetation during noncritical times for wildlife to encourage dense vegetation growth.

Wildlife

Field borders can enhance wildlife objectives. Benefits depend on the vegetative species used and management practiced. Consider using adapted native vegetative species that can provide food and cover for important wildlife. Increase width, if needed, to provide necessary protection for nesting animals from predators. Delay mowing of grassed area until after the nesting season for ground-nesting birds and animals.

Specifications

Site-specific requirements are listed on the specifications sheet. Additional provisions are entered on the job sketch sheet. Specifications are prepared in accordance with the NRCS Field Office Technical Guide and the Field Border practice standard (386).

Field Borders – Specifications Sheet

Landowner *Buddy F. Border* Field number *1*

Purpose (check all that apply)	
☑ Wildlife habitat	☐ Trap sediment, nutrients, pesticides, other contaminants
☑ Stabilize field boundaries, turnrows, and headlands	☐ Erosion control
☑ Provide protective turnrow or equipment travel lane	☐ Other (specify):

Field border layout (For exact location see job sketch)	Field border 1	Field border 2	Field border 3
Border width (ft)	30	25	
Border length along edge of field (ft)	2,150	4,900	
Area (ac)	1.5	2.8 + 0.6	
Slope (%)	3	2	
Species #1	Switchgrass 50%	Hybird Bermuda grass	
Species #2	Sideoats Grama 25%		
Species #3	Little Bluestem 25%		
Seeding rate (PLS) (lb/acre)	6 lb pls/ac	160 lb/ac	
Lime (tons/acre)	Ø	Ø	
N (lb/acre)	15	15	
P_2O_5 (lb/acre)	50	50	
K_2O (lb/acre)	30	30	

Site Preparation

Prepare firm seedbed. Apply lime and fertilizer according to recommendations.

Planting Method(s)

Drill grass and legume seed *0.25* inches deep uniformly over area. Establish stand of vegetation according to recommended seeding rate. If necessary, mulch newly seeded area with *Ø* tons per acre of mulch material. May seed small grain as a companion crop at the rate of *Ø* pounds per acre, but clip or harvest before it heads out. *Bermuda will be sprigged at a 4-inch depth.*

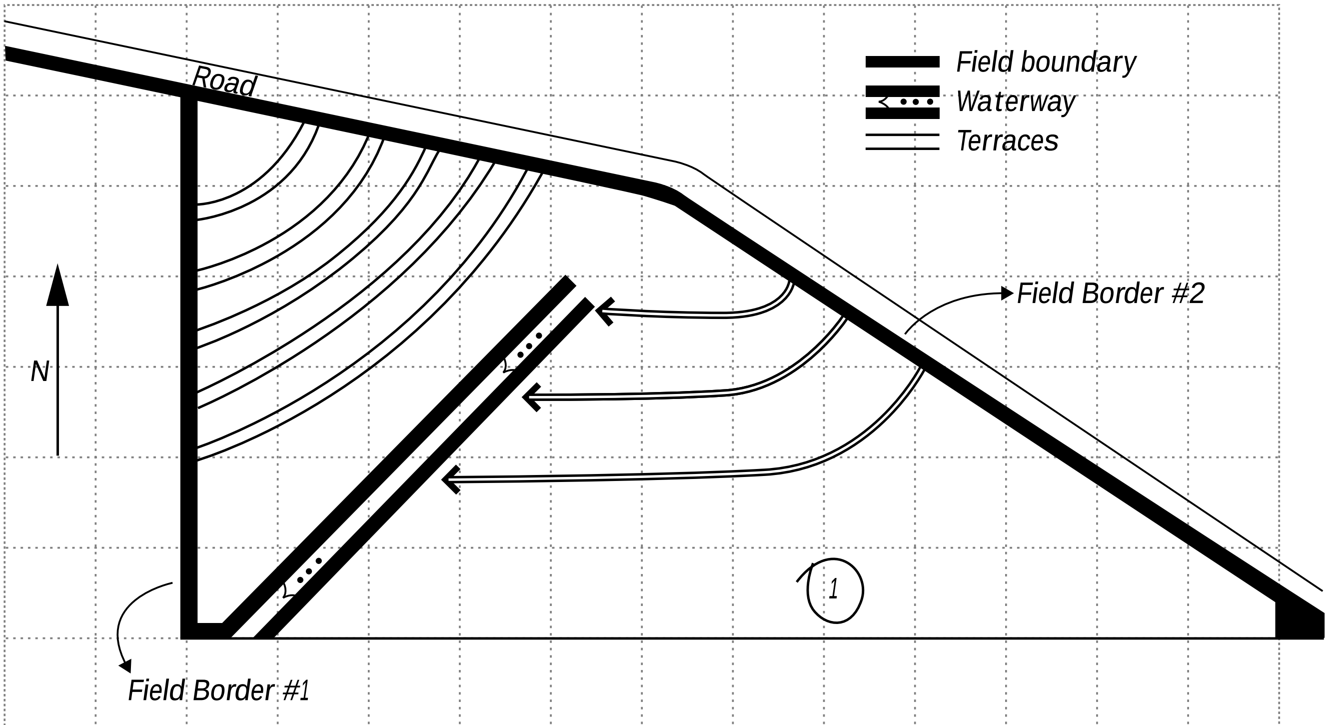
Maintenance

Maintain original width and depth of the grass area. Harvest, mow, reseed, and fertilize to maintain plant density, vigorous plant growth, and to remove plant nutrients. Inspect after major storms, remove trapped sediment, and repair any eroding areas. Shut off pesticide sprayers when turning on a field border. *Do not mow or harvest native species proir to June 15.*

Fieldborders—Jobsketch

If needed, an aerial view or a side view of the field border layout can be shown below. Other relevant information, such as complementary practices, and adjacent field or tract conditions, the positioning of multiple or single row sets across a field or tract, and additional specifications may be included.

Scale 1"=_660_ ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")



Additional Specifications and Notes:
Switchgrass 4pls/ac x 1.5 ac = 6 pls x 50% = 3 pls
Sideoats Grama 9 pls/ac x 1.5 ac = 13.5 pls x 25% = 3.4
Little Bluestem 6.8 pls/ac x 1.5 ac = 10.2 pls x 25% = 2.6 pls
Fertilizer (15-50-30) will be incorporated during seedbed preparation
Addition nitrogen will be applied after the plants are established according to growing conditions
Spot spray Johnson grass with a 3% mixture of glyphosate (Roundup)

Chapter 3e Filter Strips

Definition of filter strips

Filter strips are areas of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants in runoff.

Purposes of filter strips

Filter strips can accomplish the following purposes on the landscape:

- remove sediment (both mineral and organic) from run-on and wastewater
- infiltrate run-on water that contains potential pollutants
- transform entrapped pollutants into nontoxic compounds
- provide food and habitat for wildlife
- combine with other conservation practices to protect sensitive areas
- convert concentrated flow and trap sediment in zone 3 of riparian forest buffers

Benefits

Filter strips entrap and transform pollutants that are generated in areas upgradient to them. They should not be considered the sole management practice to prevent offsite movement of pollutants from the contributing area. Rather, other conservation practices and management techniques, such as crop residue management, nutrient management, pest management, and timing of tillage and chemical applications, should be applied to the upgradient cropland area to prevent initial contaminant movement.

Vegetation in filter strips has value and can be harvested. Many grass and forb species selected for filter strips are also highly desirable for forage hay or pasture (see Operation and Maintenance section). Other uses of vegetation can include bedding, mulch, and construction material.

Permanent vegetation along watercourses and drainageways helps stabilize the adjacent area. The width of filter strips provides a distance from the edge of the watercourse so equipment does not damage the area. It also offers a setback from the sensitive watercourse for application of agrichemicals and manure.

Wildlife habitat is enhanced when some part of the cropland area is converted to permanent vegetation. Besides the shelter, nesting sites, and food source, filter strips also create corridors on the landscape for wildlife movement.

Landscape aesthetics are important for impressing on the public the good job farmers and ranchers are doing protecting our land, water, air, plant, and animal resources. Filter strips can contribute to the landscape aesthetics by providing contrasting colors and textures.

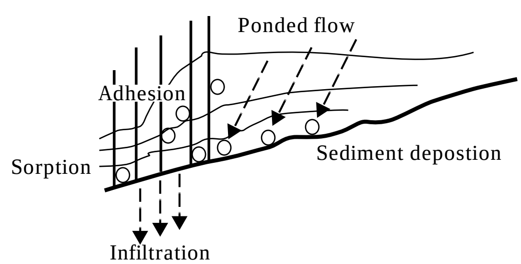
Functions

Filter strips perform several functions. These functions are described in the following paragraphs.

Entrapment and deposition

Vegetation in filter strips is dense and stands upright at a sufficient height to retard the velocity of run-on water as it enters the filter. As the water is slowed, it ponds upgradient from the vegetation. The carrying capacity of the flow is decreased and the sediment begins to fall out of the flow (fig. 3e–1). Much of the sediment falls out upgradient of where the filter strip vegetation meets the contributing area.

Figure 3e–1 Trapping mechanisms of contaminants in filter strips



Sediment entrapment in vegetated filter strips has probably been studied more than any other contaminant. Research has been fairly consistent in showing that sediment is deposited at the upgradient end of the filter strip, near the interface between the contributing area and the filter. As high as 70 percent of the sediment is actually deposited above the interface. Filter widths as short as 15 feet are effective for removal of sediment and very little additional benefit is observed in sediment removal with filters that are more than 30 feet wide. The studies were conducted on the Eastern Coast (Maryland and North Carolina, respectfully) of the United States, but observation throughout the U.S. has verified this research.

Filtration

Water moving through the vegetation is forced to take a tortuous path. In the process, particulate material, such as sediment and organics, adhere to plant stems, leaves, and crowns because the size of openings for waterflow is smaller than the particles being carried with the water. Some material adheres to plant residue and surface soil.

Infiltration

The permanent vegetation in filter strips develops surface soil conditions that favor infiltration. Surface roughness creates small pools of run-on water. These pools still the water and allow more time for water infiltration. When water is ponded, as it is upgradient of the filter area, some pressure is created that can, with time, move more water down into the soil. Plant stems and crowns break the soil surface continuity and provide portals for water infiltration. Water percolating through the soil profile is conditioned by root channels and soil fauna that habitat in the filter area.

Adsorption

Particles and soluble material that move through filter strips can get caught on the stems, leaves, crowns, and soil surface. Some of this is caused by physical filtration as described above. Other binding forces are chemical and biological in nature. Electrostatic charges build up on plant material because of the various ions that are the product of plant metabolism. These forces permit the positive charge of one material to bond with the negative charge of another. Pesticides are attracted to organic material, including soil organic matter, in this way. Another bond is developed when soluble material is held by the soil ion exchange sites and later made available for plant uptake or transformation by the chemical, physical, or biological processes that take place in soils.

Absorption

Plant roots and soil micro-organisms can extract nutrients, salts, pesticides, and heavy metals from the soil and metabolize them. Once the compounds are entrapped in the filter strip and transformed into available compounds, they can be taken up into plants and used as a food source by plants and microbes. Plant stems and leaves can also absorb nutrients and pesticides directly from the flowing water and store them either as compounds or convert them into vegetative biomass.

Decomposition

Once the pollutant compounds are entrapped in the filter strip, they begin to be decomposed by soil and plant micro-organisms. Organic material, upon decomposition, is converted to by-products of animal and plant metabolic processes, such as carbon dioxide and water. Other organic material is humified into soil organic matter. Under anaerobic conditions organic material is converted to methane gas and water.

Transformation

Besides conversion of organic material into carbon dioxide, water, and organic matter, other compounds trapped in filter strips can be transformed to less toxic material. Nitrate nitrogen (NO_3–N) is converted to gaseous forms of nitrogen by soil microbes found when anaerobic soil conditions exist in the soil. This process is called denitrification. Carbon compounds from plant roots and soil organic matter supply the energy to the anaerobic bacteria that convert nitrates to nitrous oxides (N_2O) and elemental nitrogen (N_2).

Another example of transformation is a chemical process that takes place on the soil surface allowing ammonia gas to escape from ammonium nitrogen compounds. This is called nitrogen volatilization.

Pesticides are also transformed by a number of chemical, physical, and biological processes. The by-products of pesticide metabolism by soil microbes are again carbon dioxide and water. Pathogens including bacteria, viruses, and fungi are destroyed by heat, drying, and ultraviolet light on the surface of filter strips.

Cover and food for wildlife

Vegetation in filter strips produces forage, flowers, and seed for wildlife diets. Even seeds from weeds that grow in association with filter vegetation can be good sources of wildlife food. Grass and forbs in filter strips are selected for having stiff, upright stems to retard and filter runoff water form adjacent lands. This type and form of vegetation is also suitable for escape shelter and nesting cover for wildlife. Much of the area next to filter strips is cropland. These vegetated filter areas offer shelter and food to wildlife that also forage on adjacent cropland.

Provide physical setback separation of chemical application in fields

During field applications of pesticides, fertilizers, and manure, inadvertent deposition of chemicals often occurs directly into sensitive areas when application equipment turns or comes close to these areas. Filter strips provide a physical buffer, or setback distance, to reduce this inadvertent application. Some drift and most dripping of application equipment can be controlled or restricted to the vegetated filter strip. Climate and soil permitting, these filter strips can be used as a place to turn and position equipment for more precise application.

Design considerations

Location

Filter strips are used at the lower edges of cropland fields where pollutants may move off the cropland area. They can also be used above conservation practices, such as ponds, drainageways, and terraces, to reduce the load of sediment or other contaminants moving into the practice areas. Filter strips are helpful immediately below confined animal areas to capture and transform pollutants that could move off the livestock area. In forest land and along roads, filter strips are needed as a part of the construction and operation measures to reduce delivery of sediment into waterways, trails, and roads. Keep in mind that filter strips are only a part of an overall system of conservation practices that control the source and transport of contaminants that may be lost as part of the agricultural production system.

Filter strips should be installed so that run-on water enters the filter strip as shallow flow. This allows maximum contact time between soil, vegetation, and water to enable deposition, sorption, and transformation to work. If the run-on water enters as concentrated flow, the efficiency of the filter strip to trap and transform contaminants is greatly reduced.

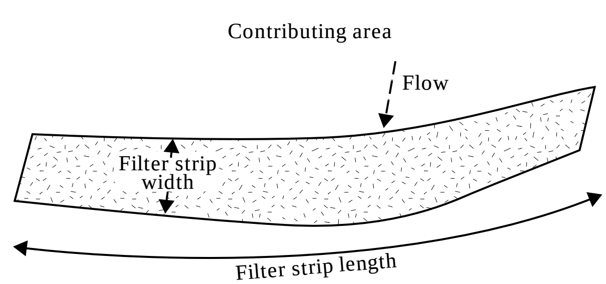
Width and length used in filter strips

Width is measured in the direction of flow. Since filter strips are placed along the contour, as much as possible, their dimension at the narrow point is called *width*. This is analogous to the width of a cultivated area in stripcropping or width of a contour buffer strip. The flow of water moves parallel with the width. (The same is the case of other conservation practices, such as cross wind trap strips, which has movement of the wind across the width.) The *length* of a filter strip is the longitudinal distance across the landscape that the strip occupies perpendicular to the direction of flow. Other terms, such as flow length, may be used to depict the direction of flow (fig. 3e–2).

The slope of the filter and soil of the filter area impact the overall filter performance. Steeper slopes in the filter strips increase flow velocity and shorten the time the contaminant material carried in the runoff water, both particulate and soluble, has to interact with the vegetation and soil in the filter area. The soils themselves are important parameters in judging filter effectiveness. Hydrologic soil groups (A, B, C, and D) are indicative of the infiltration and runoff potential. Soil groups A and B have higher infiltration potential; therefore, less runoff than groups C and D. Soil drainage class also determines the extent of soil moisture conditions and water storage available in a soil. Filter strips located on hydrologic soil groups C and D are less effective in treating run-on than filter areas on A and B soils.

In most filter systems the greater flow length (width) of the filter area provides the greater entrapment and removal of contaminants. However, an optimal length of flow or area is soon reached where further distance will not result in proportionally greater efficiency. A filter strip that achieves 100 percent removal of contaminants or completely reduces the water discharge

Figure 3e–2 Width and length in a filter strip



to zero would be difficult and impractical to design and maintain. Most practical designs are based on contaminant removals of 50 to 80 percent depending on the type of contaminant.

Type and density of vegetation also influence filter effectiveness. Table 3e–1 gives minimum stem densities required for filter strips.

Effective width of filter strips

The design width of a filter strip depends on a number of factors. First, the purpose of the filter strip must be defined. Filters to entrap and deposit sediment are not required to be as wide as filters used to remove soluble compounds, such as nitrate nitrogen or pesticides. It takes more surface area and longer flow paths to adsorb and infiltrate soluble material than to entrap solid material. Climate conditions and storm events anticipated during the expected runoff events influence the effectiveness of the filter to retard flow and remove pollutants. At some times during the year, climate conditions such as frozen and snow covered soil, saturated soil, and crusted soil surface, severely reduce the action and effectiveness of filter strips.

Animal manure and associated nutrients require longer flow areas and more soil-plant-contaminant contact. In one case study, effluent from a cattle feedlot was effectively removed within 130 feet a Kentucky bluegrass filter strip. The soil had a sandy loam texture and allowed rapid infiltration along the flow path.

In Arkansas, two studies concluded that sediment and nutrient runoff (including nitrogen and phosphorus) from poultry and swine manured fields were significantly reduced in the first 10 feet of a tall fescue grass filter grown on a Captina silt loam soil. Further lengthening of the filter strip beyond 30 feet did not significantly reduce the contaminant load of the runoff water.

In Montana, the trapping efficiency and nutrient uptake of four grasses were measured to treat dairy manure runoff in a filter strip. Orchardgrass and meadow bromegrass were effective at both entrapping the nutrients in the runoff and absorbing the nitrogen into the plant biomass within the upper 20 feet of the filter.

Case example

Filter strips on the downgradient edge of a field are required to trap and remove sediment and pesticides (atrazine) that are running off the adjacent cropland. Considering the dual purposes (remove sediment and pesticides), soil type (a silt loam), and slope of field (3%), the required filter strip width, from criteria in the Field Office Technical Guide conservation practice standard Filter Strip (393), is 40 feet. A warm-season grass, switchgrass, with resistance to the atrazine herbicide will be planted in the lower, downgradient 30 feet of the filter strip. The upper 10 feet of the filter will be planted to smooth bromegrass to tolerate the deposition of the expected entrapped sediment. Once conservation tillage and crop residue management are implemented on the adjacent cropland, minimizing the erosion and runoff, the bromegrass will be killed by herbicide and that upper 10 feet planted to switchgrass.

Information needed to fill in job sheet

Select the purpose or purposes of the filter strip

Choose the purpose or purposes described in this document and desired by the landowner. Most purposes are compatible, such as sediment entrapment and filtering out pollutants. Some purposes are, however, in conflict with each other. An example would be filters for wildlife nesting habitat with the purpose of nutrient sequestering and removal. Nutrient entrapment and removal require frequent harvest of the vegetation. This is most important during the rapid plant growth period, which could coincide with wildlife nesting periods. Increasing the width, supplement-

Table 3e–1 Required stem densities of vegetation for filter strips

Stem diameter (inches)	Number of stems (stems per square foot)
0.10	50
0.25	25
0.50	12
0.75	8
1.00	5

ing the vegetative species, or varying the maintenance may be required when two or more purposes are not compatible. For example, adding additional filter strip width as a warm-season grass and mowing and harvesting the grass less frequently may provide the necessary functions for both nutrient sequestering and wildlife habitat purposes.

Determine the filter strip layout in the field

Strip width is based on local specifications and guidance given in the Field Office Technical Guide and determined by site cẽ ditions for soil, slope, contributing pollutant, and purpose of the filter strip. Previous sections of this document give some guidance on determining proper filter strip width. Width is the direction across the filter strip that water flows.

Strip length is the measured distance along the landscape where the filter strips are placed. This is the long direction. Filters that receive runoff water must be downgradient from the contributing area. Not all areas along the edge of the field or continuous landscape receive runoff water as sheet or laminar flow. Filter strips work best in areas that contribute the runoff in shallow flow. For continuity, filter strips can be extended up and over nonflow areas to connect different segments of a filter strip and provide other benefits, such as corridors or setbacks.

Area of the filter strips

The area and location of filter strips should be sketched on the plan map. The exact location of the filter strips will be marked in the field at the time of establishment. The area of filter strips is the length times the width. The width may not be constant along the field edge because of variation in slopes and soils in the field or the desire to square-off the contributing field.

> Clipping and harvesting the vegetative biomass from filter strips significantly reduce the amount of nitrate nitrogen in the soil profile and allow less nitrogen movement below the plant root zones. This points out the importance of removing plant biomass and associated absorbed nutrients from the filter area. These data were collected for 7 years at the USDA, NRCS Plant Material Centers in Knox City, Texas; Cape May, New Jersey; and Big Flats, New York.

Percent slope of the filter area

Measure the slope of the filter strip. The slope may determine the width of the filter area. Slopes between one and 10 percent are most effective. Slopes less than one percent are too flat and may cause ponding and concentrated flow channels. Slopes greater than 10 percent are steep and may not allow ample contact time for the runoff and soil and vegetation in the filter area. Ideal slopes for filter strips range between 2 and 6 percent.

Species selected

The species selected are based on climate conditions, soils, proposed purpose and function of the filter, and desired by-products to be gained. A required density is given for filters designed to intercept sediment (table 3e–1). Select plant species that can tolerate inundation by sediment or chemicals that move from the contributing area. Operation and maintenance for a specific purpose may require the species to possess certain attributes. Filters designed for entrapping plant nutrients, such as nitrogen and phosphorus, require frequent harvest of the sequestered nutrients. Plant species selected for this purpose should take up high amounts of nitrogen and phosphorus, produce ample biomass, tolerate frequent mowing, and have some forage value.

Seeding and planting rates

Seeding rates will match recommendations given in the FOTG for the species and purpose selected. Consider the mature stem density required to meet the function of the filter.

Nutrient and soil amendments

Fertilizer and lime are applied based on the soil test recommendations or other locally accepted guidelines. Nutrients applied for establishment of filter strips can have a high risk of movement into those same sensitive areas that are intended to be protected by the established filter strips. Phosphorus and potassium should be incorporated into the seedbed to lessen the risk for surface movement during any overland flow immediately after establishment. Nitrogen usually presents less risk if it is applied to the filter strip vegetation after the vegetation is established and actively growing. Nutrient status of the filter strip must be periodically assessed to maintain a healthy, vigorous stand of vegetation.

Site preparation and planting

Methods of site preparation and planting must conform to local FOTG guidelines. Minimum surface disturbance is desirable to reduce the risk of erosion and runoff. Control weeds before filter strip establishment to avoid vegetation competition.

Operation and maintenance

The first axiom about filter strips is, “Filter strips are designed to fail!” To function properly, the filter area must get contaminated with sediment and other pollutants. Becoming dirty is a desirable result for a filter strip. Some basic operations and maintenance work must be done to maintain the function and value of filter strips.

1. Shallow sheet flow across the filter must be encouraged for filter strips to function properly. Any development of channels or rills within the filter strips must be minimized and immediately repaired. Shallow furrows or small berms placed across any concentrated flow help re-establish sheet flow.

2. Concentrated flow areas that cannot be redirected should be treated separately. A grassed waterway or shallow impoundment may be required to stabilize the waterway and reduce flow velocity to encourage deposition and infiltration. Terraces, dikes, berms, trenches, or vegetative barriers can be used.

3. Sediment accumulates along the upper part and within the filter. This sediment should be removed before it accumulates to a height higher than 6 inches and begins to divert the runoff water around the filter strip as concentrated flow. Removal and redistribution can be accomplished with tillage equipment or other machinery. The filter strip may need to be re-established at the contributing area interface.

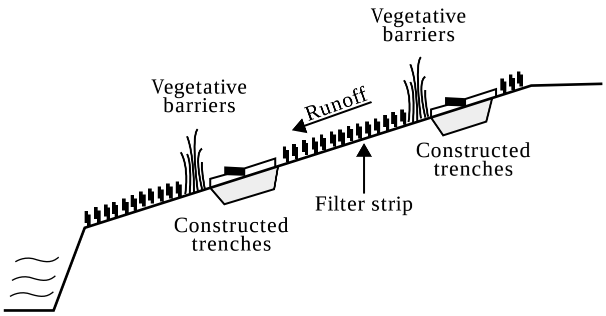
4. The vegetation of the filter strip performs such tasks as nutrient uptake and carbon sequestering more efficiently if the biomass is mowed and removed from the filter area. This keeps the filter strip in a vigorous vegetative condition and absorbs nutrients and other contaminants more effectively. A mowing and harvesting schedule should be a vial part of the operation and management plan.

5. If bacteria or other pathogens are being removed by the filter strip, a close, short-mowed sod is desirable to allow sunlight and air movement to desiccate the entrapped pathogens. Likewise, if nutrient sequestering is the purpose, continual harvesting is required to remove the nutrients from the filter area and promote a vigorous sod of filtering vegetation.

6. Weeds, particularly noxious weeds, must be controlled in the filter area. Any volunteer or spreading vegetation has to be contained within the designed filter area. The designed filter strip width and density will be maintained, but may be temporarily altered to remove accumulated sediment and re-establish the filter-contributing area interface.

7. Other conservation measures and practices can be used in the operation of a filter strip. Shallow trenches constructed across the flow direction can enhance infiltration. These trenches are dug and refilled with porous or adsorbent material (crushed limestone or wood products) to reduce runoff, encourage infiltration, and adsorb pollutants contained in the run-on water. Periodic maintenance and refurbishing of the fill material are necessary. Another enhancement could be vegetative barriers established across the slope and perpendicular to the flow of water in the filter strip, either upgradient to the filter or intermittently down the slope within the buffer. The effect is the same, to retard flow, increase infiltration, and adsorb pollutants. The vegetative barrier area will actively transform pollutants because of the plant material and improved biological activity (fig. 3e–3).

Figure 3e–3 Constructed trenches filled with porous material and vegetative barriers used within a filter strip to enhance performance



Additional reading

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Oksendahl, V.E. 1997. Effectiveness of grass species for nitrogen recovery from dairy waste. MS thesis. Montana State University, Bozeman, MT.

Robison, M. and S. Primard. 1997. Nutrient removal and recovery from vegetated filter strips. Final report of the PMC filter strip studies at Big Flats Plant Material Center and Cape May Plant Material Center. United States Department of Agriculture, Natural Resources Conservation Service Plant Material Program. Big Flats, NY.

Practice Standard Guidance, Filter Strips (393) in the Field Office Technical Guide. Additional guidance on vegetation selection and establishment in practice standard Critical Area (342).

Filter Strips

Conservation Practice Job Sheet *393*

Natural Resources Conservation Service (NRCS) ***April 1997***

Landowner____

Definition

A filter strip is an area of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants from runoff and to maintain or improve water quality.

Purpose

Filter strips intercept undesirable contaminates from runoff before they enter a waterbody. They provide a buffer between contaminant source, such as crop fields, and waterbodies, such as streams and ponds.

Filter strips slow the velocity of water, allowing the settling out of suspended soil particles, infiltration of runoff and soluble pollutants, adsorption of pollutants on soil and plant surfaces, and uptake of soluble pollutants by plants.

Secondary benefits:

- Forage—onfarm use or cash crop
- Field borders
- Turnrows and headlands
- Access
- Aesthetics

Where used

- At the lower edge of crop fields or in conjunction with other conservation practices.
- On fields along streams, ponds, lakes, and drainageways.
- As part of a riparian forest buffer system.
- Where there is sheet or uniform shallow flow (avoid concentrated flow).
- As part of an agricultural waste management system.
- When they can be installed on the approximate contour.
- Where conservation practices reduce soil losses to acceptable level.
- In conjunction with conservation practices on the contributing area to reduce sources of contaminants.
- On slopes less than 10 percent.

Conservation management system

Filter strips are normally established as part of a conservation management system to address the soil, water, air, plant, and animal needs and the owner's objectives. It is important to plan the conservation crop rotation, nutrient and pest management, crop residue management, and other cropland practices. Filter strips can also provide forage production and improve farm aesthetics. They are most effective when used in combination with other agronomic or structural practices to provide conservation benefits.

Wildlife

Filter strips can enhance wildlife objectives depending on the vegetative species used and management practiced. Consider using native or adapted vegetative species that can provide food and cover for important wildlife. Delay mowing of filter area until after the nesting season.

Specifications

Site-specific requirements are listed on the specifications sheet. Additional provisions are entered on the job sketch sheet. Specifications are prepared in accordance with the NRCS Field Office Technical Guide. See practice standard Filter Strip (393).

Operation and maintenance

- Mow (and harvest if possible) filter strip grasses several times a year to encourage dense vegetative growth. For ground nesting wildlife, care should be taken to avoid mowing during nesting periods.
- Control undesirable weed species.
- Inspect and repair after storm events to fill in gullies, remove flow disrupting sediment accumulation, reseed disturbed areas, and take other measures to prevent concentrated flow in the filter strip.
- Lime and fertilize to soil test recommendations.
- Exclude livestock and vehicular traffic from filter strip during wet periods of the year since filter strips rely on infiltration for reducing contaminants. It is recommended that this type of traffic be excluded at all times to the extent that is practical.
- Restoration is required once the filter strip has accumulated so much sediment that it is no longer effective.

Filter Strips – Specifications Sheet

Landowner *Phil Terstrip* Field number *6*

Purpose (check all that apply)	
☑ Collect sediment	☑ Pollutant filtration
☐ Increase infiltration	☐ Other (specify):

Filter strip layout	Filter strip 1	Filter strip 2	Filter strip 3
Strip width (ft)	40		
Strip length (ft)	4,200		
Area of filter strip (ac)	3.9		
Slope (%)	3%		
Species #1	Switchgrass		
Species #2	Bromegrass		
Species #3			
Seeding rate (PLS) (lb/acre)	(see notes)		
Lime (tons/acre)	1		
N (lb/acre)	30		
P_2O_5 (lb/acre)	50		
K_2O (lb/acre)	60		

Site Preparation

Prepare firm seedbed. Apply lime and fertilizer according to recommendations. *Incorporate P & K fertilizer*

Planting Method(s)

Drill grass and legume seed *0.25* inches deep uniformly over area. Establish stand of vegetation according to recommended seeding rate. If necessary, mulch newly seeded area with *Ø* tons per acre of mulch material. May seed small grain as a companion crop at the rate of *Ø* pounds per acre, but clip or harvest before it heads out.

Maintenance

Maintain original width and depth of the grass area. Regularly remove debris and sediment from filter area. Harvest, mow, reseed, and fertilize to maintain good vegetation. Inspect periodically after every major storm and repair any eroding areas.

Filter Strips – Job Sketch

If needed, an aerial view or a side view of the filter strips field layout can be shown below. Other relevant information, such as complementary practices, adjacent field or tract conditions, the positioning of strips across a field, including structures and crop types, and the positioning of multiple or single row sets across a field or tract, and additional specifications may be included.

Scale 1"=________ ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")

Additional Specifications and Notes:

Chapter 3f Grassed Waterway with Vegetated Filter

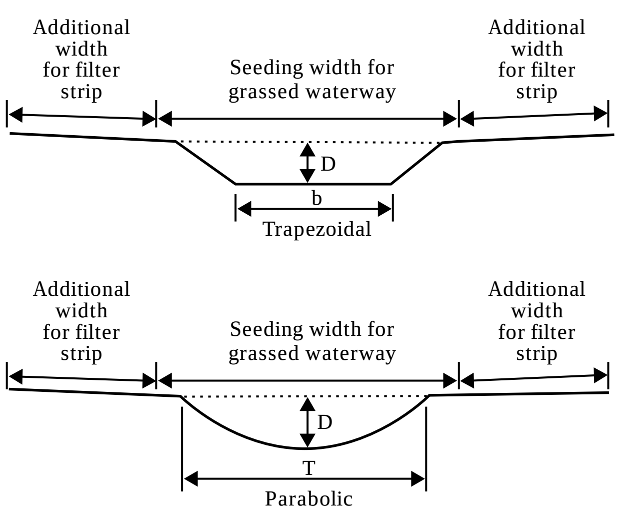
Definition of grassed waterway with vegetated filter

A grassed waterway is a natural or constructed channel that is shaped or graded to carry surface water at a nonerosive velocity to a stable outlet that spreads the flow of water before it enters a vegetated filter. The required dimensions are those needed to convey runoff from the design storm, generally the 10-year, 24-hour storm event. The grassed waterway is designed to ensure that the velocity during the runoff event is within the permissible limits of the soil-vegetation combination (fig. 3f–1).

Purposes of a grassed waterway/filter strip

The primary purposes of a grassed waterway are to convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding and to improve water quality.

Figure 3f–1 Typical grassed waterway with a filter strip on each side



Note: Feild slope draining to filter strip must be greater than 1 percent

Benefits

A grassed waterway provides a vegetative strip on the landscape that benefits the environment in several ways in addition to the primary benefit of providing a nonerosive waterway. These additional benefits include wildlife habitat, corridors connection, vegetative diversity, noncultivated strips of vegetation, and improved aesthetics. An additional grassed width on each side of the grassed waterway may enhance these benefits so the waterway can better serve as a conservation buffer.

Functions

The primary function of a grassed waterway is to transport water and sediment. Nearly all grassed waterways are located topographically so that runoff enters the waterway either as sheet or concentrated flow. Because of the high velocities within the grassed waterway, little or no sediment deposition occurs within the waterway. Therefore, suspended sediment entering the grassed waterway will most likely exit the waterway at its outlet to the possible detriment of the receiving waterbody. As such, the function of a grassed waterway is not to reduce sediment loading in runoff. However, providing additional grassed width on each side of the waterway sufficient to serve as filter strips reduces the sediment loading entering the waterway. This would enhance the water quality benefit of the waterway as well as the additional benefits already mentioned.

Design considerations

Criteria for grassed waterway planning, design, construction, and maintenance are in Practice Standard 412, Grassed Waterway. A 10-step procedure is recommended for designing a grassed waterway. This procedure is outlined in NRCS's Engineering Field Handbook (EFH) Chapter 7, Grassed Waterways and Outlets. These two references provide adequate guidance in how to plan and design a grassed waterway for its primary purposes.

The basic design of a grassed waterway can be modified to further enhance its purpose of improving water quality and to better serve as a conservation buffer on the landscape. Providing an additional vegetative width to the grassed waterway allows the waterway to serve as a filter strip/buffer. An alternative outlet to the traditionally used vegetated waterway, earth ditch, or grade stabilization structure is also beneficial.

The additional width needed on the sides of the grassed waterway to serve as a filter strip can be determined using procedures given in Chapter 3e, Filter Strips. The land slope toward the filter strip must be greater than 1 percent. Field slopes of 1 percent or less are not suitable for vegetative filter strips because the hydraulic gradient is insufficient to force water through the vegetative cover in the filter strip. On slopes of less than 1 percent, runoff flows parallel to the filter strip until a low point is reached rather than flowing evenly through the filter strip into the waterway.

As with any filter strip, to be effective in reducing sediment loading from the adjacent field, the runoff must enter a filter strip along the grassed waterway as sheet flow (fig. 3f–2 and 3f–3). Grassed waterway construction can complicate achieving this because of the spoil from its excavation that is generally spread adjacent to the waterway. To ensure sheet flow enters the waterways filter strip, plans and specifications for the waterway construction must address proper spoil spreading. Spoil from the waterway excavation must be spread so it does not cause a reverse grade. A reverse grade causes runoff to concentrate on the field side of the spoil and flow parallel to the waterway until a low place is reached where it can enter the waterway. Another concern is the concentrated flow that may enter the waterway at various points along the waterways length.

Concentrated flow must be spread to sheet flow before it enters the filter strip. Where this is not practical, provision should be made so the concentrated flow enters the waterway without causing erosion.

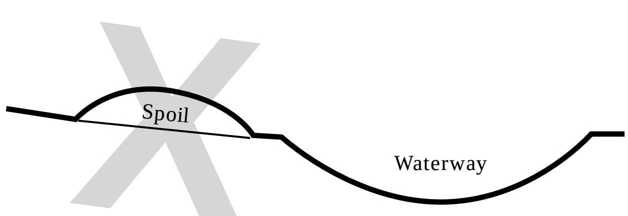
Vegetation in the grassed waterway must be well established to withstand velocities that it is designed to accommodate. In some areas special measures are needed to ensure that vegetation has a chance to establish. These measures may include mulching or flow diversion. The Field Office Technical Guide should be consulted for the proper vegetation establishment. If diversion is recommended, using spoil for this purpose may be a possibility. At some locations it is advantageous to leave enough spoil from waterway excavation to form a berm adequate to prevent runoff from entering the waterway. Once the vegetation is established, the berm must be removed so runoff can enter the filter strip and waterway.

Example waterway design

This example for the design of a grassed waterway follows the steps recommended by EFH chapter 7. It allows use of design charts, which makes sizing the waterway rather simple compared to working through the applicable design formula. Knowing the many facets of waterway design described in EFH chapter 7 is necessary to be fully proficient in the design of a waterway.

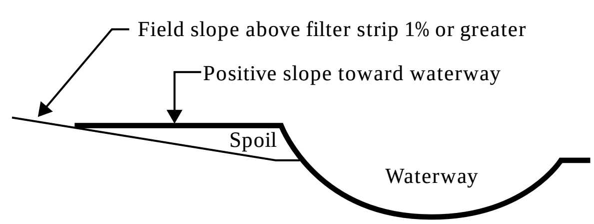
Step 1: Plan the location of the waterway centerline that minimizes impact.
An onsite inventory is conducted and the centerline located. This example assumes that the waterway is located accordingly.

Figure 3f–2 Improper soil spreading



Note: Consider delaying spoil spreading until after grass in the water way has been established.

Figure 3f–3 Proper spoil spreading to achieve sheet flow



Step 2: Select design points along the waterway where grades change or drainage areas and type of lining change significantly.
This step requires the evaluation of the chosen alignment in terms of the site's topography and where major side drainages enter the waterway. This example assumes that the design points are selected accordingly and that the only design point is its outlet.

Step 3: Determine the watershed area for the points in step 2 and for the outlet.
This step involves delineating the boundary of the watershed contributing to the waterway on a map and then measuring this delineated area with a planimeter or similar tool. The example assumes a 90-acre drainage area at the waterways outlet.

Step 4: Find the peak runoff produced by the design storm.
The procedures given in EFH Chapter 2, Estimating Runoff and Peak Discharges, or the technical release, Hydrology for Urban Watersheds, may be used for making this determination. This example follows the procedures of EFH chapter 2. The calculations for peak runoff are shown in appendix 3f–2. Before making these calculations, however, the watershed must be inventoried for information in addition to its area. This information includes an inventory of the watersheds soils and cover, average slope, and flow length. The watersheds flow length, in simple terms and for this example, is how far a single drop of water originating at the most distant point in the watershed must travel to get to the waterways outlet. For this example, the average slope for the watershed is assumed to be 1 percent and the watershed flow length is 3,400 feet. Watershed and soils assumptions are shown in table 3f–1.

The frequency of the design storm to use must be determined. To meet Practice Standard 412, the minimum capacity shall be that required to convey the peak runoff expected from a storm of 10-year frequency, 24-hour duration. The minimum 10-year frequency is used for this example design.

The 10 year, 24-hour storm event for the Eastern United States, which is 5.5 inches, issued in this example. The rainfall distribution type for this area is Type II.

The peak discharge calculated using worksheets 1 and 2 (appendix 3f–1 and 3f–2) is 120 cubic feet per second.

Step 5: Determine the slope of the waterway from the topographic map, profiles, or cross sections.
This step is self explanatory. A 5 percent gradient is assumed for this example.

Step 6: Select the appropriate waterway cross section and type of waterway protection to be used — bare, vegetated, or lined.
Typically the shapes of grassed waterways are parabolic (fig. 3f–4), trapezoidal, or triangular. This example is a parabolic shape. Since this waterway is to also serve as a buffer, it has a vegetative lining.

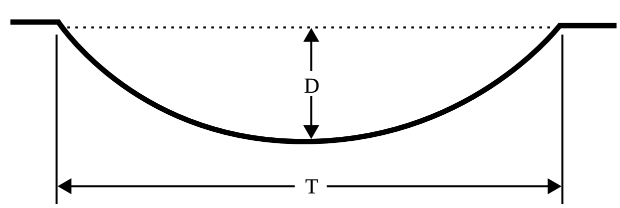
Step 7: Design the waterway for stability by selecting the maximum permissible velocity.
The maximum permissible velocity is based on the erosivity of the soil and the type of vegetative lining. EFH, chapter 7, exhibit 7–3 (also shown in appendix 3f–4), relates permissible lining to the combined factors of the type of vegetation and soil erodibility. For this example, a good stand of Kentucky bluegrass and an easily erodible soil are assumed. The maximum permissible velocity for this situation is 5 feet per second.

Vegetation in a grassed waterway tends to bend and oscillate under the influence of flow velocity and depth. Retardance to flow varies as these factors

Table 3f–1 Watershed and soils assumptions

Soil name	Cover description (cover type, treatment, and hydrologic condition)
Dover	Pasture in good condition
Berea	Straight row crops, good
Easton	Woods, poor

Figure 3f–4 Selected parabolic shape



change. The approach in designing a grassed waterway is to design for stability using a retardance factor for when the vegetation has the least retardance to flow and to design for capacity using a retardance factor for when the vegetation has the most retardance to flow. This approach assures that regardless of what stage the vegetation is in, the flow velocity does not exceed the maximum permissible velocity nor will the waterway overtop during the design storm.

According to EFH, chapter 7, exhibit 7–2 (also shown in appendix 3f–3), classification of Vegetative Cover as to Degree of Retardance, Kentucky bluegrass has a **C** retardance when it is headed at 6 to 12 inches in height. When cut to a 2 inch height, it has a **D** retardance. Of the two vegetative conditions, the **D** retardance (cut to a 2-inch height) is when the vegetation is least able to cope with the erosive forces of the water flowing in the waterway. Therefore, retardance **D** is used to design for stability based on velocity. On the other hand, when the grass is such that it has a **C** retardance, it is better able to withstand the erosive force, but the flow depth will be greater. Because the **C** retardance causes the greatest flow depth, it is used to base the determination for capacity or the depth required to contain the design flow.

The waterway size required so the velocity will not exceed the maximum permissible is determined either using Manning's equation or the tables in EFH chapter 7, exhibits 7–4 or 7–5. These tables are for parabolic waterways. If another shape is used, Manning's equation must be used. The tables are used in this example because values are for the parameters selected — a parabolic shape, a **D** and **C** retardance combination, and a 5 percent grade. If the design parameters fall outside those included in the two EFH exhibits, Manning's equation would be used along with EFH chapter 7, exhibit 7–1. This exhibit relates Manning's *n* to the velocity times hydraulic radius. Determining waterway size using Manning's equation is a trial-and-error process and requires a basic understanding of making hydraulic computations. How these computations are made is beyond the scope of this section.

The tables in EFH exhibit 7–4 associate V1 for a **D** retardance to the waterway top width and V2 for a **B** retardance while EFH exhibit 7–5 associate V1 for a **D** retardance to the waterway top width and V2 for a **C** retardance. For Kentucky bluegrass we determined that the design should be based on a **D** and **C** retardance combination. Therefore, the tables in EFH exhibit 7–5 are the appropriate tables to use. The table in exhibit 7–5 for a grade = 5 percent is included in appendix 3f–5 for use with the example.

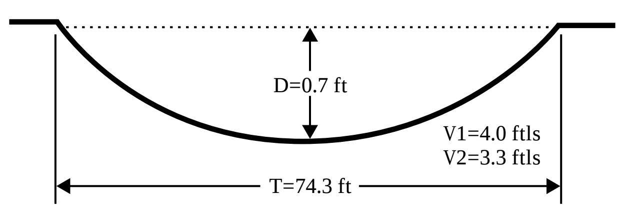
The maximum permissible velocity is already determined to be 4 feet per second. Therefore, the column used in this table is headed by V1 = 4 ft/s. Scanning down this column to 120 under the Q (ft^3/s) column at the far left of the table, the information is: T = 74.3, **D** = 0.7, V2 = 3.3. What these values are indicating is that a parabolic grassed waterway with 74.3 foot top width will carry 120 cubic feet per second on a 5 percent grade at a 4.0 foot per second velocity with a **D** retardance and will flow 0.7 feet deep and with 3.3 foot per second velocity at a **C** retardance. The flow depth with a **D** retardance would be less than 0.7 feet. This is illustrated in figure 3f–5.

Step 8: Design the waterway for adequate capacity using Manning's formula.
Use of the tables as demonstrated in step 7 makes this step unnecessary because one of the table values was for depth, the value needed when solving for adequate capacity.

Step 9: Design a system to adequately dispose of baseflow and to keep the waterway or lining well drained.
The concern in this step is dealing with a continual flow in the waterway or saturation resulting from a high water table that if allowed, would drown out the vegetation depriving the waterway of the protection of the vegetative lining. Several alternatives provide this system. The alternatives include stone centers, subsurface drainage, and underground outlets.

Step 10: Select depth of waterway from EFH exhibit 7–4 or 7–5.
A depth of 0.7 feet was determined from the table in a previous step.

Figure 3f–5 Values for the example design



Grassed waterway enhancements with a vegetative filter strip outlet

Traditionally, grassed waterways have been designed to outlet directly into a receiving waterbody, such as a stream, ditch, or lake. As mentioned, a grassed waterway in itself is not designed to reduce sediment loadings. Rather it provides a stable waterway that is nonerosive in an area that would otherwise erode. If reducing the sediment loading in the runoff transported by the waterway is an objective, an outlet that spreads the flow from the grassed waterway to a vegetative filter strip for treatment prior to discharge to a waterbody might be a possibility. One possible layout for this follows. Generally, this type of outlet is feasible only for waterways with small drainage areas that outlet into wide, mild-gradient receiving stream valleys. Otherwise, structural costs for this type of outlet would be high compared to the benefits gained.

Upstream of the waterways receiving waterbody, a water distribution structure is designed and constructed to first divert flow to the water spreader ditch. Flow in excess of what can be treated by the vegetative filter strip is diverted directly to the receiving stream. This excess flow, of course, would not be treated. EFH Chapter 6, Structures, may be useful in obtaining ideas for this structure. Undoubtedly many configurations could be used. Figure 3f–6 is a schematic of an example structure arrangement.

Schematic of distribution structure

The purpose of the pipe in the schematic drawings in figures 3f–7 and 3f–8 is to meter water to the water spreader ditch. This pipe is sized for the capacity of the vegetative filter strip/riparian forest buffer to treat the runoff water. The pipe is designed as a culvert. EFH Chapter 3, Hydraulics, has guidance on the hydraulic design of culverts.

Figure 3f–6 Typical layout for grassed waterway with a vegetative filter strip outlet

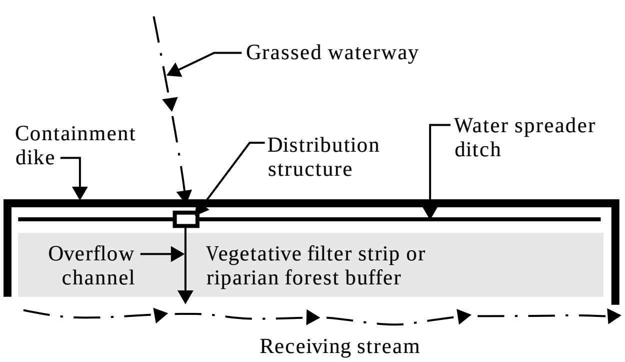


Figure 3f–7 Plan view of distribution structure

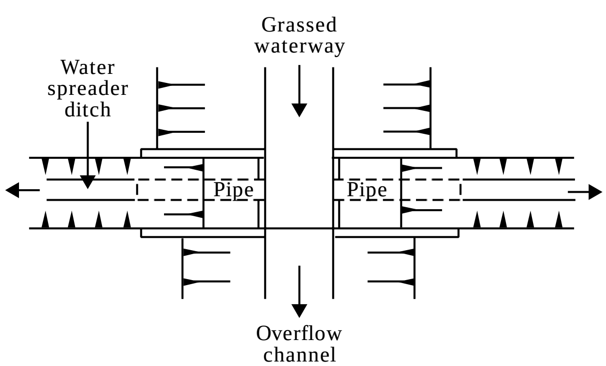


Figure 3f–8 Section view of distribution structure

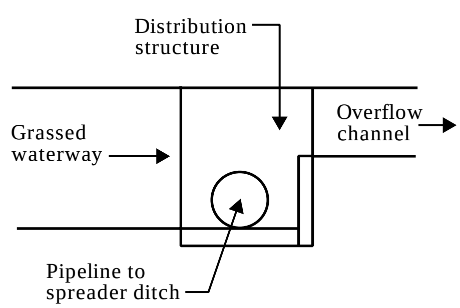
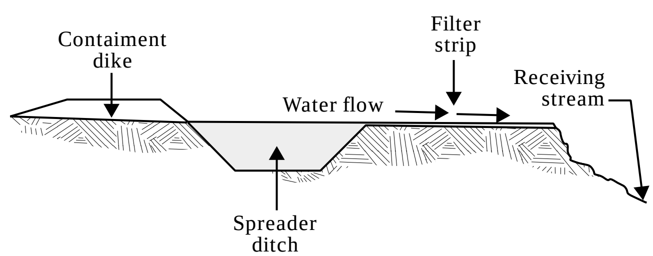


Figure 3f–9 Typical cross-section of spreader ditch and vegetative filter strip



The spreader ditch (fig. 3f–9) is constructed on the exact contour so that water spills from the downstream bank evenly the entire length to the filter strip/ riparian forest buffer. Depending on the topography, a containment dike may be needed on the uphill bank of the spreader ditch to ensure water moves to the filter strip. Spoil from excavation of the spreader ditch could be used for this purpose.

Key to designing this system is determining the capacity of the filter strip to effectively treat runoff to reduce sediment loading. Sediment deposition is highly complex depending on many factors including the type and size distribution of the sediment particles, surface roughness, and flow velocity. It is beyond the scope of this section to give a method for its determination. Instead, the computations are based on the assumption that adequate deposition will occur at velocities less than 0.5 foot per second. Local experience may justify either higher or lower velocities.

Manning's equation can be used for this determination. (See eq. 3–15 EFH chapter 3)

$$V = \frac{1.486\ r^{0.67} s^{0.5}}{n}$$

where:
- V = Mean velocity of flow (ft/s)
- r = Hydraulic radius (ft)
- s = Slope of channel bottom (ft/ft)
- n = Coefficient of roughness

Also using the flow continuity equation (eq. 3–4 EFH chapter 3) expressed as:

$$Q = AV$$

where:
- A = the flow cross sectional area

The roughness coefficient, n, is based on the type of vegetation used in the filter strip. Retardance to flow varies as flow depth and velocity change. In EFH chapter 7, exhibit 7–2 gives retardance class for various vegetative covers and exhibit 7–1 relates the product of velocity times hydraulic radius to Manning's *n*.

Example solution

Given is a filter strip with a Retardance Class B vegetation (EFH chapter 7, exhibit 7–2) that is 250 feet wide and 50 feet long (flow length). The filter strip's slope is 0.01 foot per foot (or 1 percent). It is also assumed the velocity should be less than 0.5 foot per second for deposition to occur.

For the wide widths involved in filter strips, the hydraulic radius, **r**, can be assumed to be equal to the flow depth in the filter strip. The velocity is assumed to be about 0.5 foot per second. Using 3-inch or 0.25-foot depth of water, the product of velocity times hydraulic radius, assumed to be flow depth, is 0.25. Select n = 0.3 from exhibit 7–1.

Try a flow depth of 3 inches:

$$\begin{aligned} V &= \frac{1.486\left(\frac{3\ \text{in}}{12\ \text{in / ft}}\right)^{0.67}\left(0.01\ \text{ft / ft}\right)^{0.5}}{0.3} \\ &= (4.95)(0.395)(0.1) \\ &= 0.2\ \text{ft / s} \end{aligned}$$

This velocity is substantially less than the 0.5 foot per second assumed to be maximum for deposition.

Try a depth of 6 inches:

$$\begin{aligned} V &= \frac{1.486\left(\frac{6\ \text{in}}{12\ \text{in / ft}}\right)^{0.67}\left(0.01\ \text{ft / ft}\right)^{0.5}}{0.3} \\ &= (4.95)(0.63)(0.1) \\ &= 0.31\ \text{ft / s} \end{aligned}$$

Again, this velocity is substantially less than 0.5 foot per second assumed to be the maximum for deposition. However, greater flow depths may not be appropriate for the vegetation in the filter strip, so the velocity of 0.31 foot per second is used.

The cross sectional area of flow across the filter strip then is:

$$\begin{aligned} A &= (250\ \text{ft})\left(\frac{6\ \text{in}}{12\ \text{in / ft}}\right) \\ &= 125.0\ \text{ft}^2 \end{aligned}$$

Find the quantity of water that can be diverted to the filter strip:

$$\begin{aligned} Q &= AV \\ &= \left(125.0\ \text{ft}^2\right)\left(0.31\ \text{ft / s}\right) \\ &= 38.75\ \text{ft}^3\ /\ \text{s} \end{aligned}$$

Therefore, 38.75 cubic feet per second would be diverted to the spreader ditch with the remaining Q for the waterway diverted directly to the receiving stream. If the peak discharge determined for the waterway design example of 120 cubic feet per second is used, the amount diverted directly to the receiving stream would be Q diverted directly = 120 – 38.75 = 81.25 cubic feet per second.

Assuming a pipe is used to meter the water to the spreader ditch, the size and the head required to operate it must be determined. The head requirement will determine the crest elevation for the structures overflow weir that takes excess flow directly to the receiving waterbody.

Assuming that two-thirds of the filter strip area is downstream of the diversion structure and one-third is upstream, 38.75 cubic feet per second will be proportioned so two-thirds of the flow (0.67 x 38.75 = 25.96 cubic feet per second — use 26 cubic feet per second) goes to the spreader ditch that flows in downstream direction with the rest (28.75 – 26 = 12.75 cubic feet per second — use 13 cubic feet per second) goes to the spreader ditch flowing in the upstream direction.

The pipe will be assumed to operate as a culvert with outlet control. Outlet control occurs when the tailwater is at or above the top of the pipe at its outlet. The spreader ditch is designed so this occurs. Also assumed is that the pipe is corrugated metal, will be 20 feet long, and has a 0.5 entrance loss coefficient, Ke. EFH chapter 3, exhibit 3–11, can be used for sizing the pipe.

First, size a culvert for 26 cubic feet per second using the exhibit. For a trial, a head of 0.5 foot is assumed. This is the difference in elevation between the water surface on the upstream and downstream ends of the culvert. With a straight edge, draw a line between 0.5 foot head (vertical line on far right) to 26 cubic feet per second (vertical line on far left). Make a pencil mark on the turning line. Pivot on the turning line so the straight edge is on turning point marked with the pencil and the culvert length, 20 feet on the Ke = 0.5 curve. The projection of this line to the pipe size line indicates that a 30-inch diameter pipe is needed. It may be decided that a small pipe is desired. A trial could be made using a head greater than 0.5 feet. For this example, a 30-inch diameter pipe is okay.

Next, size a culvert for the 13 cubic feet per second. Important in sizing is matching the headwater elevation requirement with the headwater for the culvert for the 26 cubic feet per second. If the headwater is different, one culvert will flow more or less than desired. Begin by sizing a culvert for the same 0.5 foot head. Using exhibit 3–11 and following the same procedure as described, a 21-inch pipe is selected.

The water spreader ditch needs to be designed so it will spill water as sheet flow to the filter strip evenly for its entire length. As such, the top of the spreader ditchbank that interfaces with the filter strip needs to be carefully constructed so it is on the exact contour. Sizing this spreader ditch to the exact dimensions required to carry the flow would be a significant hydraulic problem involving development of backwater curves. However, for this purpose an approach is proposed that will be conservative and will result in a larger channel than may be required. This can be justified because it provides space for the sediment deposition that will occur in the ditch as a result of the slow velocities. The larger the channel the less frequent it will need to be cleaned of accumulated sediment. It is proposed to use Manning's equation and assume a flat gradient, (0.001) even though the ditch should be constructed on a level grade. The water depth needs to be at least 30 inches deep for the side with 26 cubic feet per second so the outlet of the culvert will be submerged.

Manning's equation (eq 3–16 EFH chapter 3) is:

$$Q = \frac{1.486\, r^{0.67} s^{0.5} A}{n}$$

where:

- Q = Mean flow (ft^3/s)
- r = Hydraulic radius (ft)
- s = Gradient (ft/ft)
- n = Coefficient of roughness
- A = Flow area (ft^2)

Try a trapezoidal channel having a 4-foot bottom, 3:1 side slopes, and 2.5-foot depth. In addition to *s* = 0.001, the coefficient of roughness is n = 0.035.

From EFH exhibit 3–13, the equation for hydraulic radius, r, for a trapezoidal channel is:

$$r = \frac{\left(bd + zd^2\right)}{\left(b + 2d\left(z^2 + 1\right)^{0.5}\right)}$$

where:
b = Bottom width (ft)
d = Flow depth (ft)
z = Side slope ratio

$$\begin{aligned} r &= \frac{\left(bd + zd^2\right)}{\left(b + 2d\left(z^2 + 1\right)^{0.5}\right)} \\ &= \frac{(4)(3) + (3)(3)^2}{4 + (2)(3)\left(3^2 + 1\right)^{0.5}} \\ &= \frac{12 + 27}{4 + (6)(3.16)} \\ &= \frac{39}{22.97} \\ &= 1.69 \text{ ft} \end{aligned}$$

From exhibit 3–13 we find that the equation for area A for a trapezoidal channel is:

$$\begin{aligned} A &= bd + zd^2 \\ &= (4)(3) + (3)(3)^2 \\ &= 12 + 27 \\ &= 39 \text{ ft}^2 \end{aligned}$$

Solving Manning's equation

$$\begin{aligned} Q &= \frac{1.486\, r^{0.67} s^{0.5} A}{N} \\ &= \frac{(1.486)(1.69)^{0.67}(0.001)^{0.5}(39)}{0.035} \\ &= \frac{(42.46)(1.42)(0.0316)(39)}{0.035} \\ &= 74.31 \text{ ft}^3/\text{s} \end{aligned}$$

The 74 cubic feet per second far exceeds 26 cubic feet per second, the design flow. In the example, the 4-foot bottom was initially used because it was assumed to be the minimum sized ditch that would be practical to construct with the equipment available. However, if it would be practical to excavate a channel with less than a 4-foot bottom width, a lesser bottom width should be evaluated. Since at least a 3-foot depth is needed to submerge the outlet to the culvert pipe, a shallower depth should not be used. Because the spreader ditch in the upstream direction has half the flow requirement, it can be safely assumed that the 4-foot bottom width channel size would be more than adequate for it as well.

The weir elevation for the overflow can now be established. With a flow depth in the channel of 3 feet plus 0.5 foot of head required to operate the culverts, the water surface elevation at the upstream side of the weir is assumed to be 3.5 feet above the invert elevation of the culverts. The water surface upstream of the weir minus the head required to operate the weir equals the crest of the weir. The weir equation is used for determining the head required. Again, this is a trial-and-error process. It must also be remembered that the flow going directly to the receiving stream is 81.25 cubic feet per second.

Ideally, the weir length should be such that the head requirement is minimal so that flow to the spreader ditches will approach the design flows of 13 and 26 cubic feet per second even at storms of a lesser magnitude than the design storm for the waterway. The weir equation (see EFH chapter 3, eq. 3–21) is:

$$Q = CLH^{1.5}$$

where:

Q = Discharge (ft^3/s)
C = Weir coefficient
L = Length of weir (ft)
H = Head (ft)

The weir coefficient for a broad crested weir (as opposed to a sharp crested weir) that would be used for this purpose is 3.1. Therefore:

$$\begin{aligned} Q &= CLH^{1.5} \\ 81.25 &= (3.1)LH^{1.5} \\ LH^{1.5} &= \frac{81.25}{3.1} = 26.21 \end{aligned}$$

Try a weir with a 4-foot length:

$$\begin{aligned} LH^{1.5} &= 26.21 \\ (4)H^{1.5} &= 26.21 \\ H &= 6.55^{0.67} \\ H &= 3.52 \text{ ft} \end{aligned}$$

The crest of a 4-foot weir would be set at 3.5 to 3.52. This is the bottom of the channel. Therefore, the head requirement for a 4-foot long weir is much too great.

Try a weir with a 10-foot length:

$$LH^{1.5} = 26.21$$
$$(10)H^{1.5} = 26.21$$
$$H = 2.62^{0.67}$$
$$H = 1.90 \text{ ft}$$

This weir length would place its elevation crest at 3.5–1.90=1.6 feet. This would mean flow would begin to be diverted directly to the receiving stream when the flow depth is only 1.6.

Try a weir with a 20-foot length.

$$LH^{1.5} = 26.21$$
$$(10)H^{1.5} = 26.21$$
$$H = 1.31^{0.67}$$
$$H = 1.19 \text{ ft}$$

Try a weir with a 30-foot length.

$$LH^{1.5} = 26.21$$
$$(30)H^{1.5} = 26.21$$
$$H = 0.87^{0.67}$$
$$H = 0.91 \text{ ft}$$

The crest elevation for a 30-foot-long weir would be set at 3.5–0.91 = 2.6 feet. This means that water will flow to the spreader ditches until the flow depth upstream of the weir is 2.6 feet. When the flow depth reaches that depth, water begins spilling directly to the receiving stream. This would not maximize the flow being diverted to the spreader ditches. However, at some point the weir length will be too long to be practical. For this example, the point is assumed to have been reached.

The overflow waterway should be designed to carry the amount of the design storm not diverted to the spreader ditch/vegetative filter strip. For this example, this flow is 81.25 cubic feet per second. The outlet of this waterway at the receiving stream must be protected from erosion. Again, Manning's equation can be used to determine its size. This will not be demonstrated.

Information needed to fill in the job sheet

The job sheet provides for data entry for the designed grassed waterway/vegetative filter system on pages 3 and 4. Following is an explanation of information that can be put on page 3, Specification Sheet.

Landowner

Enter the name of the landowner being assisted.

Field number

Enter the farm plan or FSA number for the field where the waterway(s) for which design information will be entered is located.

Purpose

Check the appropriate purpose or purposes that the waterway will serve.

Design information - grassed waterway

This section allows for entry of design information for up to three single reach waterways or for one waterway that has been designed with up to three different reaches or another combination of waterways and reaches that does not exceed three in number. If it is necessary to enter information on waterways and reaches in a single field that total more than three, this sheet of the job sheet should be photocopied and attached. A note should be added that there is a continuation sheet. The self explanatory information in this section should be in design computations for the waterway(s).

Vegetative filter and layout and plant establishment

This section allows entry of the filter strips on the sides of the grassed waterway for which data were entered in the section above. The information required is self explanatory.

Site preparation

If additional site preparation specifications are needed, they may be added to the "Additional Specifications and Notes" section on the following page. Although no space is provided, a note should indicate additional specifications for site preparation are on the next page.

Planting method(s)

Fill in the depth that the seed is to be drilled and the amount of mulch in tons per acre in the spaces provided.

Operation and maintenance

Additional operation and maintenance items may be given on the next page in the space provided for additional specifications and notes. Insert a note at this location that additional operation and maintenance items are given at this location on the next sheet.

Job sketch

Develop sketches that illustrate location and cross section of waterway. Indicate the scale in the space provided and show north arrow if appropriate.

Additional specifications and notes

This space is provided for an elaboration of sections given on page 3 of the job sheet or other information the landowner would find helpful for installing the grassed waterway/vegetative filter strip system. It is suggested that the name of the person filling out the job sheet be entered here.

Additional reading

United States Department of Agriculture, Natural Resources Conservation Service. Grassed waterways. Eng. Field Handb., chap. 7.

Grassed waterway practice standard 412.

USDA Grassed Waterway/Vegetated Filter System

Conservation Practice Job Sheet *412*

Natural Resources Conservation Service (NRCS) ***April 1997***

Landowner____

Definition

A grassed waterway/vegetated filter system is a natural or constructed vegetated channel that is shaped and graded to carry surface water at a nonerosive velocity to a stable outlet that spreads the flow of water before it enters a vegetated filter.

Purpose

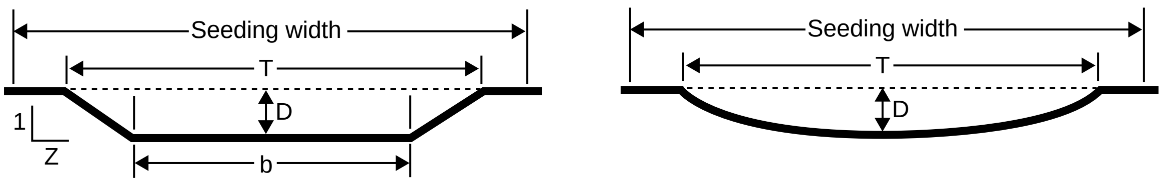
Grassed waterways convey runoff from terraces, diversions, or other water concentrations. Vegetation in the waterway protects the soil from erosion caused by concentrated flows, while carrying water downslope. The stable outlet is designed to slow and spread the flow of water before the water enters a vegetated filter.

The vegetated filter is designed to trap sediment and increase infiltration so that other pollutants, such as pesticides and nutrients, can be reduced from surface runoff. The grassed waterway also offers diversity and cover for wildlife.

Where used

- Where water concentrates and gully erosion is a problem, commonly in draws and other low-lying areas.
- As outlets for other conservation practices, such as diversions and terraces.
- Where a stable, spreading-type outlet and vegetated filter can be designed and maintained.

Waterway



Trapezoidal shape cross section

Parabolic shape cross section

Typical Cross-section

Vegetation establishment

Establish the waterway vegetation according to Critical Area Planting Practice (342). For the stable, spreading type outlet, select perennial plant species (native species are encouraged where possible) that have compatible characteristics to the site. Use sod-forming plants that have stiff, upright stems that provide a dense filter. Use the recommendations for filter strips for the area below the outlet. Establish vegetation before allowing water to flow in the waterway. Use irrigation and mulch to hasten establishment of vegetation as necessary.

Operation and maintenance

- Tillage and row direction should be perpendicular to the grassed waterway to allow surface drainage into the waterway and to prevent flows along edges.
- Provide stabilized machinery crossings, where needed, to prevent rutting of the waterway.
- Protect vegetation from direct herbicide sprays and use plant species tolerant of chemicals used.
- The grassed waterway outlet should be kept as wide and shallow as possible to slow the velocity of water, increase infiltration, and spread flows evenly across a wide area before entering a vegetated filter.

Conservation management system

Grassed waterway/vegetated filter systems and filter outlets are normally established as part of a conservation management system to address the soil, water, air, plant, and animal resource concerns and the landowner’s objectives. Grassed waterway/vegetated filter systems are an important part of the overall soil erosion and water quality plan. They are used along with other needed conservation practices located in the field, such as contour buffers, terraces, crop residue management, and nutrient and pesticide management. Waterways located below areas of high sediment production need special design and additional maintenance. Other measures to reduce sediment production or to trap sediment should be considered.

Wildlife

The grassed waterway and filter system can also enhance the wildlife objectives depending on the vegetative species used and management practiced. Consider using native or adapted vegetative species that can provide food and cover for important wildlife. Delay mowing of waterway and filter area until after the nesting season.

Specifications

Site-specific requirements are listed on the specifications sheet. Additional provisions are entered on the job sketch sheet. Specifications are prepared in accordance with the NRCS Field Office Technical Guide. See practice standards Grassed Waterway (412) and Filter Strip (393).

Grassed Waterway/Vegetated Filter System – Specifications Sheet

Landowner____ Field number__________

Purpose (check all that apply)	
☐ Convey concentrated flow runoff	☐ Reduce pollutants from runoff
☐ Prevent gully erosion	☐ Other (specify):

Location and Layout		
Waterway shape	☐ Parabolic	☐ Trapezoidal
Field number ______ (For exact location see job sketch)		

Design information - Grassed Waterway	1	2	3
Waterway number			
Reach number			
Grade (%)			
Depth-D (ft)			
Top width-T (ft)			
Bottom width-b (ft) (trapezoidal only)			
Side slopes (Z:1)			
Length (ft)			
Seeding width (ft)			
Seeding area (acres)			
Plant establishment			
Species*			
Seeding rate (PLS) (lb/acre)			
Lime (tons/acre)			
N (lb/acre)			
P_2O_5 (lb/acre)			
K_2O (lb/acre)			

*For multiple species separate with a /. (example species 1/species 2/species 3)

Vegetated filter layout and plant establishment			
Waterway number			
Strip width (ft)			
Strip length (ft)			
Area of filter strip (acres)			
Slope (%)			
Species*			
Seeding rate (PLS) (lb/acre)			
Lime (lb/acre)			
N (lb/acre)			
P_2O_5 (lb/acre)			
K_2O (lb/acre)			

*For multiple species separate with a /. (example species 1/species 2/species 3)

Site Preparation
Prepare firm seedbed. Apply lime and fertilizer according to recommendations.
Planting Method(s)
Drill grass and legume seed _______ inches deep uniformly over area. Establish stand of vegetation according to recommended seeding rate. If necessary, mulch newly seeded area with ______ tons per acre of mulch material. May seed small grain as a companion crop at the rate of _______ pounds per acre, but clip or harvest before it heads out.
Operation and Maintenance
Maintain original width and depth of the grass area. Regularly remove debris and sediment from waterway and filter area. Harvest, mow, reseed, and fertilize to maintain good vegetation. Inspect periodically after every major storm and repair any eroding or bare areas.

Grassed Waterway/Vegetated Filter System – Job Sketch

If needed, an aerial view or a side view of the grassed waterway/vegetated filter system can be shown below. Other relevant information, such as complementary practices, and adjacent field or tract conditions including structures and crop types, and additional specifications may be included.

Scale 1"=________ ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")

Additional Specifications and Notes:

Appendix 3f–1 Worksheet 1, Runoff curve number (CN)[1/]

Worksheet 1
Runoff curve number

Worksheet 1
Runoff curve number

Client *A. B. Smith* **By** *DEW* **Date** *6-6-99*

County *Adams* **State** *MD* **Checked** *KO* **Date** *6-6-99*

Practice *Grassed waterway*

Soil name and hydraulic group (table 2-1)	Cover description (cover type, treatment, and hydraulic condition)	CN (table 2-3)	Area (acres)	Product of CN x area
Dover B	*Pasture in good condition*	*61*	*25*	*1525*
Berea C	*Straight row crops, good*	*85*	*55*	*4675*
Easton D	*Woods, poor*	*83*	*10*	*830*
			90	*7030*

CN (weighted) = $\frac{7030}{90}$ **= 78.1** **Use CN =** *78*

1 Engineering Field Handbook, chapter 2

Appendix 3f–2 Worksheet 2, Time of concentration and peak discharge [1]

Worksheet 2
Time of concentration and peak discharge

Client *A. B. Smith* By *DEW* Date *6-6-99*

County *Adams* State *MD* Checked *TAS* Date *6-7-99*

Practice *Grassed waterway*

Estimating time of concentraton

1. Data:

Rainfall distribution type.. = *II* (I, IA, II, III)

Drainage area..A = *90* ac

Runoff curve number..CN = *78* (Worksheet 1)

Watershed slope..Y = *1* %

Flow length..ʃ = *3,400* ft

2. T_c using ʃ, Y, CN, and EFH figure 2-27 or using EFH equation 2-5

$$T_c = \frac{ʃ^{0.8}\,(1{,}000/CN-9)^{0.7}}{1{,}140\,Y^{0.5}} = \frac{(3{,}400)^{0.8}\,(1{,}000/78-9)^{0.7}}{1{,}140\;1^{0.5}} = 1.5\text{ hr}$$

Estimation peak discharge

	Storm number 1	Storm number 2	Storm number 3
1. Frequency.......... yr	*10*		
2. Rainfall, P (24 hour).......... in	*5.5*		
3. Initial abstraction (use CN with EFH table 2-4).... in	*0.564*		
4. Compute I_a/P ratio	*0.10*		
5. Unit peak discharge qu .... ft^3/s/ac/in (Use T_c and I_a/P with EFH exhibit 2- ______)	*0.43*		
6. Runoff, Q .... in (Use P and CN with EFH figure 2-6 or table 2-2)	*3.1*		
7. Peak discharge q_p .... ft^3/s (Where $q_p = q_u AQ$)	*120*		

1 Engineering Field Handbook, chapter 2

Appendix 3f–3 Classification of vegetation cover as to degree of retardance

Classification of vegetation cover as to degree of retardance

Retardance	Cover	Condition
A	Weeping lovegrass	Excellent stand, tall (average 30 inches)
	Reed canary grass or Yellow bluestem ischaemum	Excellent stand, tall (average 36 inches)
B	Smooth bromegrass	Good stand, moved (average 12 to 15 inches)
	Bermudagrass	Good stand, moved (average 12 inches)
	Native grass mixture (little bluestem blue grama, and other long and midwest grasses)	Good stand, unmowed
	Tall fescue	Good stand, unmowed(average 18 inches)
	Servicea lespedeza	Good stand, not woody, tall (average 19 inches)
	Grass-legume mixture— Timothy, smooth bromegrass or orchardgrass	Good stand, uncut (average 20 inches)
	Reed canary grass	Good stand, uncut (average 12 to 15 inches)
`	Tall fescue, with birdsfoot trefoil or ladino clover	Good stand, uncut (average 18 inches)
	Blue grama	Good stand, uncut (average 13 inches)
C	Bahiagrass	Good stand, uncut (6 to 8 inches)
	Bermudagrass	Good stand, mowed (average 6 inches)
	Redtop	Good stand, headed (15 to 20 inches)
	Grass-legume mixture-summer (orchardgrass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6 to 8 inches)
	Centipedegrass	Very dense cover (average 6 inches)
	Kentucky bluegrass	Good stand, headed (6 to 12 inches)
D	Bermudagrass	Good stand, cut to 2.5-inch height
	Red fescue	Good stand, headed (12 to 18 inches)
	Buffalograss	Good stand, uncut (3 to 6 inches)
	Grass—legume misture—fall, spring (orchardgrass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (4 to 5 inches)
	Sericea lespedeza or Kentucky bluegrass	Good stand, cut to 2-inch height. Very good stand before cutting
E	Bermudagrass	Good stand, cut to 1.5-inch height
	Bermudagrass	Burned stubble

Appendix 3f–4 Permissible velocities for waterways lined with vegetation

Permissible velocities for waterways lined with vegetation

Cover	Slope range 2/ (%)	Permissible velocity 1/ Erosion resistant soils 3/ (ft/s)	Easily eroded soils 4/ (ft/s)
Bermudagrass	<5	8	6
	5-10	7	4
	Over 10	6	3
Bahiagrass Buffalograss Kentucky bluegrass Smooth brome Blue grama	<5 5-10 Over 10	7 6 5	5 4 4
Grass mixture Reed canary grass	<5 2/ 5-10	5 4	4 3
Sericea lespedeza Weeping lovegrass Yellow bluestem Redtop Alfalfa Red fescue	<5 5/	3.5	2.5
Common lespedeza 6/ Sudangrass 6/	<5 7/	3.5	3.5

1/ Use velocities exceeding 5 ft/s only where good cover and proper maintenance can be obtained.
2/ Do not use on slopes steeper than 10 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistance vegetative center section.
3/ Cohesive (clayey) fine-grain soils and coarse-grain soils that have cohesive fines with a plastic index of 10 to 40 (CL, CH, SC, CG).
4/ Soils that do not meet requirements for erosion resistant soils.
5/ Do not use on slopes steeper than 5 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.
6/ Annuals—Use on mild slope or as temporary protection until permanent cover is established.
7/ Use on slopes steeper than 5 percent is not recommended.

Chapter 3g Herbaceous Wind Barriers

Definition of herbaceous wind barriers

Herbaceous wind barriers are tall grass or other nonwoody plants established in single- or double-row narrow strips spaced across the field perpendicular to the normal wind direction. They are commonly used on cropland to protect soils and crops from the damaging effects of wind and for snow management. Wind barriers may be composed of either perennial or annual vegetation. Perennial barriers have the advantages of not requiring annual establishment and are often effective throughout the year. Annual vegetative barriers may provide greater flexibility in the farming operation and are easier and less expensive to establish. They may, however, be difficult to establish during periods of extreme drought or wetness.

Purposes

This practice has four primary purposes:

- Reduce soil erosion by windA wind barrier reduces soil erosion by sheltering an area immediately downwind.
- Protect growing crops from damage by wind-borne soil particlesWind barriers protect plants by trapping incoming soil particles and by reducing the wind speed downwind from the barriers.
- Manage snow to increase plant available moistureAdditional water for subsequent crops can be provided by trapping snow in winter with wind barriers.
- Provide food and cover for wildlifeSeeds and vegetation from wind barrier plants can provide an excellent source of food and cover for wildlife.

Function

The main effect of a wind barrier is to modify the flow of air in the immediate downwind area. The extent of this modification is dependent on such factors as barrier height, porosity, spacing, and the wind speed and direction.

Benefits

Effects on the microclimate resulting from the modified flow of air can be numerous. The daytime air and soil temperatures near the barrier are increased while evaporation and windspeed are reduced as compared to open field conditions. Crop yields often increase in part because of higher soil moisture and relative humidity. Figure 3g–1 is a diagram of the general effects of a wind barrier on the microclimate and other factors, such as crop yield. Although observations of wind barrier effects vary, the diagram shows the general direction of magnitude observed by many investigators.

Design considerations

Layout

Number of rows

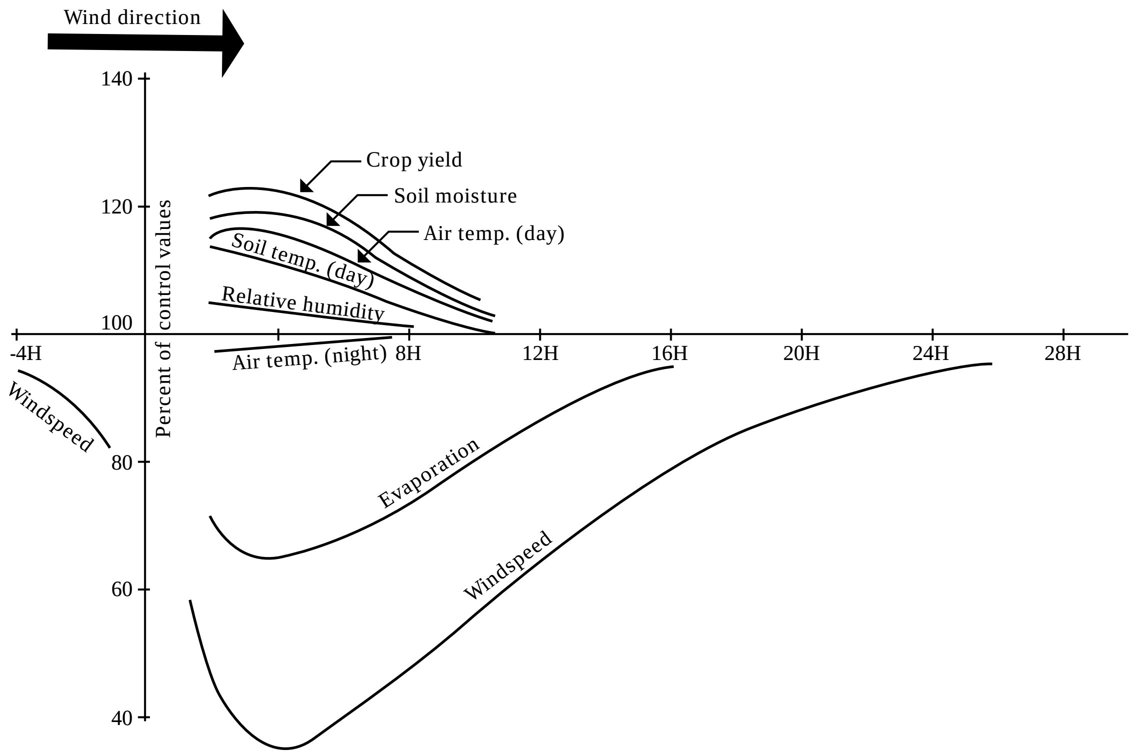
Herbaceous wind barriers may consist of one row of plants, providing the required porosity can be achieved with a single row and there are no gaps in the barrier. Where conditions exist, such as sandy soils, that may have detrimental effects on the establishment or survival of the barriers, more than one row of plants should be planned for each barrier. Using more than one row is recommended with annual barriers.

Where two or more rows are needed to achieve the required porosity and to avoid gaps in the barrier, space the rows no more than 36 inches apart. Closely spaced rows, such as a drill row width apart, provide less opportunity for weeds to become established between the rows. For barriers that are planned for the main purpose of providing food and cover for wildlife, two or more rows are often more effective than a single row. If two or more rows are used for wildlife, do not space the rows closer than 24 inches apart.

Height

The recommended height of herbaceous wind barriers varies depending on the main purpose(s) for applying the practice. Barriers designed for the purpose of reducing soil erosion from wind or for managing snow should have a minimum barrier height of 1.5 feet during the wind erosion period for which the barriers are designed or during periods of expected snow

Figure 3g–1 Summary diagram of the effect of barriers on micrometeorological and other indicated factors



How to use figure 3g–1:
Values on the horizontal axis indicate distances downwind from a barrier in multiples of the barrier height. For example, 8H indicates a distance downwind that is eight times the height of the barrier. Values on the vertical axis are in percent of the control condition. The control is a no-barrier condition and is assigned a value of 100 percent.
The following examples may be helpful in learning to interpret the diagram:

1. Evaporation at a point 8H (8 times the height of the barrier) downwind from the barrier is approximately 73 percent of that without a barrier.
2. Crop yield at a distance of 8H downwind from a barrier is approximately 110 percent of that without a barrier. The diagram shows that as the distance increases from a barrier in the downwind direction, the barrier effects progressively approach the no-barrier condition.

cover, respectively. The minimum height of barriers designed to protect growing crops from wind-borne soil is 2 feet during the periods when protection is needed. For wildlife food and cover, design the barriers so their minimum expected height provides adequate cover for the targeted wildlife species.

Length

The length of the barriers will be determined by the field configuration and planned positioning of barriers on the landscape. For maximum spacing between barriers, orient them perpendicular to the prevailing wind erosion direction or prevailing wind direction as applicable for the purpose. These spacings are identified in the following sections. As barriers designed for erosion protection deviate from perpendicular to the applicable wind direction, the designed spacing between barriers is correspondingly reduced.

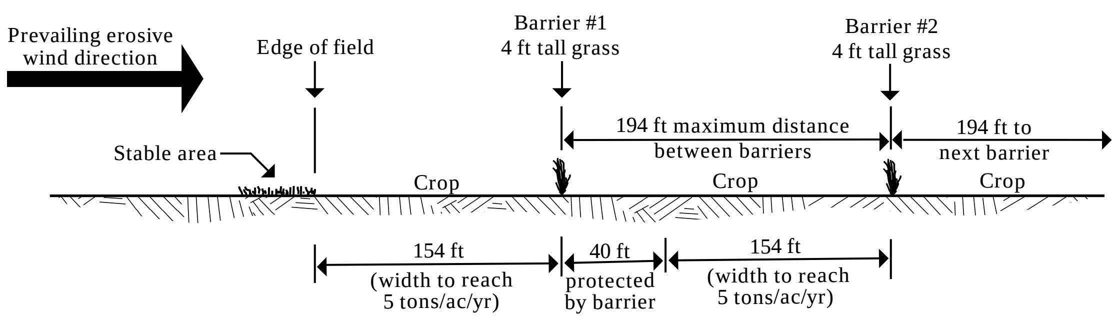
Reduce soil erosion from wind

If the barriers are being designed to reduce soil erosion from wind, the spacing is not to exceed 10 times the expected height of the barrier plus additional width permitted by the soil loss tolerance (T) or other planned soil loss objective. Measure the distance along the prevailing wind erosion direction for the time period when wind erosion is expected to occur. This distance is the unsheltered distance (L) in the Wind Erosion Equation. Use current wind erosion prediction technology to calculate the spacing required to meet the soil loss objective. The spacing between barriers may be adjusted within the limits established above to accommodate widths of farm machinery. The barrier spacing calculations should account for the effects of other conservation practices or treatments in the conservation management system. See figure 3g–2 for barrier spacing designed to reduce soil erosion by wind.

Figure 3g–2 Barrier spacing designed to reduce soil erosion by wind

Example 1

Crop rotation: Winter wheat - Fallow
Soil loss tolerance (T) = 5 tons per acre per year
Barrier height = 4 feet
Barrier porosity = 40 to 50%
Wind erosion equation factor values:
- Soil erodibility index (l) = 86
- Ridge roughness (K) = 0.8
- Climatic factor (C) = 80
- Vegetative cover (V) = 1,000 pounds of flat small grain equivalent
- Unsheltered distance (L) = Determined to be 154 feet to reach 5 tons per acre per year



Protect growing crops from damage by wind-borne soil

Barrier systems designed to protect growing crops are spaced similarly to those intended to reduce soil erosion by wind. Do not exceed 10 times the expected height of the barrier plus additional width permitted by the crop tolerance to wind erosion or other planned crop protection objective. The crop tolerance to wind erosion is the maximum rate of wind-borne soil movement that crop plants can tolerate without significant damage from abrasion, burial, or desiccation. Table 3g–1 provides tolerance values for several crops.

Use current wind erosion prediction technology to estimate wind erosion during the periods of crop sensitivity. The calculations should account for the wind direction during crop sensitive periods and the effects of other conservation practices or treatments in the conservation management system. Planners should also consider the crop value when designing barrier spacing based on crop tolerances. For high value crops, it may be best to space barriers closer than design procedures suggest. This would reduce the risk of crop damage associated with wind. See figure 3g–3 for barrier spacing designed to protect growing crops from damage by wind-borne soil.

Table 3g–1 classifies crops with respect to their tolerance to physical and mechanical damage from wind and wind-borne soil. Tolerant crops are those that show little or no damage from the direct effects of wind and tolerate significant soil abrasion (soil losses from wind erosion between 2.5 and 6.0 tons per acre per year). Moderately tolerant crops are those crops that have some tolerance to the whipping action of the wind and tolerate some soil abrasion (soil losses between 1.0 and 2.5 tons per acre per year). Low tolerance crops are those that are subject to extensive damage from the direct effects of the wind or wind related desiccation. Very low tolerance crops are those crops that are subject to extensive damage from wind or soil abrasion (soil losses less than 1 ton per acre per year).

Figure 3g–3 Barrier spacing designed to protect growing crops from damage by wind-borne soil

Example 2

Crop rotation: Corn - Grain sorghum
These crops are moderately tolerant to wind-borne soil (1 - 2.5 tons per acre per year)
Soil loss tolerance (T) = 5 tons per acre per year
Barrier height = 4 feet
Barrier porosity = 40 to 50%
Wind erosion equation factor values:
Soil erodibility index (l) = 86
Ridge roughness (K) = 0.8
Climatic factor (C) = 80
Vegetative cover (V) = 1,000 pounds of Flat Small Grain Equivalent
Unsheltered distance (L) = Determined to be 28 feet to reach 1 ton per acre per year

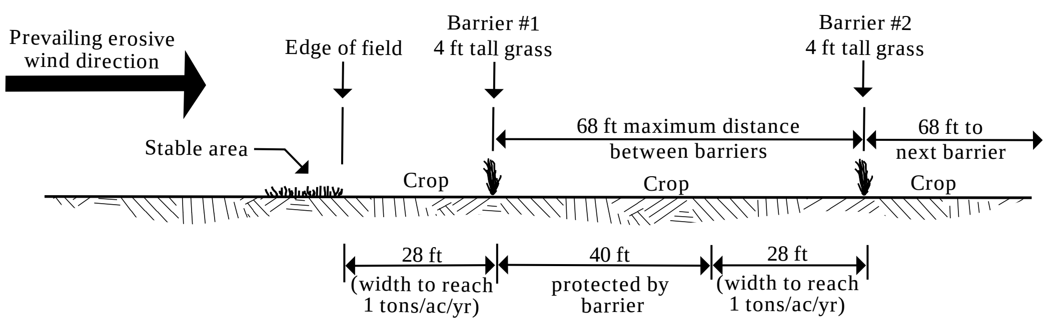


Table 3g–1 Tolerance of crops to physical and mechanical damage from wind and wind-blown soil

Tolerant (3.5–5 tons/acre/year)		Moderate (2–3.5 tons/acre/year)	
Barley	*Hordeum vulgare* L.	Corn	*Zea mays* L.
Buckwheat	*Fagopyrum* sp.	Grain sorghum	*Sorghum bicolor* (L.) *Moench.*
Flax	*Linum usitatissimum* L.	Sunflower	*Helianthus annuus* L.
Millet	*Panicum miliaceum* L.	Sweet corn	*Zea mays* L.
Oats	*Avena sativa* L.		
Rye	*Secale cereale* L.		
Wheat	*Triticum aestivum* L.		

Low (1–2 tons/acre/year)		Very low (less than 1 ton/acre/year)	
Apples	*Malus* spp.	Alfalfa (new seedlings)	*Medicago sativa* L.
Avocados	*Persea americana* Mill.	Asparagus	*Asparagus officinalis* L.
Cherries	*Prunus* spp.	Beans	*Phaseolus* spp.
Grapefruit	*Citrus paradisi* Macfad.	Cane berries	*Rubus* spp.
Grapes	*Vitus* spp.	Green beans	*Phaseolus* sp.
Lemons	*Citrus limon* (L.) N.L. Burm.	Lima beans	*Phaseolus* sp.
Limes	*Citrus aurantifolia* (L.) Swingle	Snap beans	*Phaseolus* sp.
Oranges	*Citrus sinensis* (L.) Osbeck	Table beet	*Beta vulgaris* L.
Peaches	*Prunus persica* L.	Sugar beet	*Beta vulgaris* L.
Plums	*Prunus* spp.	Broccoli	*Brassica oleracea* (L.) var. *botrytris*
Pears	*Pyrus* spp.		
Tangerines	*Citrus reticulata* Blanco	Cabbage	*Brassoca oleracea* (L.) var. *capitata*
		Carrots	*Daucus carota* L.
		Celery	*Apium graveolens* (L.) var. *duke*
		Cotton	*Gossypium hirsutum* (L.)
		Cucumbers	*Cucumis sativus L.*
		Eggplant	*Solanum melongena* (L.) var. *esculentum*
		Flowers	(All species, seed production and cut flowers)
		Garlic	*Allium sativum* L.
		Green peas	*Pisum sativum* L.
		Kiwifruit	*Actinidia chinensis* L.
		Lettuce	*Lactuca sativa* L.
		Muskmelons	*Cucumis melo* L.
		Onions	*Allium cepa* L.
		Peanuts	*Arachis hypogaea* L.
		Peppers	*Capsicum annuum* L.
		Potatoes	*Solanum tuberosum* L.
		Soybeans	*Glycine max* (L.) Merrill
		Spinach	*Spinacia oleracea* L.
		Strawberries	*Fragaria X ananassa*
		Tobacco	*Nicotiana tabacum* L.
		Tomatoes	*Lycopersicon esculentum* Mill.
		Watermelons	*Citrullus lanatus* (Thumb.) Matsum. ex Nakai
		Young orchards	*Citrus spp.*, *Malus* spp., *Persica* spp., *Prunus* spp., *Pyrus* spp.

Manage snow to retain additional soil moisture

If the barrier system is designed to manage snow, the barrier spacing is not to exceed 12 times the expected height of the barriers (12H). The spacing distance is measured along the direction of prevailing winds during periods of expected snow cover.

Provide food and cover for wildlife

Barriers designed for food and cover for wildlife are often applied in conjunction with one of the other purposes. To determine the barrier spacing, use the criteria for the additional purpose as outlined above. If food and cover for wildlife is the only purpose for applying the practice, use a spacing that meets the needs of the targeted wildlife species. Also, when possible, locate barriers where they connect areas of existing perennial vegetation. Barriers that connect such areas as woody draws often provide additional benefits for wildlife.

Barrier porosity

Barrier porosity can be thought of as the area of a barrier that is not occupied by vegetative material as viewed from the direction of the wind. In other words, if you look at a barrier as the wind sees it, the percent area not occupied by vegetation is the percent porosity. Barriers with a porosity of 40 to 50 percent protect a downwind area of 10 times the barrier height. To reduce soil erosion by wind and to protect growing plants, select species and plant spacings that will achieve 40 to 50 percent porosity as shown in figure 3g–4. For snow management, a porosity of 60 to 75 percent, as shown in figure 3g–5, is best as it helps to achieve more even distribution of snow within the barrier system.

Plant materials

Perennial barriers

Species selected for perennial herbaceous wind barriers should consist of stiff, erect perennial grasses and forbs adapted to local soil and climate conditions. Consider all of the local soil and climate extremes including pH, drainage, root zone restrictions, wetness, drought, heat, and freezing temperatures. Barrier species must have sufficient strength to remain erect against anticipated high velocity winds and waterflows. They should also have good leaf retention and pose minimum competition to adjacent crops. Additional desirable characteristics include tolerance to sediment deposition, long life expectancy, and highly competitive with weeds.

Actual species selection should be made from guidelines developed for the local area. These species are named or referenced in the Field Office Technical Guide (FOTG). The VegSpec software (http://plants.usda.gov and follow links to VegSpec), is an excellent source of plant species information.

Figure 3g–4 Barrier porosity of 40 to 50 percent

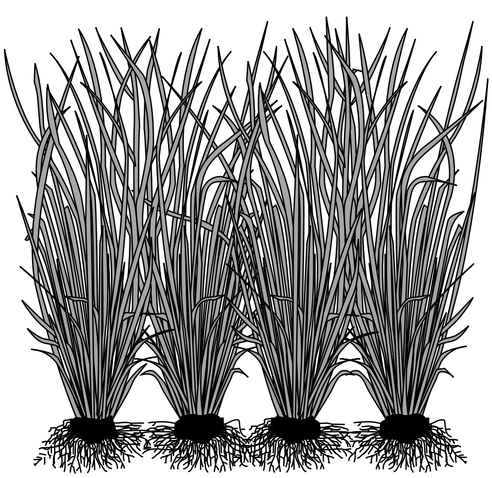
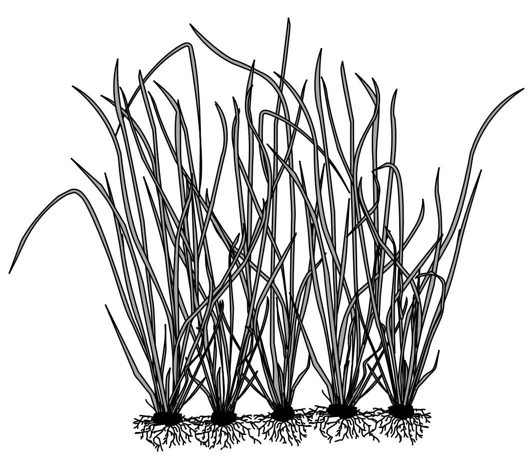


Figure 3g–5 Barrier porosity of 60 to 75 percent



Annual barriers

Various annual crops have been evaluated for use as herbaceous wind barriers. Species selected for annual barriers should be adapted to the site, easy to establish, tall-growing, leafy, and resistant to lodging. Annual barriers used for erosion reduction must be maintained throughout critical erosion periods. Annual plants that have been successfully used for wind barriers include grain and forage sorghum, flax, sudangrass, pearl millet, and corn.

Actual species selection should be made from guidelines developed for the local area that are named or referenced in the FOTG.

Additional species selection considerations where saline seeps are a concern

Many areas of the United States are susceptible to saline seeps. These seeps result from:

- precipitation in excess of plant needs,
- geologic formations predominantly high in soluble salts, and
- farming practices that tend to accumulate soil moisture.

Utilization of precipitation that falls on the saline seep recharge area is the most effective means of preventing or reclaiming saline seeps. Deep rooted species in the barrier planting, along with the use of deep-rooted crops between the barriers, help prevent subsurface water from moving laterally to an existing or potential seep site.

When planning herbaceous wind barriers on a saline seep prone landscape, supporting practices should be considered that help use the potential increase in soil moisture associated with the barriers. A change, for example, in the rotation from crop-fallow to annual cropping can be an effective way to use excess soil moisture.

Refer to practice standard number 610, Toxic Salt Reduction, in section IV of the FOTG for additional criteria on saline seep control.

Additional species selection considerations where wildlife food and cover are a concern

Select barrier species that are adapted to the site and that meet the intended needs of the targeted wildlife. Barriers can produce seed for wildlife diets and escape and nesting cover. Do not use species that will be extensively grazed or foraged by wildlife or domestic animals, which would severly diminish effectiveness of the barriers for other purposes.

Seeding rate

The seeding rate should be high enough to achieve the desired plant spacing and required barrier porosity.

Seeding rates for single species or mixtures should be obtained from guidelines developed for the local area. These species are named or referenced in the FOTG. The VegSpec software is an additional source of seeding rate information for some species used for wind barriers.

Seeding date

Seeding dates should consider the optimum planting date for species germination and establishment and the time period when the barriers are needed to accomplish their intended purpose(s). Seeding date information should be obtained from guidelines developed for the local area that are named or referenced in the FOTG.

Lime and fertilizer

Herbaceous wind barriers often receive lime and fertilizer at the same time and rate as adjacent crops.

Site preparation

Preparation for herbaceous wind barrier establishment is dependent on the species selected and the site characteristics, such as soils, topography, and climate. Guidelines should be available or referenced in the local FOTG. General guidelines for perennial barriers of grasses and forbs include a seedbed that is firm and free of weeds. Many grass and legume seeds should be planted no deeper than 0.5 inch and must have good seed/soil contact.

Seedbed preparation for annual barriers of crop species can generally be completed in a fashion that is common and appropriate for the crop. For more information on site preparation and plant materials, see Chapter 4, Establishing Conservation Buffers.

Operation and maintenance

Herbaceous wind barriers need to be inspected routinely to identify potential problems, such a gaps, pest infestations, or poor plant vigor. Gaps in the barriers should be replanted as soon as practical to maintain barrier effectiveness. Pest infestations need to be managed using methods and timing as appropriate for the pest. Spot treatments, rather than broadcast applications, should be considered where pest populations are to be managed with chemical pesticides. Plant vigor problems can be related to a number of conditions, such as soil fertility, drought, excessive wetness, or restrictive layers in the soil profile. Causes for these problems need to be identified and corrective action applied. Fertility problems are often corrected by fertilizing the barriers the same as the adjacent crops. In cases where fertilizers are not used on adjacent crops or the crop fertility program is not adequate for the barriers, a special program may be needed for the barrier system.

Annual barriers need to be re-established each year by planting at the recommended dates. For areas prone to soil erosion by wind, the annual barriers should be left standing after harvest of the crop and throughout critical erosion periods.

Barriers that are harvested need to be managed in such a way that the barriers are of sufficient height and condition to meet their intended purpose(s). For example, if a barrier system is planned to be 3 feet high for erosion reduction by wind, the barriers should have a minimum height of 3 feet at the beginning and throughout critical wind erosion periods.

Sediment accumulation in the barriers should be removed and distributed over the surface of the adjacent field.

Barriers designed to enhance wildlife habitat should not be mowed unless their height or width exceeds that required to achieve the wildlife objectives and they become competitive with the adjoining land use. Any mowing should be scheduled during the non-nesting season.

Information needed to fill in job sheet

Select purpose of the barrier

Checkmark applicable purposes on the specifications sheet. Herbaceous wind barriers may have more than one primary purpose. The *Other* block may be used to identify secondary purposes for the practice. Additional specifications may be required in practice design and layout to accommodate secondary purposes. Secondary purposes may include reducing sediment and organic material in surface runoff or significantly increasing soil carbon and thus provide a sink for atmospheric carbon dioxide. These purposes should be entered on the back of the specifications sheet or on additional sheets as necessary.

Determine the filter strip layout in the field

Space is provided on the specifications sheet to record the width, height, length, and barrier area for up to four barriers. Commonly, all of the barriers within a barrier system are designed the same. In some cases, however, it may be desirable to change the design of some of the barriers to address additional purposes. A system, for example, may have every fifth barrier designed specifically for wildlife food and cover. Use the *Barrier Strip* columns to record the one or more separate barrier designs within the system. The strip number in the column headings may be changed as appropriate to match your specific system design.

Acres in barrier area

Calculate the acres of barriers using the planned width and length of the barriers. Completion of the *Job Sketch* on the back of the specifications sheet may be helpful prior to making the calculations. Record the acres in the appropriate row and column on the specifications sheet.

Planting method

Record the planting method information in the space provided on the specifications sheet. Consider the use of mulching or a cover crop to aid with herbaceous barrier establishment. Identify the desired type of drill, such as disk opener or deep furrow, and the desired seeding depth. Guidelines should be available or referenced in the local FOTG.

Record the species/cultivar selected for the barriers in the designated column on the specifications sheet. The specifications sheet is designed to accommodate situations where species vary within the barrier system. Change the strip numbers, as needed, to indicate the appropriate species for each strip.

Record the seeding rate in pounds of pure live seed per acre in the *Seeding Rate* column on the specifications sheet.

Record the planned seeding date in the designated *Seeding Date* column.

The specifications sheet contains columns to record planned lime and fertilizer applications, if appropriate.

Job sketch

Complete the *Job Sketch* on the back of the specifications sheet. Include the field orientation and direction of the prevailing wind of concern. Show the orientation and spacing of the planned barrier system. See figure 3g–6 for an example of barrier system design and layout for the reduction of soil erosion by wind.

Additional Reading

Aase, J.K., F.H. Siddoway, and A.L. Black. 1976. Perennial grass barriers for wind erosion control, snow management and crop production. MT. Agric. Exp. Sta., Journal Series No. 690.

Black, A.L., and F.H. Siddoway. 1975. Snow trapping and crop management with tall wheatgrass barriers in Montana. *In* Snow Management on the Great Plains Symposium Pub. #73.

Black, A.L., and F.H. Siddoway. 1976. Dryland cropping sequences within a tall wheatgrass barrier system. J. Soil and Water Conser.

Brandle, J.R., D.L. Hintz, and J.W. Sturrock, eds. 1988. Windbreak technology. Amsterdam, Oxford, New York, Tokyo: Elsevier. 135-161, 219-222.

Dewald, C.L., J. Henry, S. Bruckerhoff, J. Ritchie, S. Dabney, D. Shepherd, J. Douglas, and D.Wolf. 1996. Guidelines for establishing warm season grass hedges for erosion control. Journal of Soil and Water Conserv. 51:16-20.

Marshall, J.K. 1967. The effect of shelter on the productivity of grasslands and field crops. Field Crop Abstracts 20(1):1-14.

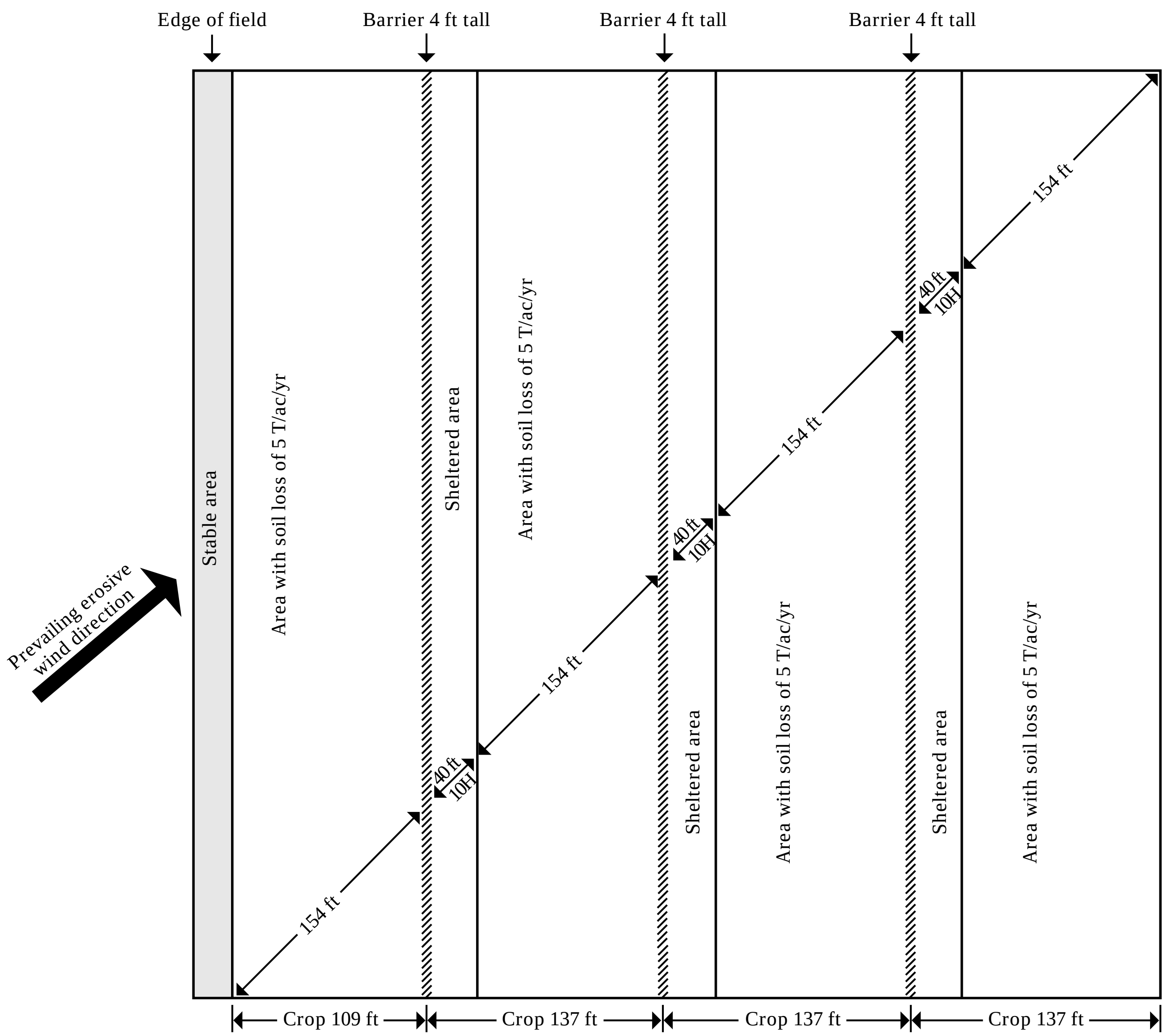
United Stated Department of Agriculture, Soil Conservation Service. 1986. Designing wind erosion control systems. Midwest National Technical Center Agronomy Note 190-LI-14.

United States Department of Agriculture, Soil Conservation Service. Field Office Technical Guide.

Figure 3g–6 Example of barrier system design and layout for the reduction of soil erosion by wind

Example 3

Crop rotation: Winter Wheat - Fallow
Soil Loss Tolerance (T) = 5 tons per acre per year
Barrier Height = 4 feet
Barrier Porosity = 40 - 50%
Prevailing Erosive Wind: 45° from perpendicular to barriers
Wind Erosion Equation factor values:
- Soil Erodibility Index (I) = 86
- Ridge Roughness (K) = 0.8
- Climatic Factor (C) = 80
- Vegetative Cover (V) = 1,000 lbs. of Flat Small Grain Equivalent
- Unsheltered Distance (L) = Determined to be 154 feet to reach 5 tons per acre per year



Herbaceous Wind Barriers

Conservation Practice Job Sheet *422A*

Natural Resources Conservation Service (NRCS) *April 1997*

Landowner____

Definition

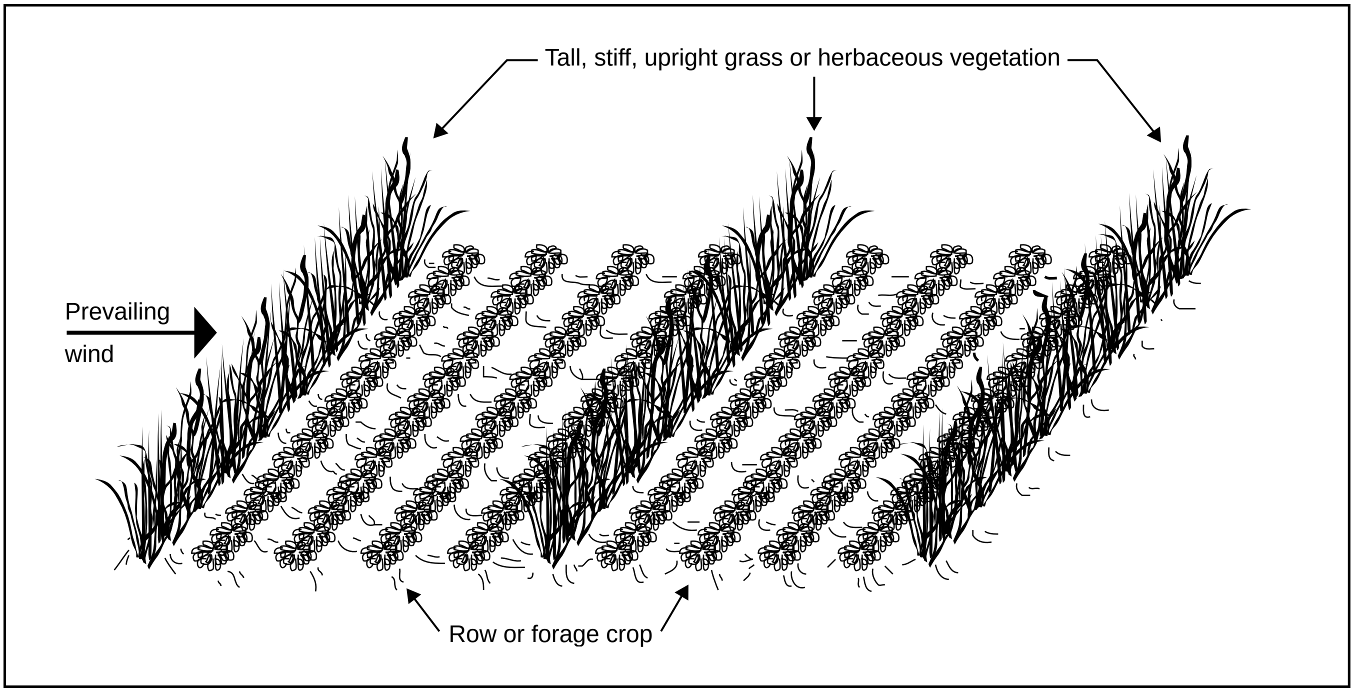
Herbaceous wind barriers are tall grass and other non-woody plants established in 1- to 2-row narrow strips spaced across the field perpendicular to the normal wind direction.

Purpose

Herbaceous wind barriers reduce wind velocity across the field and intercept wind-borne soil particles.

Secondary benefits

- Protect crops from damage by the wind or wind-blown soil particles.
- Provide food and cover for wildlife.
- Trap and distribute snow across the field.
- Reduce pesticide drift and the movement of other contaminants.



Herbaceous wind barriers reduce wind velocity, which prevents wind erosion, protects crop plants, and influences the deposition of sediment, snow, and other wind-borne material. For optimum effect on wind, the barriers should not be farther apart than 10 to 12 times the height of the barrier vegetation.

Where used

- On cropland and other land where wind-associated problems occur.
- Where snow management is desirable for improved moisture conservation.
- Where wildlife food, cover, and corridors are part of the landowner's desired objectives.
- On irrigated land using center pivot irrigation where taller, woody species would interfere with the pivot system.

Conservation management system

Herbaceous wind barriers are normally established as part of a conservation management system to address the soil, water, air, plant, and animal resources and the owner's objectives. When agronomic and horticultural crops are grown, it is important to plan the conservation crop rotation, nutrient and pest management, crop residue management, and other cropland practices.

Wildlife

Connecting herbaceous wind barriers with existing perennial vegetation, such as woodlots and woody draws *(tree/shrub establishment)* or hedgerows *(windbreak/shelterbelt establishment),* benefits wildlife and aesthetics. Adapted native species that provide wildlife food and cover should be planted.

Specifications

Site-specific requirements are listed on the specifications sheet. Additional provisions are entered on the job sketch sheet. Specifications are prepared in accordance with the NRCS Field Office Technical Guide. See practice standard Herbaceous Wind Barrier (442A).

Herbaceous Wind Barriers – Specifications Sheet

Landowner____ Field number___________

Purpose (check all that apply)	
☐ Reduce wind erosion	☐ Provide wildlife habitat
☐ Reduce wind-borne sediment	☐ Provide protection to growing crops
☐ Distribute snow across the field	☐ Other (specify)

Location and Layout	Barrier strip 1	Barrier strip 2	Barrier strip 3	Barrier strip 4
Barrier width (ft)				
Barrier height (in)				
Barrier length (ft)				
Acres in barrier area				

Plant Materials Information				
Species/cultivar by barrier number	Seeding rate (lb/acre)	Seeding date	Recommend lime (tons/acre)	Recommend fertilizer $N\text{-}P_2O_5\text{-}K_2O$ (lb/acre)
Strip #1				
1				
2				
3				
4				
Strip #2				
1				
2				
3				
4				
Strip #3				
1				
2				
3				
4				
Strip #4				
1				
2				
3				
4				

Site Preparation
Prepare firm seedbed. Apply lime and fertilizer according to recommendations.
Planting Method(s)
Drill grass and/or legume seed _______ inches deep uniformly down the row. Establish stand of vegetation according to recommended seeding rate. If necessary, mulch newly seeded area with ______ tons per acre of mulch material. May seed small grain as a companion crop at the rate of _______ pounds per acre, but clip or harvest before it heads out.
Operation and Maintenance
Control weeds. Reestablish barriers as needed to ensure adequate growth before critical wind period. Remove sediment accumulation. Reestablish gaps in barrier row. See standard maintenance requirements.

Herbaceous Wind Barriers – Job Sketch

If needed, an aerial view or a side view of the herbaceous wind barrier field layout can be shown below. Other relevant information, such as complementary practices and adjacent field or tract conditions including structures and crop types, and additional specifications may be included.

Scale 1"=________ ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")

Additional Specifications and Notes:

Chapter 3h Riparian Forest Buffers

Definition of a riparian forest buffer

Riparian forest buffers are areas of primarily trees and shrubs located adjacent to streams, lakes, ponds, and wetlands.

Purposes

This practice has three purposes:

- Create shade to lower water temperature to improve habitat for aquatic organisms.
- Provide a source of detritus and large woody debris for aquatic organisms and habitat for wildlife.
- Reduce excess amounts of sediment, organic material, nutrients, and pesticides in surface runoff; and reduce excess nutrients and other chemicals in shallow ground water flow.

Design considerations

Location and layout

For riparian forest buffers to achieve their intended purpose(s), they must be properly located and sized (width, length, area) in relation to the stream or waterbody. Buffers are located immediately adjacent to the watercourse or waterbody needing protection or enhancement. For streams, one or both sides may need treatment. A historical investigation of stream, waterbody, and riparian conditions using aerial photography or landowner interviews can provide valuable information for designing the extent and configuration of buffers. Buffers consist of a zone (identified as zone 1) that begins at the normal water line, or at the upper edge of the active channel or shore top of the bank, and extends a minimum distance of 15 feet, measured horizontally on a line perpendicular to the watercourse or waterbody. The zone can be adjusted to include the entire riparian area (area with a year-long or seasonal soil-moisture regime influenced by the stream or waterbody) and/or to accommodate the special needs of local, year-long or seasonal fish and wildlife species. General guidelines for wiÀdhs (which include the total of two-side plantings along streams) for some representative species are:

Species (common names)	Desired width (feet)
Bald eagle, cavity nesting ducks, herons, sandhill crane	600
Common loon, pileated woodpecker	450
Beaver, dabbling ducks, mink, salmonids	300
Deer	200
Lesser scaup, harlequin duck	165
Frog, salamander	100

Listed widths may extend beyond riparian boundaries to upland settings. In such cases refer to Tree/Shrub Establishment, 612, for design of upland woody plantings.

A minimum length for most buffers (distance as measured parallel to the streambank edge or shoreline) can be set at two times its width (include the total of widths for both sides of a stream buffer). For habitat purposes, the buffer length can be extended along the entire stream reach within the ownership (or beyond if possible) or to existing riparian forests; i.e., the longest distance possible.

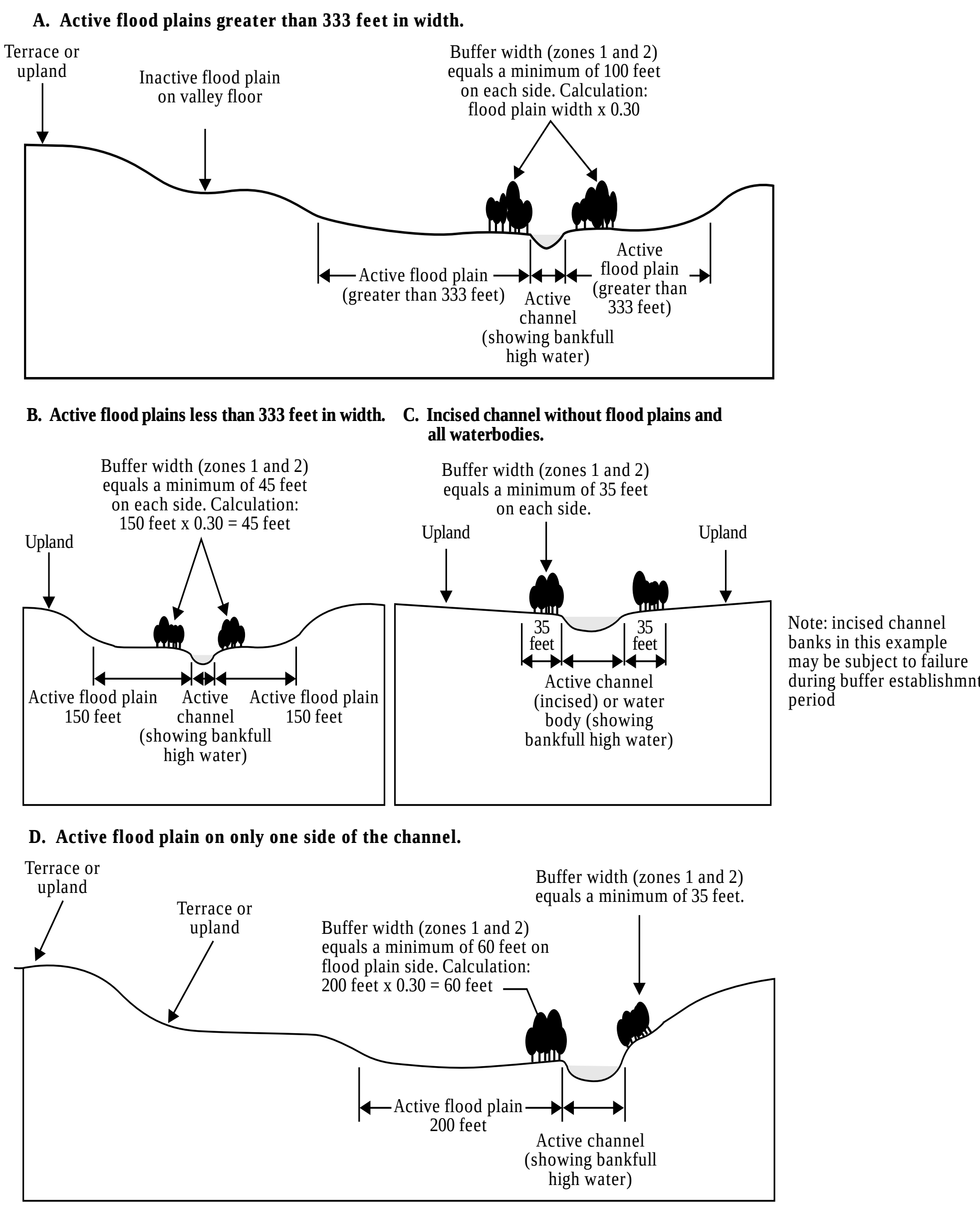
For watercourses or waterbodies with streambank or shoreline erosion, the establishment of riparian forest buffers must be done at the same time or following the installation of streambank and shoreline protection (see Conservation Practice 580). If poor upland conditions and high runoff make successful streambank or shoreline protection unlikely, a riparian forest buffer is not advised until cropland, grazing, or other applicable conservation management systems are installed.

An additional strip or area of land, zone 2, may be needed to reduce excess amounts of sediment, organic material, nutrients, and pesticides in surface runoff and to reduce excess nutrients and other chemicals in shallow ground water flow. On small streams or water bodies planned or having buffers with a minimum zone 1 width, zone 2 will begin at the edge and upgradient of zone 1 and extend a minimum distance of 20 feet (for a total of 35 feet, measured horizontally on a line perpendicular to the watercourse or waterbody). For larger streams or waterbodies, the minimum combined width of zones 1 and 2 is 100 feet or 30 percent of the geomorphic flood plain, whichever is less. See figure 3h–1.

The total width of Zone 1 plus Zone 2 buffers may be increased to include the entire riparian area (area with a year-long or seasonal soil-moisture regime influenced by the stream or waterbody). The minimum length of zones 1 and 2 must match the adjacent dimension of the source field or area. To achieve multiple purposes, the buffer length can be extended along the entire waterbody within the ownership (or beyond if possible) or to existing riparian forests, i.e., the longest distance possible.

Zone 3 is an area of sufficient size identified and created to control concentrated flow erosion or soil movement in the upgradient area immediately adjacent to zone 2. (See figure 3h–2.) Zone 3 is designed in accordance with criteria for applicable practices.

Figure 3h–1 Examples of minimum riparian forest buffer widths for watercourses and waterbodies



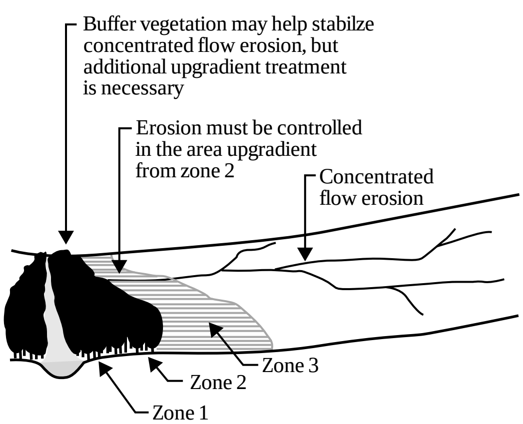
On some sites, ground water flows that carry excess nutrients, pesticides, or other chemicals may connect with aquifers (which feed into streams and waterbodies) through deep flows. These flows would pass beneath the rooting zones of existing or planned riparian forest buffers (fig. 3h–3). The establishment of a new riparian forest buffer is not advised in these situations if the sole purpose for the buffer is subsurface control of pollutants.

Generalized riparian buffer widths necessary for adequate performance of several specific buffer functions—based upon their biological, chemical and physical characteristics —are:

- 60 to 100 feet for water temperature moderation
- 30 to 200 feet for sediment removal
- 15 to 300 feet for nutrient removal
- 10 to 350 feet for species diversity (habitat)

These widths illustrate the wide variation needed to achieve a specific function required for a particular buffer. Based on existing literature, buffers necessary to protect wetlands and streams should be a minimum of 50 to 100 feet in width under most circumstances. Site-specific conditions may indicate the need for substantially larger buffers or for somewhat smaller buffers. (Castelle 1994).

Figure 3h–2 Control of concentrated flow erosion upgradient of the buffer (zone 3)



Plant material information

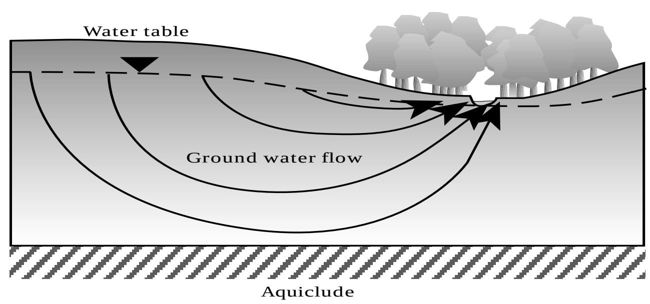
Plant or manage trees and shrubs suited to the site and the intended purpose. Favor tree and shrub species that are locally native (match the potential of the site) and have multiple values, such as those suited to timber, biomass, nuts, fruit, browse, nesting, aesthetics, and tolerance to locally used herbicides. Species that resprout are preferred when establishing new rows nearest to watercourses or waterbodies subject to flooding or ice damage.

For detritus and large woody debris, use species that meet the specific requirements of fish and other aquatic organisms for food, habitat, migration, and spawning. Plantings should consist of two or more species with individual plants suited to the seasonal variation of soil moisture status of individual planting sites (fig. 3h–4). Plant types and species shall be selected based on their compatibility in growth rates and shade tolerance. Only viable, high quality, and adapted planting stock will be used. An adequate upstream or

Wooded riparian buffers in the Maryland coastal region were found to remove as much as 80 percent of excess phosphorus and 89 percent of excess nitrogen with most effect occurring in the first 62 feet (19 m).

Shisler et al. 1987

Figure 3h–3 Deep flows enter watercourse below the rooting zone



adjacent seed source must be present when using natural regeneration to establish a buffer. Criteria for determining natural regeneration potential varies by locale and species.

Generally, plant densities for trees and shrubs will depend on their potential height at 20 years of age. Heights may be estimated based on:

- Performance of the individual species (or comparable species) in nearby areas on similar sites.
- Predetermined and documented heights using Conservation Tree/Shrub Suitability Groups, if availble, Section II of the NRCS Field Office Technical Guide or other documents. Planting density specifications are shown in table 3h–1.

Planting stock may include bareroot, container, rooted cuttings, stock, or cuttings. The stock must be of suitable size, caliper, height, and age (regenerative potential for unrooted cuttings) to produce shoots and a vigorous rooting system during the first growing season or period.

The timing or dates of planting must coincide with optimum soil moisture and temperature for the selected species and be suited to the kind of stock. The planting period may be extended for container stock and sites that receive supplemental water. Advice for optimum planting dates may be obtained from local public and private woody plant nurseries.

Site preparation

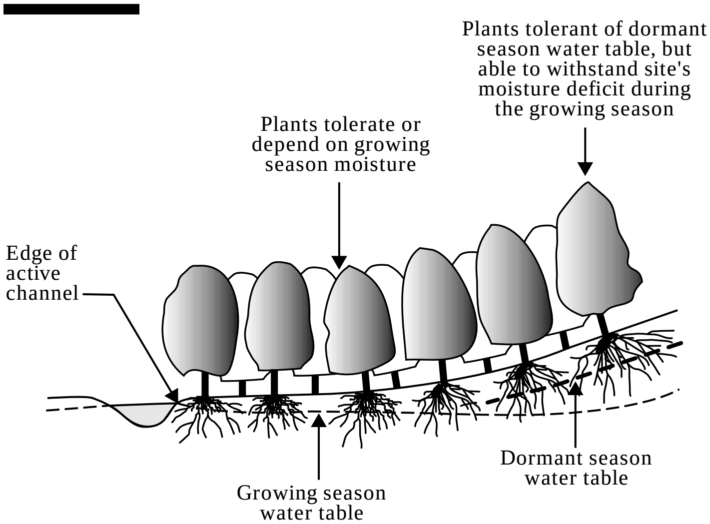
Site preparation shall be sufficient for establishment and growth of selected species and be done in a manner that does not compromise the intended purpose.

Woody plants rarely survive and establish quickly if planted (or naturally regenerated) directly in heavy competitive vegetation. Also, planting becomes difficult if crops, crop residue, or other debris cover individual planting sites. Site preparation may include removal of competitive vegetation or debris by shovel, brush hog, or brush blade; tilling with moldboard plow, disk plow, or rototiller; the use of a herbicide; and special treatment to control such harmful wildlife as moles, gophers, and mice.

Table 3h–1 Planting density specifications

Plant types/heights	**Plant-to-plant spacing (plants/acre)**
Shrubs less than 10 feet in height	3 to 6 feet (1,210 to 4,840)
Shrubs/trees from 10 to 25 feet in height (includes columnar trees)	5 to 8 feet (681 to 1,742)
Trees greater than 25 feet in height	8 to 12 feet (302 to 681)

Figure 3h–4 Plant adaptation to soil moisture



Function and value of riparian forest buffers

Studies that may help during the location and layout design process

Nitrogen uptake by trees—Some generalized averages for average annual nitrogen (N) uptake by trees include: 1) about 60 pounds per acre (70 kg ha^{-1}) for deciduous species, and 2) about 35 pounds per acre (40 kg ha^{-1}) for coniferous species. Temperate deciduous tree species produce about 180 pounds of biomass per one pound of N uptake and temperate coniferous tree species about 100 pounds. Uptake and biomass values can be quite variable and have overlapping ranges for deciduous and coniferous species (Cole and Rapp 1980).

Channel influences—Riparian forest buffers influence channel width. A study in the Pennsylvania Piedmont basin showed that: 1) first- and second-order wooded reaches averaged about two times wider than their meadow counterparts of the same order, and 2) third- and fourth-order forested reaches were about 1.7 times wider than in deforested areas. The channel narrows in the absence of a streamside forest because of grassy vegetation which develops a sod that gradually encroaches on the channel banks. The loss of stream width translates into a proportionate loss of substrate and habitat for benthic organisms important in the aquatic food chain (Sweeney 1992).

Denitrification in riparian forests—Estimates for denitrification in natural riparian forests in the U.S. are in the range of 25 to 35 pounds N per acre per year (30 to 40 kg N ha^{-1} yr^{-1}). Several studies indicate that denitrification (anaerobic microbial conversion of nitrate to N gases) is concentrated in surface soil down to about 6 to 12 inches (Hendrikson 1981).

Temperature—Small streams flowing through exposed reaches can experience increases in temperature of up to 1.5 degrees Fahrenheit (F) for every 100 feet of sun exposure. Maximum daily temperatures can be as much as 12 to 15 degrees higher in exposed streams, rendering them unfit for many species of fish (Maryland Dept. of Natural Resources Undated).

Infiltration—Forest buffers can absorb runoff that carries soil and pollutants at 10 to 15 times the rate of grass turf, and 40 times that of a plowed field (Maryland Dept. of Natural Resources Undated).

Large woody debris—As much as 75 percent of the large woody debris (LWD) in streams comes from trees within the first 50 feet of the streambank. About 90 percent comes from within 80 feet of the stream. In small headwater streams in Oregon, one study placed LWD (8-, 16-, and 24-inch diameter logs) in streams and looked at pool creation 4 years later. The LWD created an additional 43 percent pool volume in one stream and 71 percent in the other. Local trout species were attracted to new pool locations, particularly during low flows in summer (Montana State University 1997).

Avian habitat—Hundreds of bird species use riparian forests. In western Montana, 59 percent of all land birds use riparian forests for breeding. Of that, almost half are totally dependent on riparian areas and are unable to reproduce in other habitats. The number of species of neotropical migrant birds (birds that fly south of the U.S. border each winter) in Montana total 144, which is over half of the breeding land birds in that state (Montana State University 1997).

For tilled sites, leave at least a 3-foot untreated strip intact at the edge of the bank or shoreline. If flooding and erosion are anticipated before buffer establishment, use mulching or fast-establishing, noncompetitive ground covers. Ground covers are applicable if sufficient moisture for their establishment is expected. The last tilling should be timed to allow the soil to settle before trees or shrubs are planted. Tillage widths should be kept as small as possible to leave as much of the riparian area intact and resistant to any flood flows. Mowing between tilled strips may be needed to control rodent populations.

For new buffers, avoid sites that have had recent application of pesticides harmful to the selected woody species. If herbicides are used, apply only when needed. They should be handled and disposed of properly and within Federal, State, and local regulations. Follow label directions and heed all precautions listed on the container.

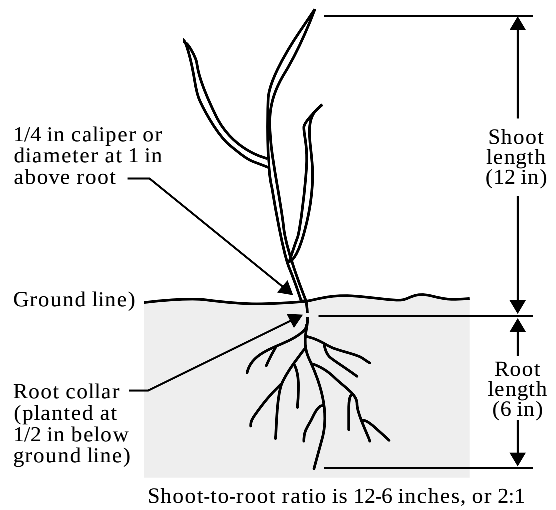
Fabric mulch may be used for weed control and moisture conservation for new plantings on all sites, particularly those with pronounced growing season moisture deficits or the potential for invasive weedy species. Refer to Mulching, 484, for installation procedures. To be effective, fabric mulches must be laid directly on the soil surface, not suspended above weeds or debris.

Planting methods

The method of planting for new buffers shall include hand or machine planting techniques, be suited to achieving proper depths and placement of planting stock roots, and not impair the intended purpose and function of the buffer.

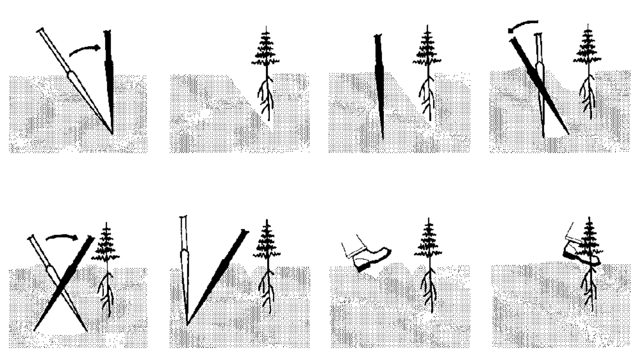
Roots of bareroot stock shall be kept moist during planting operations by placing in a water-soil (mud) slurry, peat moss, super-absorbent (e.g., polyacrylamide) slurry, or other equivalent material. Rooting medium of container or potted stock shall be kept moist at all times by periodic watering. Pre-treat stored cuttings with several days of soaking just before planting. Stock shall not be planted when the soil is frozen or dry. Rooted stock is planted in a vertical position with the root collars even with or approximately a half inch below the soil surface (fig 3h–5). Insert cuttings to the depth required to reach adequate soil moisture with at least two to three buds above ground. The planting trench or hole must be deep and wide enough to permit roots to spread out and down without J-rooting or L-rooting. After planting of rooted stock or cuttings, pack soil around each plant firmly to eliminate air pockets (fig. 3h–6). Enter additional planting methods requirements on the specifications sheet.

Figure 3h–5 Planting methods



Seedlings shall not be less than 1/4 inch in caliper at 1 inch above the root collar. For cuttings, use material greater than 1/2 inch in diameter, cut off tops with apical buds, remove side branches, and produce lengths long enough to reach adequate soil moisture required by the individual species during the growing season. Tops of dormant-season collected cuttings may be dipped into latex paint, paraffin, or sealing wax to prevent desiccation and mark the up-end. Rooted planting stock must not exceed a 2:1 shoot-to-root ratio. See figure 3h–4. Container stock shall normally not exceed a 1 gallon can size.

Figure 3h–6 Proper plant and root placement of rooted stock using a planting bar



Temporary storage instructions

When planting stock first arrives at the planting site, check it for dry root conditions, mold, pests, or heat. Arrange to replace damaged stock. Stock that is not immediately planted should be left in the containers in which they were shipped and stored in a cool (34 to 38 degrees F in temperate climates), shaded, and moist environment. During all stages of handling and storage, keep stock tops dry and free of mold and roots moist and cool. Do not use stock that has been allowed to dry, to heat up in storage (e.g., within a bale, delivery carton, or container), or that has developed mold or other pests.

For stock that is expected to begin growth before planting, dig a V-shaped trench (heel-in bed) at a well-drained site of sufficient dimensions to bury seedlings so that all roots are covered by soil. Pack the soil firmly and water thoroughly.

Enter additional temporary storage requirements on the specifications sheet.

Operation and maintenance

Various actions need to be carried out to ensure that this practice functions as intended throughout its expected life. These actions include normal repetitive activities in the application and use of the practice (operation) and repair and upkeep of the practice (maintenance). Riparian forest buffers are inspected periodically, protected, and/or treated as needed to maintain the intended purpose from adverse impacts, such as excessive vehicular and pedestrian traffic, pest infestations, pesticide use on adjacent lands, livestock damage, and fire.

Replacement of tree or shrub seedlings that die and control of undesirable vegetative competition is continued until the buffer is, or will progress to, a fully functional condition.

As applicable, control of concentrated flow erosion or mass soil movement is continued in the upgradient area, zone 3, immediately adjacent to zone 2 to maintain buffer function.

Any use of fertilizers, mechanical treatment, prescribed burning, pesticides, and other chemicals to assure buffer function shall not compromise the intended purpose. Biological control of undesirable plant species and pests (e.g., using predator or parasitic species, or grazing of domestic animals) should be used where available and feasible.

Removal of tree and shrub products, such as high value trees, is permitted provided the intended purpose is not compromised by the loss of vegetation or harvesting disturbance. Felling and skidding of trees is directed away from the watercourse or waterbody. Skidding is done in a manner to prevent creation of ephemeral channels perpendicular to the stream.

For purposes of reducing excess pollutants in surface runoff and shallow ground water (zone 1 and 2) or providing habitat and corridors for wildlife (zone 1 at a minimum), the dominant canopy is managed to maintain maximum vigor of overstory and understory species. For purposes of moderating water temperatures and providing detritus and large woody debris, riparian forest buffer management must maintain a minimum of 50 percent canopy cover. To continue providing habitat and corridors for wildlife, manage the buffer to favor food, shelter, and nesting cover that would satisfy the habitat requirements of the indicator or target wildlife. Refer to Habitat Evaluation Procedures by the United States Fish and Wildlife Service or equivalent state document for the particular species.

To achieve benefits provided by large, woody debris from older riparian forest buffers, natural mortality of trees and large shrubs may need to be supplemented by periodically felling and placing selected stems or large limbs within watercourses and waterbodies to reach original design specifications.

Livestock shall be controlled or excluded as necessary to achieve and maintain the intended purpose. Watercourse crossings and livestock watering shall be located and sized to minimize impact to buffer vegetation and function. On established buffers included within grazed areas, set utilization rates of key woody browse to allow woody vegetation to regrow sufficiently for its intended function. Impairment of buffer function by livestock overuse (trampling, compaction or overutilization of woody plants) requires immediate removal of livestock from the riparian area.

Additional operation and maintenance requirements shall be developed on a site-specific basis to assure performance of the practice as intended.

Information needed to fill in job sheet

Select the purpose of the riparian forest buffer

Checkmark applicable purposes on the specifications sheet. A buffer may have more than one primary purpose. The *Other* block may be used to identify secondary purposes. Additional specifications may be required in practice design and layout to accommodate secondary purposes; enter these on the back of the specifications sheet or additional sheets as necessary.

Determine location and layout

For reference purposes enter the name and type of waterbody or watercourse that the buffer will protect or enhance.

Based on these instructions, enter the widths, lengths and total area of the buffer zone(s) on the specifications sheet and any accompanying instructional notes. Specify left and right of stream (facing upstream) for a two-side buffer; use left only for waterbodies, such as lakes and ponds.

Information for zone 3 is filled in with reference to an accompanying specifications sheet; e.g., a Filter Strip, 393, specifications sheet.

Provide woody plant material information

In the first column, list the species that will be used in each zone. Species should be suited to the site and the intended purposes. Select species from a state or locally prepared plant list or, if Internet access is available, use the VegSpec software (www.plants.usda.gov).

If existing vegetation is adequate in Zone 1, there may be no need to plant additional species. In these cases, write "maintain existing vegetation" under zone 1 and leave the columns to the right blank.

For each species listed, provide information on the planting density (number of plants per acre) and average spacing between plants. The density will vary depending on the intended purposes and the growth rates of the selected species.

Job sketch

Sketches are helpful in communicating the design to landowners. On the back of the specifications sheet, a grided area is provided to sketch a plan or side view of the proposed riparian forest buffer. A larger sheet may be needed to show more complex designs. Plan views help to illustrate the spacing between plants and species arrangements. Plants can be shown either as points representing their trunk locations or as circles representing their canopy. Side views help to illustrate the desired horizontal composition of the design. Sketch plants to illustrate their mature sizes and forms.

If drawn to scale, indicate how many feet are in an inch of drawing. The half-inch grid provides a convenient way to draw the sketch to scale.

Additional specifications and notes

Some space is provided to write additional information and direction. For temporary storage instructions, site preparations, planting method(s), and buffer maintenance, a larger block of space is on the back of the specifications sheet. Include any information that is critical to design, installation, operation, or maintenance. You may also want to include a phone number and contact name for future reference.

Additional reading

Castelle, A.J. 1994. Wetland and stream buffer size requirements - a review. Journal of Environmental Quality, 23-5. Madison, WI.

Cole, D.W., and M. Rapp. 1980. Elemental cycling in forest ecosystems. In Dynamic properties of forest ecosystems, Cambridge Univ. Press, New York.

Hendrikson Jr., O.Q. 1981. Flux of nitrogen and carbon gases in bottomland soils of an agricultural watershed. Ph.D. dissertation 82-01544, Univ. Georgia, Athens, GA.

Maryland Department of Natural Resources. Stream Releaf. Undated.

Montana State University. 1997. Riparian forest wildlife. Extension Service EB146.

Sweeney, B.W. 1992. Streamside forests and the physical, chemical, and trophic characteristics of Piedmont streams in Eastern North America. Water Science Technology 26:2653-2673.

United States Department of Agriculture, Natural Resources Conservation Service. Conservation Practice Standards: Filter Strip-393A, Riparian Forest Buffer-391A, Streambank and Shoreline Protection-580, Tree/Shrub Establishment-612. Section IV, Field Office Technical Guide.

United States Department of Agriculture, Natural Resources Conservation Service. Conservation tree/shrub suitability groups. Section II, Field Office Technical Guide.

Wenger, Seth. 1999. A review of the scientific literature on riparian buffer width, extent, and vegetation. Office of Public Service and Outreach, Institute of Ecology. University of Georgia, Athens, GA.

United States
Department of
Agriculture

Natural
Resources
Conservation
Service
(NRCS)

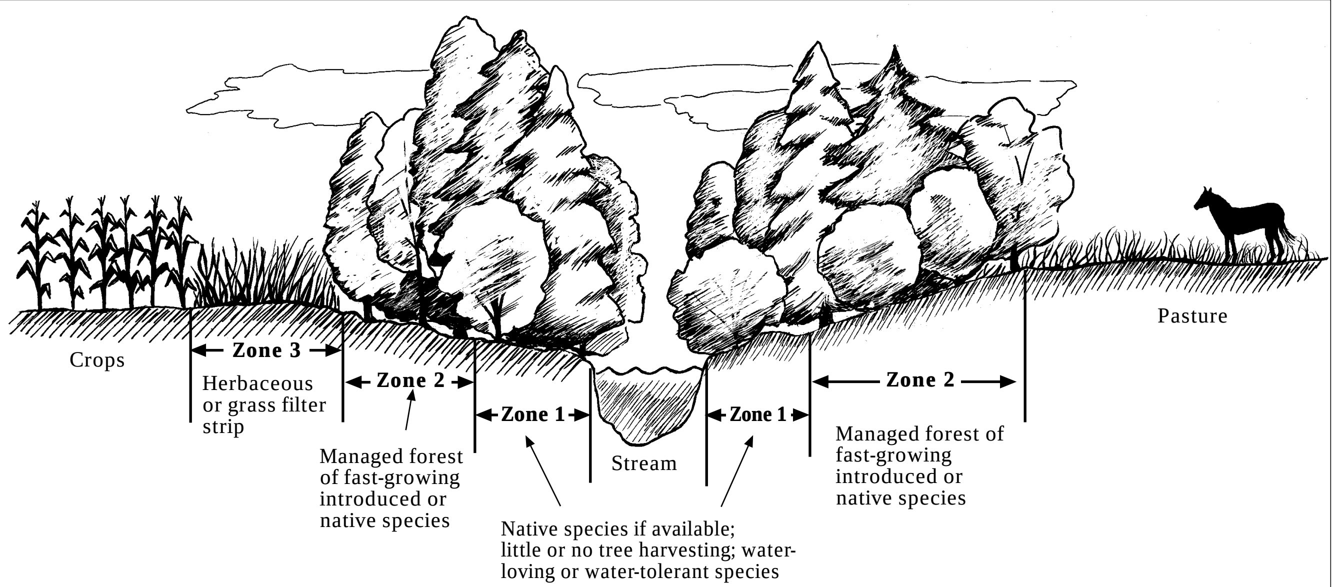
and

Collaborating Technical Centers,
States, and Partners

1999

Riparian Forest Buffer

A *Design Exercise* for use with the Conservation Practice Job Sheet - 391



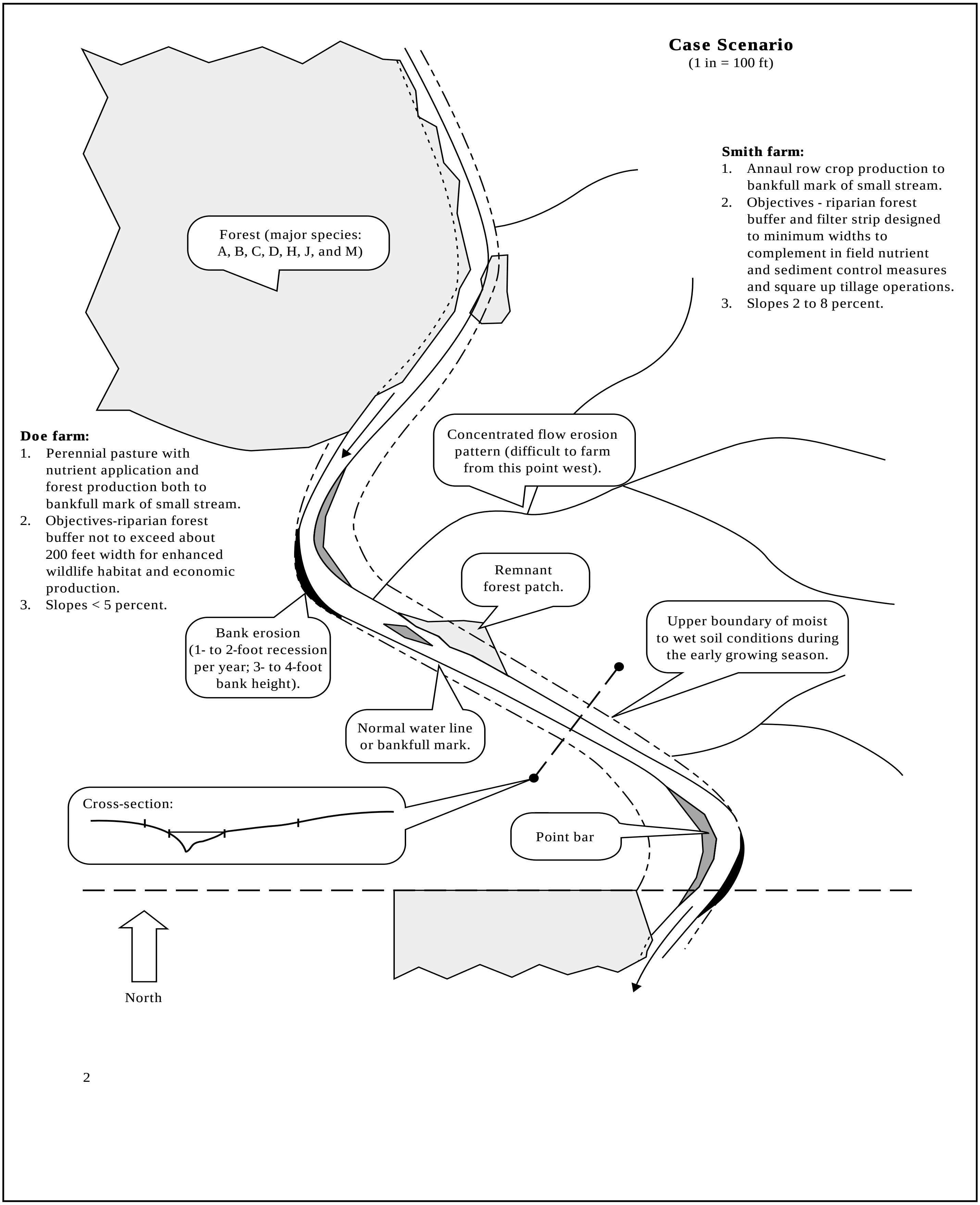
Instructions (read all instruction before starting):

1. Given the case scenario on page 2 and your knowledge of riparian forest buffer design, prepare a possible design sketch on page 4 of the riparian forest buffer zones for the Smith Farm. Study the design sketch for the Doe Farm on page 5 and ask the instructor for the design strategy.

2. Focus on the area surrounding the dashed line noted as the Cross-section near the bottom of page 2. Using the generic NRCS Field Office Technical Guide (FOTG) information on page 3, prepare a possible layout of species for each of your zones on page 6. Denote each plant by its letter. Study the layout of species for the Doe Farm on page 7 and ask the instructor for the design strategy.

3. Work in pairs. There are many right answers! Pay attention to the given details and sketch map scales. Be ready to explain your design strategy.

1


Case Scenario
(1 in = 100 ft)
Smith farm:
1. Annaul row crop production to bankfull mark of small stream.
2. Objectives - riparian forest buffer and filter strip designed to minimum widths to complement in field nutrient and sediment control measures and square up tillage operations.
3. Slopes 2 to 8 percent.
Forest (major species: A, B, C, D, H, J, and M)
Doe farm:
1. Perennial pasture with nutrient application and forest production both to bankfull mark of small stream.
2. Objectives-riparian forest buffer not to exceed about 200 feet width for enhanced wildlife habitat and economic production.
3. Slopes < 5 percent.
Concentrated flow erosion pattern (difficult to farm from this point west).
Remnant forest patch.
Upper boundary of moist to wet soil conditions during the early growing season.
Bank erosion (1- to 2-foot recession per year; 3- to 4-foot bank height).
Normal water line or bankfull mark.
Cross-section:
Point bar
North
2

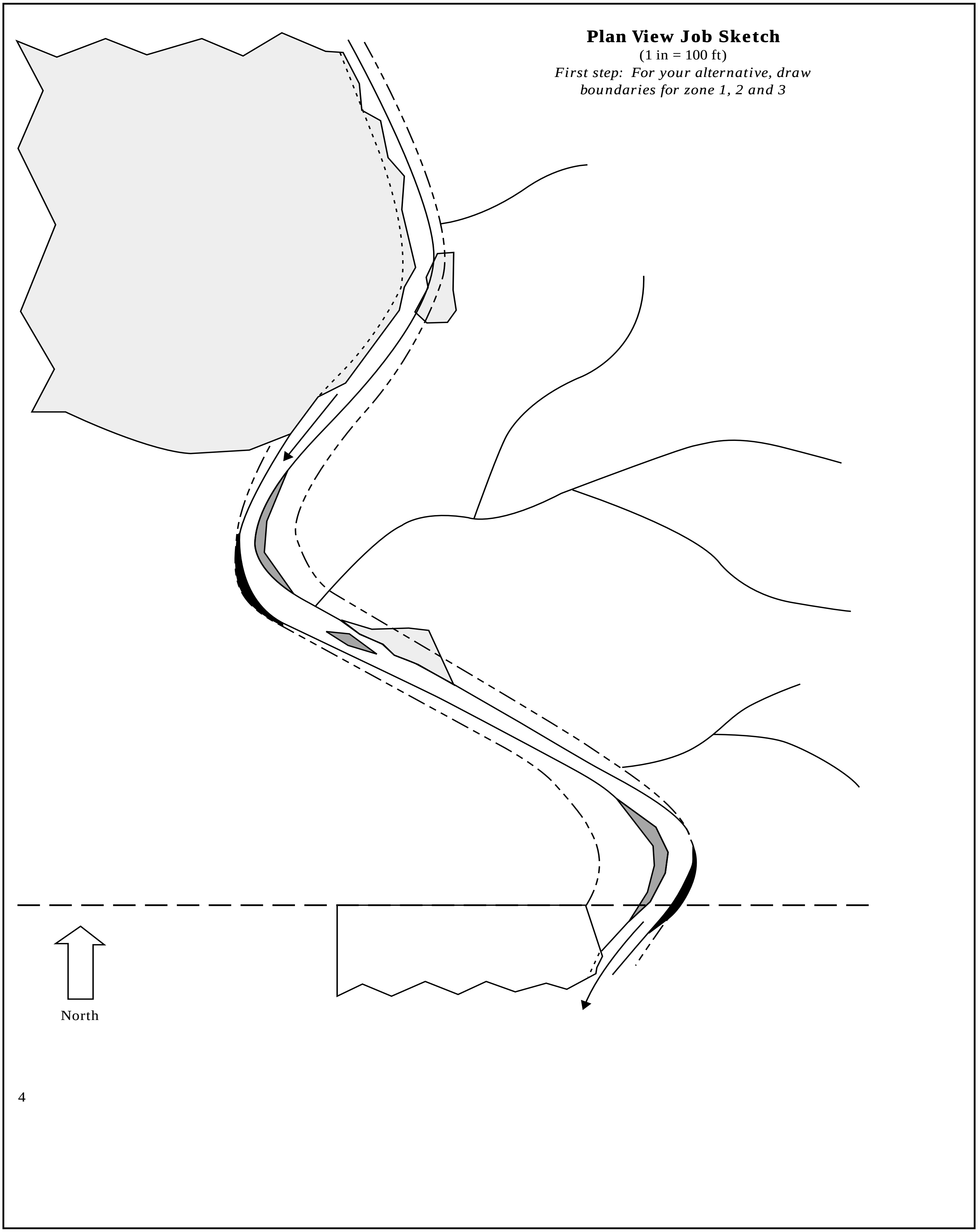
onservation Tree/Shrub Sutiability Groups (for use with planning exercise).

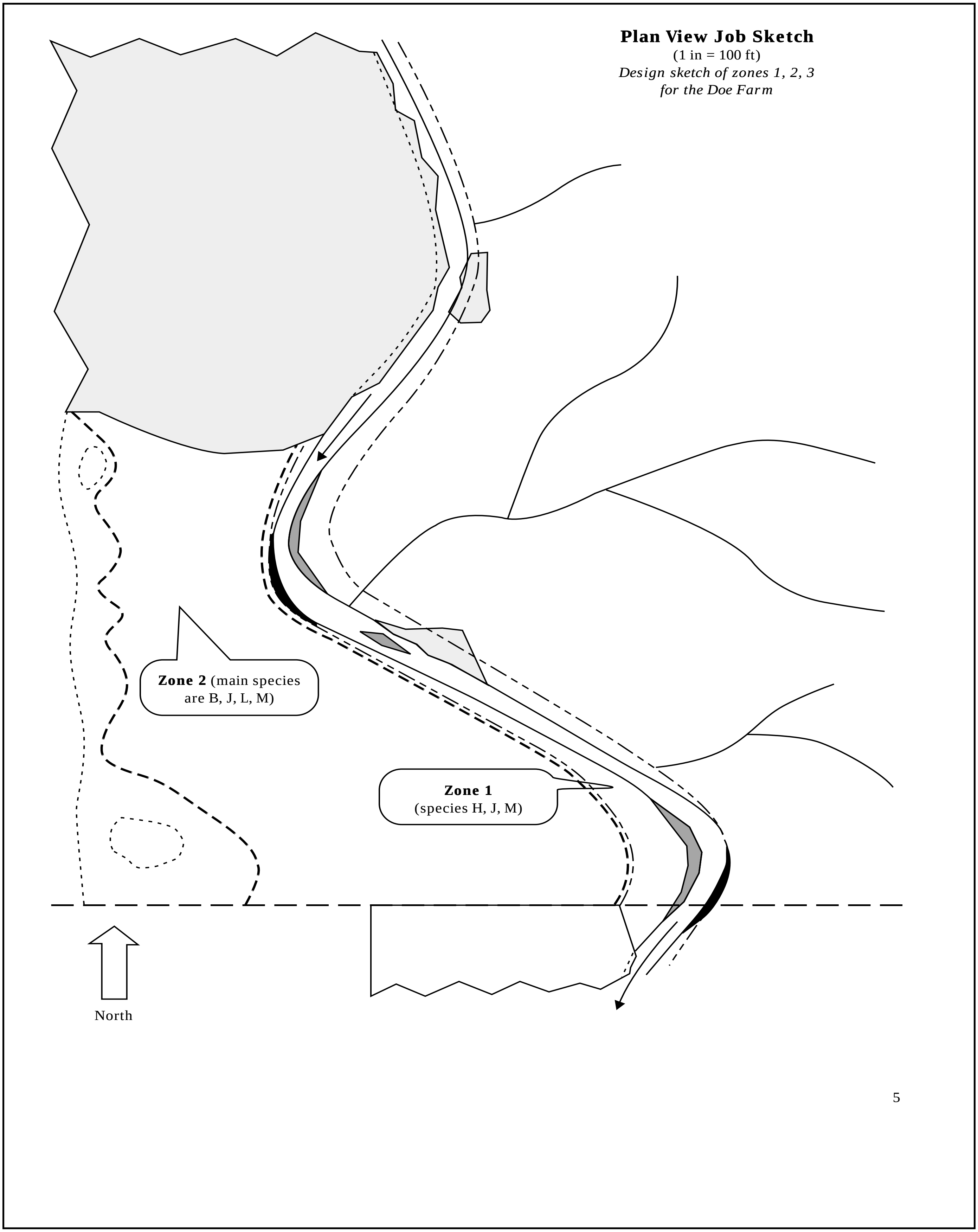
	Native or Introduced	**C**onifer, **D**eciduous	**I**ntolerant, **M**od. **T**olerant, or Tolerant of shade	Suited for **T**imber-veneer, **F**iber (short rotation), or **C**hristmas trees	**I**ntolerant, **M**oderately tolerant, or **T**olerant of soil wetness	**R**apid, **M**oderate or **S**low growth rate	20-year height-feet	**R**esprouts	Wildlife habitat value-**H**igh, **M**oderate, **L**ow	Notes
	N	C	M	T, C	I	M	35-55	-	H	
	N	D	I	T	T	R	45-65	-	M	
	N	D	M	T	T	M	45-55	R	M	
	N	C	T	T	M	S	30-55	-	H	
	N	D	I	F	T	M	35-60	R	L	
	I	D	I	F	T	R	45-75	R	L	
	N	D	I	-	T	R	25-35	R	M	Multiple stems
	N	D	I	-	T	R	15-25	R	M	Multiple stems
	I	D	I	-	T	R	12-20	R	M	Multiple stems
	N	C	M	T, C	M	M	35-50	-	M	
	I	C	M	C	M	M	35-55	-	M	
	N	D	M	-	M	M	5-8	-	H	
	N	D	M	-	T	M	5-8	-	M	
	I	D	M	-	T	R	7-10	R	M	
	I	C	M	T	T	M	30-50	-	M	
	N	D	M	-	M	M	10-18	M		
	I	D	M	-	T	M	10-18	-	H	
	I	D	I	-	M	M	15-25	R	M	Multiple stems
	I	D	M	-	T	R	15-20	R	M	Multiple stems

ss

	Native or Introduced	**C**onifer, **D**eciduous	**I**ntolerant, **M**od. **T**olerant, or Tolerant of shade	Suited for **T**imber-veneer, **F**iber (short rotation), or **C**hristmas trees	**I**ntolerant, **M**oderately tolerant, or **T**olerant of soil wetness	**R**apid, **M**oderate or **S**lor growth rate	20-year height-feet	**R**esprouts	Wildlife habitat value-**H**igh, **M**oderate, **L**ow	Notes
	I	H*	I	-	I	R	-	-	M	
	I	H*	I	-	M	R	-	-	M	
	I	H*	I	-	M	R	-	-	M	
	I	H*	I	-	T	R	-	-	M	

ıss Species 3

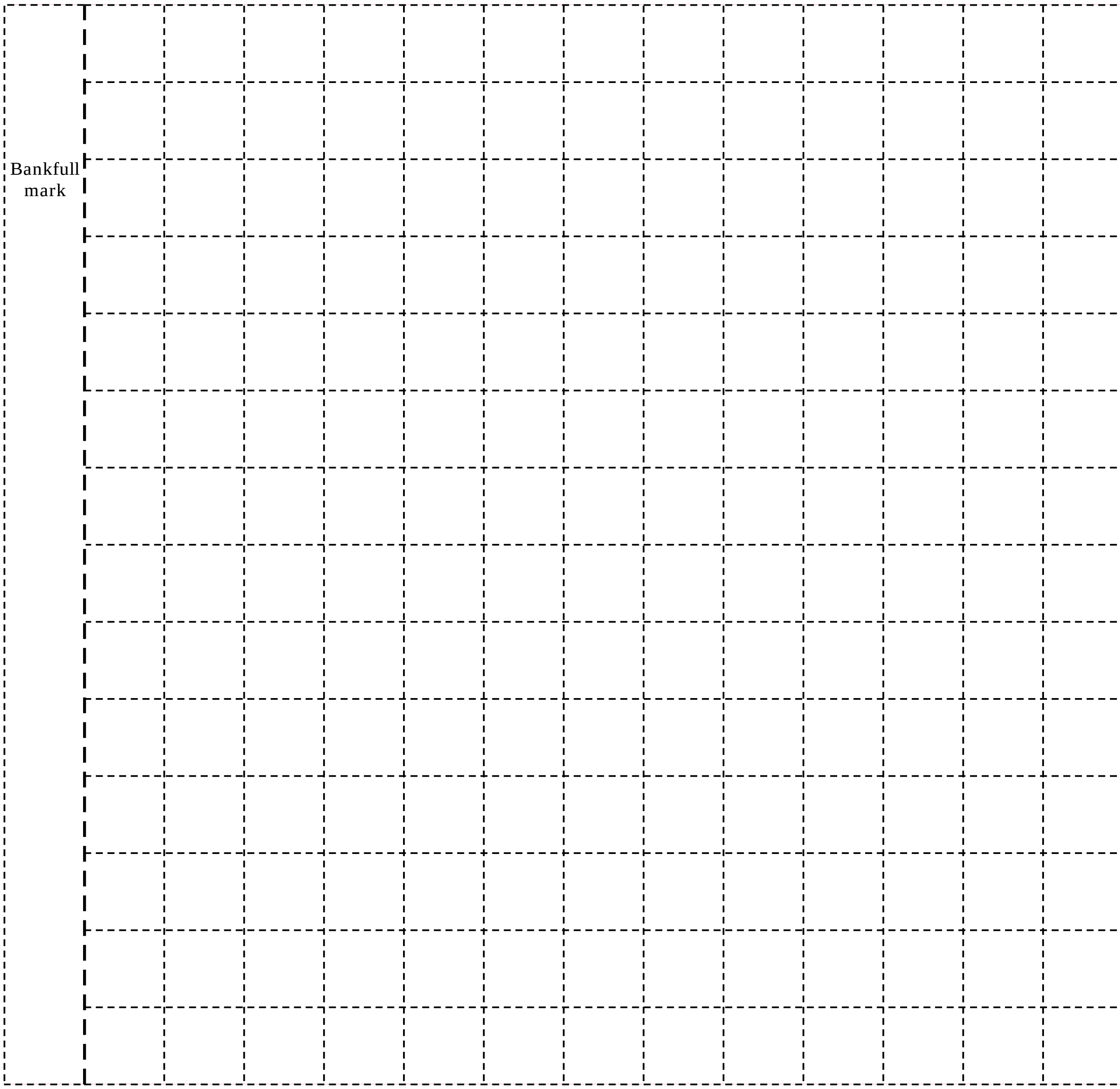

Plan View Job Sketch
(1 in = 100 ft)
First step: For your alternative, draw boundaries for zone 1, 2 and 3
North
4


Plan View Job Sketch
(1 in = 100 ft)
Design sketch of zones 1, 2, 3
for the Doe Farm
Zone 2 (main species are B, J, L, M)
Zone 1 (species H, J, M)
North
5

Plan View Close-up - Job Sketch

Scale: 1 in = 10 ft. Use 5-foot spacing for plants < 25 feet in height and 10-foot for > 25 -foot heights.

Task: Indicate a representative area's relative proportions of species and planting densities by using the species "letter" for individual plants. Sketch zone boundaries and any other pertinent features. Use the area noted as "Cross-section" line on the Case Scenario map.



Gridlines are 1/2 inch squares (5 ft by 5 ft)

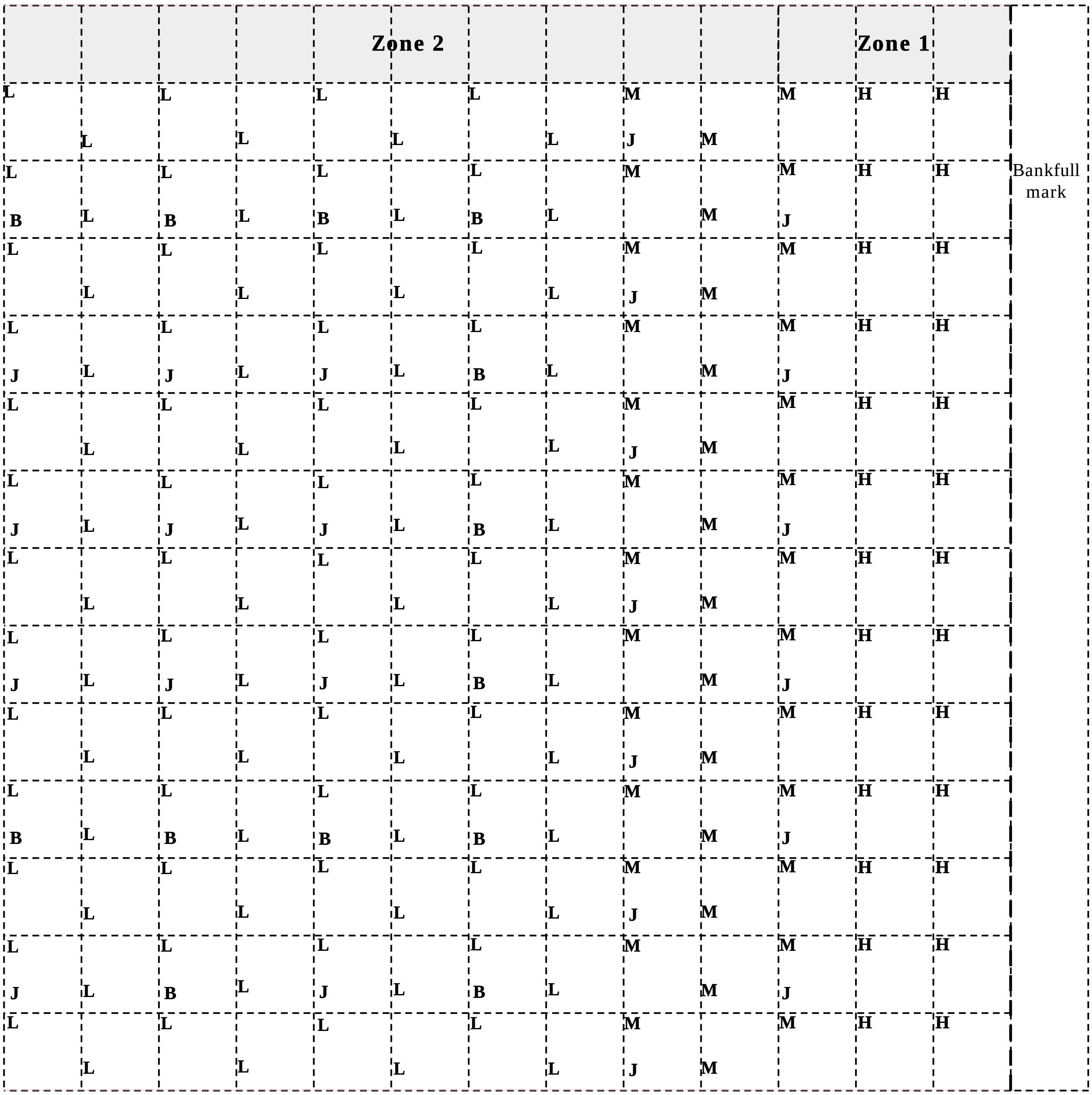
6

6

Plan View Close-up - Job Sketch - Doe Farm

Scale: 1 in = 10 ft. Use 5-foot spacing for plants < 25 feet in height and 10-foot for > 25-foot heights.

Task: Indicate a representative area's relative proportions of species and planting densities by using the species "letter" for individual plants. Sketch zone boundaries and any other pertinent features. Use the area noted as "Cross-section" line on the Case Scenario map.



Gridlines are 1/2 inch squares (5 ft by 5 ft)

7

Riparian Forest Buffer

Conservation Practice Job Sheet *391*

Natural Resources Conservation Service (NRCS) *January 1998*

Landowner____

Definition

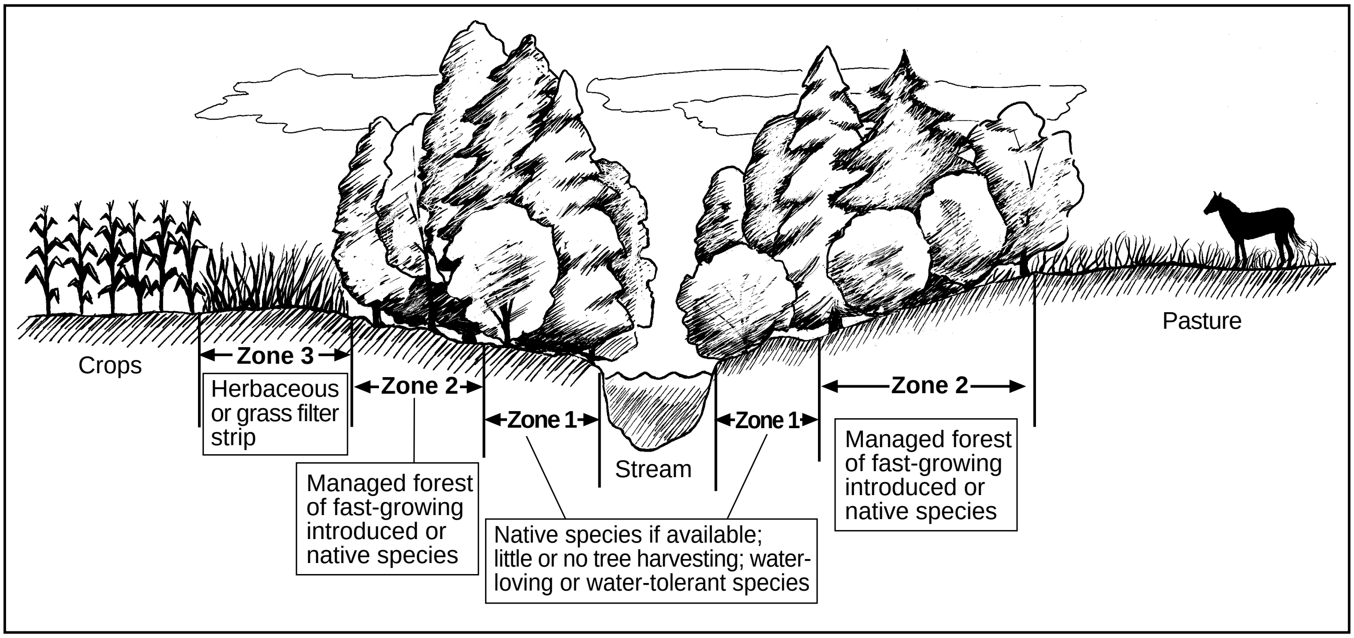
A riparian forest buffer is an area of trees and shrubs located adjacent to streams, lakes, ponds, and wetlands.

Purpose

Riparian forest buffers of sufficient width intercept sediment, nutrients, pesticides, and other materials in surface runoff and reduce nutrients and other pollutants in shallow subsurface water flow. Woody vegetation in buffers provides food and cover for wildlife, helps lower water temperatures by shading waterbody, and slows out-of-bank flood flows. In addition, the vegetation closest to the stream or waterbody provides litter fall and large woody debris important to aquatic organisms. Also, the woody roots increase the resistance of streambanks and shorelines to erosion caused by high water flows or waves. Some species established or managed in a riparian forest buffer can be managed to provide timber, wood fiber, and horticultural products.

Where used

Buffers are located by permanent or intermittent streams, lakes, ponds, wetlands, and seeps. Many of these areas have year-round or seasonal beneficial



A riparian forest buffer includes zone 1, the area closest to the waterbody or course, and zone 2, the area adjacent to and up gradient of zone 1. Trees and shrubs in zone 1 provide important wildlife habitat, litter fall for aquatic organisms, and shading to lower water temperature. This zone helps stabilize streambanks and shorelines. Trees and shrubs in zone 2 (along with zone 1) intercept sediment, nutrients, pesticides, and other pollutants in surface and subsurface water flows. Zone 2 can be managed to provide timber, wood fiber, and horticultural products. A third zone, zone 3, is established if periodic and excessive water flows, erosion, and sediment from upslope fields or tracts are anticipated. Zone 3 is generally of herbaceous plants or grass and a diversion or terrace, if needed. This zone provides a “first defense” to assure proper functioning of zones 1 and 2.

moisture, which allows woody species to establish quickly. A new riparian forest buffer can rapidly benefit a variety of settings, such as cropland, rangeland, forest land, and urban areas.

Conservation management system

Riparian forest buffers are normally established concurrently with other practices as part of a conservation management system. For example, adjoining streambanks or shorelines must be stabilized before or in conjunction with the establishment of the buffer (streambank and shoreline protection). To maintain proper functioning of a planting, excessive water flows and erosion must be controlled upslope of the riparian forest buffer (filter strip, diversion, critical area planting). New plantings must be protected from grazing during establishment.

Wildlife

Connecting a buffer with existing perennial vegetation, such as woodlots and woody draws (tree/shrub establishment) or hedgerows (windbreak/shelterbelt establishment), benefits wildlife and aesthetics. Select species and a planting pattern that benefits the wildlife species of interest.

Operation and maintenance

Trees in the buffer as well as adjacent forested areas are periodically maintained and harvested (forest stand improvement and forest harvest trails and landings). As the buffer matures, periodic harvesting of some of the trees becomes an important activity for maintaining plant health and buffer function.

Specifications

Site-specific requirements are listed on the specifications sheet. Additional provisions are entered on the job sketch sheet. Specifications are prepared in accordance with the NRCS Field Office Technical Guide. See practice standard Riparian Forest Buffer code 391.

Riparian Forest Buffer – Specifications Sheet

Landowner ____ Field number____________

Purpose (check all that apply)	
☐ Intercept sediment, nutrients, pesticides, other contaminants	☐ Wildlife habitat
☐ Lower water temperature	☐ Other (specify):

Location and Layout		
Water body/course type and name, other:		
Minimum buffer zone widths (ft) - specify left and right of stream [facing upstream / downstream (circle appropriate one)] for a two-side buffer; use left only for water bodies, such as lakes and ponds; include herbaceous species in zone 3 notes or refer to other job sheets:		
Zone 1	**Zone 2**	**Zone 3**
Left: Right:	Left: Right:	Left: Right:
Notes:	Notes:	Notes (refer to filter strip job sheets):
Buffer zone length (ft):	Buffer zone area (ac):	
Additional location and layout requirements:		

Woody Plant Materials Information				
Species/cultivars: Spacing[2]:	Plants/acre:	Kind of stock[1]:	Planting dates:	Average
Zone #1				
1				
2				
3				
4				
Zone *#2*				
1				
2				
3				
4				

[1]BAreroot, COntainer, CUtting; include size, caliper, height, and age as applicable. [2]Average spacing between plants to achieve plants/acre.

Temporary Storage Instructions
Planting stock that is dormant may be stored temporarily in a cooler or protected area. For stock that is expected to begin growth before planting, dig a V-shaped trench (heeling-in bed) sufficiently deep and bury seedlings so that all roots are covered by soil. Pack the soil firmly and water thoroughly.
Site Preparation
Remove debris and control competing vegetation to allow enough spots or sites for planting and planting equipment. Additional requirements:
Planting Method(s)
For container and bareroot stock, plant stock to a depth even with the root collar in holes deep and wide enough to fully extend the roots. Pack the soil firmly around each plant. Cuttings are inserted in moist soil with at least 2 to 3 buds showing above ground. Additional requirements:

Buffer Maintenance
The buffer must be inspected periodically and protected from damage so proper function is maintained. Replace dead or dying tree and shrub stock and continue control of competing vegetation to allow proper establishment. Periodic harvesting of trees and shrubs in zones 1 and 2 may be necessary to maintain the health and vigor of mature stands. Additional requirements:

Riparian Forest Buffer – Job Sketch

If needed, an aerial view or a side view of the vegetation types, widths of zones 1, 2, and 3 (as applicable to this site), a direction arrow, and the type of water body or water course are shown below. Other relevant information, such as shoreline or bank shape, upslope field conditions including crop types, and complementary practices, and additional buffer specifications may also be included.

Scale 1"=________ ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")

Additional Specifications and Notes:

Chapter 3i Vegetative Barriers

Definition of vegetative barriers

Vegetative barriers (also referred to as grass hedges) are narrow, parallel strips of stiff, erect, dense grass planted close to the contour. These barriers cross concentrated flow areas at convenient angles for farming. This practice differs from other conservation buffers because vegetative barriers are managed in such a way that any soil berms that develop are not smoothed out during maintenance operations.

This new conservation practice is undergoing a national evaluation and a recommendation to adopt it as a practice listed in the National Handbook of Conservation Practices. A National Standard will be developed once this practice has been accepted by the National Technical Guide Committee. This section reviews research and experiences and provides the best guidance available at this time.

Purposes

Vegetative barriers can be used for the following purposes:

- Control sheet and rill erosion, trap sediment, and facilitate benching of sloping cropland.
- Control rill and gully erosion and trap sediment in concentrated flow areas.
- Trap sediment at the bottom of fields and at the end of furrows.
- Improve the efficiency of other conservation practices.

Benefits

The following benefits are provided:

- Retard and reduce surface runoff by promoting detention and infiltration.
- Divert runoff to a stable outlet.
- Entrap sediment-borne and soluble contaminants and facilitate their transformations.
- Provide wildlife habitat.

Function

Coarse, stiff, hedge-forming grasses can withstand high water flows that would bend and overtop finer vegetation. They retard flow velocity and spread out surface runoff. Reduced velocity prevents scouring, causes deposition of eroded sediment, and lessens ephemeral gully development. Vegetative barriers can disperse flow where water enters other types of conservation buffers.

Tillage not only creates conditions conducive to water erosion, but directly moves soil downslope. Where conventional tillage is used, slope gradients between barriers become flatter and more uniform over time, and contour lines gradually align with the barriers. Some tillage operations move soil directly into vegetative barriers. Berms formed in this way may divert runoff along the barriers in the same way that terraces redirect water. This diversion of runoff reduces erosion between barriers, but also results in increased flows of water and wetness where barriers cross low spots in a field. In these low areas, concentrated runoff is retarded and dispersed as it passes through the vegetative barriers.

Soil erosion occurs on all cropped landscapes. The rate of erosion depends on soil and rainfall characteristics, slope steepness and length, and land management practices. Landscape changes occur slowly on a cropped field for any rate of soil erosion. Placing vegetative barriers on the landscape divides fields into cropped and vegetative strips. Even if the rate of soil erosion is reduced, the rate of translocation resulting from tillage remains constant within the cropped intervals and soil is removed from the upper part of each cropped area and deposited upslope of the next barrier. This process reduces soil depth downslope of barriers and increases it above them (fig. 3i–1), resulting in alterations in water holding capacity, rooting depth, and fertility. The desirability of these changes and their impact on the productivity of a particular soil should be considered in planning this practice.

When used in combination with contouring, reduced tillage, and crop residue management, soil movement is small, large changes in slope do not occur, and, therefore, the main impact of barriers is to disperse concentrated flow and prevent ephemeral gully development. When used in combination with filter strip or other buffer technology, the main impact is dispersed flow of runoff entering the conservation buffer area. This ensures that sediment and associated contaminants are deposited above, rather than within, the buffer and will increase buffer effectiveness and longevity.

Design considerations

Location

This practice applies to all eroding areas, including, but not limited to cropland, pastureland, rangeland, feedlots, mined land, gullies, and ditches. This practice is used in conjunction with other conservation practices in a conservation management system. Management practices, such as crop rotation and crop residue management, must be considered in designing the conservation management system on cropland. Associated structural practices, such as water and sediment control basins, subsurface drainage, and underground outlets, must be considered to adequately handle surface and subsurface water. This practice may improve the efficiency of other practices, such as strip cropping, filter strips, riparian forest buffer zones, grassed waterways, diversions, and terraces.

Design spacing and the lateral extent of vegetative barriers vary for the different purposes. They are described sequentially.

Reducing sheet and rill erosion, trapping sediment, and facilitating benching of cropland

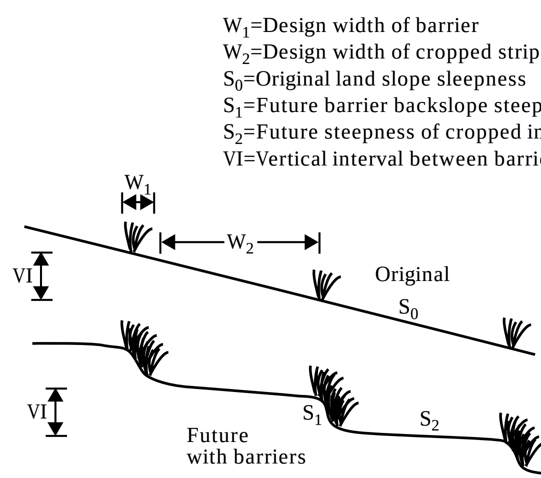
Figure 3i–1 is a definition sketch of a system of vegetative barriers placed on an initially uniform slope. The vertical interval (VI), or vertical fall between sequential hedge centers, is the parameter that limits hedge design spacing. The maximum VI for this purpose is the lesser of 6 feet (2 meters) or the spacing calculated by formulas for terraces (refer to Conservation Practice Standard 600, Terrace). On slopes less than 5 percent, the terrace standard often results in a maximum VI less than 6 feet. A VI less than the maximum value should also occur in areas that have shallow soils where deep benches are undesirable.

Vegetative barriers are arranged parallel to each other on or near the contour, but cross concentrated flow areas at angles convenient for farming. Over time, sediment and tillage fill in the low areas and contours adjust to conform closer to barriers. All tillage is done parallel to the vegetative barriers and contributes significantly to the leveling and benching between vegetative barriers.

Gradients along barriers should be 0.6 percent or less except where the vegetative barriers cross concentrated flow areas. Gradients entering a concentrated flow area may deviate from this criteria for a distance of 100 feet on either side of the concentrated flow area. This helps to get better row alignment.

In designing barrier systems for variable fields, one approach is to select a constant hedge spacing based on the steepest 30 percent of the field. This spacing is a convenient multiple of the working width of the field equipment. Lay out barriers starting at midslope. Keep upslope and downslope barriers parallel to facilitate field operations. Where variable slopes cause excessive deviations from the contour, extra barriers can be included on the gentler slopes to keep barriers on steeper slopes close to the contour (see case study). For more local irregularities, a barrier's width may be altered along with the width of the cropped strip, with subsequent barriers being parallel to the new line.

Figure 3i–1 Schematic definition sketch of grass hedge system illustrating expected changes in land slope over time resulting from tillage and erosion/deposition processes



Erosion control credit

Vegetative barrier practice benefits for soil erosion control may be calculated using the Revised Universal Soil Loss Equation (RUSLE). Erosion control credit comes from modification to the practice (P) and length and steepness of slope (LS) factors. This depends on the design, management, and maturity of the barriers. When initially established, the barriers serve as guides to contour cultivation and receive credit for contouring and stripcropping practice (P)—subfactors that reflect alignment and vegetation characteristics. After barriers are well established and begin to create backwater that causes sediment to be deposited upslope of the actual vegetative barrier area, the effective width of the barrier should be used rather than the actual width of the grass in RUSLE computations.

Based on research results, the latest RUSLE recommendation is to use an effective strip width of the barrier as a percent of hillslope length: 12 percent for hillslope steepness of less than 5 percent, 8 percent for slopes of 5 to 10 percent, and 4 percent for slopes of 10 to 15 percent. Backwater distances are negligible on slopes steeper than 15 percent.

For planning purposes, it is also worthwhile to use RUSLE to estimate the erosion that would occur if vegetative barriers diverted flow and acted as terraces. In this case, slope length is reduced to the barrier spacing, and the vegetative barrier systems receive conservation credit in both the LS factor and the contouring and terrace P subfactors. After barriers have been established for some years, the conservationist should inspect the field and determine if the barriers are functioning as terraces. If it is then it is appropriate to apply this approach.

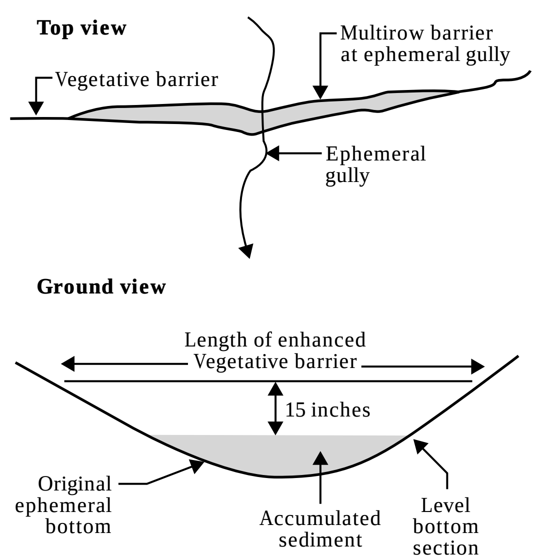
Controlling rill and gully erosion and trapping sediment in concentrated flow areas

Where sheet and rill erosion are controlled with other practices, such as residue management, separate and discrete barrier sections may be installed across concentrated flow areas to control ephemeral gully development. When used to control only ephemeral erosion, barriers do not need to extend across the ridgetops, but only long enough to prevent bypass flow around the ends. This bypass flow can be avoided if each strip is extended far enough to provide 1.25 feet of elevation above the base level section that will develop after a few years of sedimentation (fig. 3i–2). Barriers must consist of at least two rows in concentrated flow areas and must extend long enough to avoid bypass around the ends at high flow. Level bottom section may develop from sediment accumulation above original bottom or may be created by minor earthmoving as part of barrier establishmentHigh on the slope where contributing areas are small, barrier lengths need not be this large.

A level base area adds stability to vegetative barriers in high flow areas (fig. 3i–2). Experience has shown that established barriers are stable if the length of the level base section (measured in feet) is numerically greater than the contributing area (measured in acres) of the watershed above the barrier. This level base section forms gradually over time, but where contributing areas are large, some earthmoving may be desirable prior to vegetative barrier establishment to create this level base section to disperse runoff.

Barriers have special spacing and vegetation requirements in concentrated flow situations. Here, vegetative barriers should be at least 3 feet wide and consist of at least two rows of vegetation. The maximum VI for discontinuous barriers is reduced to 4 feet to minimize step heights. It may need to be only 2 feet on vertisols to avoid block failure of developed benches. Vegetation should be maintained at a height of at least 15 inches throughout the year. Stem density should exceed 50 stems per square foot and contain a sufficient density of large anchored stems (living or dead)

Figure 3i–2 Multirow barrier and ephemeral gully



so that the product of the large-stem density (M=stem number per square foot) times the large-stem diameter, D (D in inches, measured 2 inches above the ground raised to the fourth power exceeds 0.1):

$$(M)(D^4) > 0.1$$

As an example, for vegetation with 70 stems per square foot and stems 0.2 inches in diameter, the product is:

$$(70)(0.2)^4 = (70)(0.0016) = 0.112$$

This is adequate for a concentrated flow barrier, but the greater the product the better. Where mixtures of vegetation exist, count only stems larger in diameter than the value (D) used in calculations.

As barriers are established and trap sediment, the slope of the landscape between them is reduced as a result of soil movement by tillage translocation and erosion/sedimentation processes. Concave areas where flows concentrate are most rapidly filled with sediment help to disperse flows (fig. 3i–3). Rills initially develop immediately below barriers in concentrated flow locations. Tillage smooths and spreads these areas laterally along the barrier. Subsequent storms move more sediment and deposit it upslope of the next barrier. The net effect is an accelerated benching of the landscape (fig. 3i–1) in concentrated flow areas.

Backwater created above each barrier protects the submerged areas from high velocity flows and further erosion (fig. 3i–4). Benching continues until the backwater from a downslope barrier submerges the base of the next barrier upslope and erosion below the upslope barriers ceases. Therefore, the most downslope barrier in a field should be located in the footslope area below which ephemeral gully development is not anticipated and where the velocity of dispersed runoff leaving the barriers does not exceed critical values for the soil conditions existing downslope of the barrier.

Trapping sediment at the edge of fields and/or the ends of furrows

Vegetative barriers may be used to trap sediment at the edge of fields and/or the ends of furrows whether the furrows are aligned up and down the slope, across the slope, or on the contour. Used as a field border, barriers can effectively reduce sediment delivery offsite, prevent the development of headcuts into the field, and ensure uniform overbank flow into streams and ditches. However, such barriers will not reduce in-field sheet and rill erosion rates, and those factors used in erosion prediction models should not be altered.

Utilization of subsurface drainage to remove water from sediment accumulated in the flattened areas above the barriers can avoid development of wet areas and combine to make these areas highly productive. A

Figure 3i–3 Progressive delta development and flow dispersion where vegetative barrier impedes a concentrated sediment-carrying flow

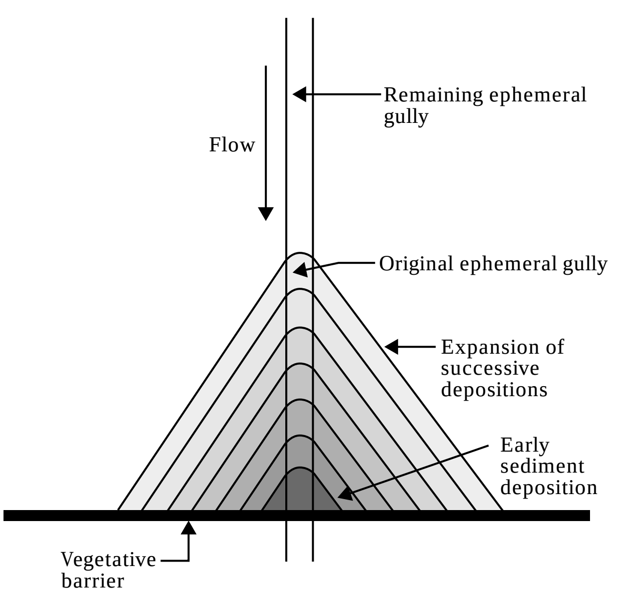
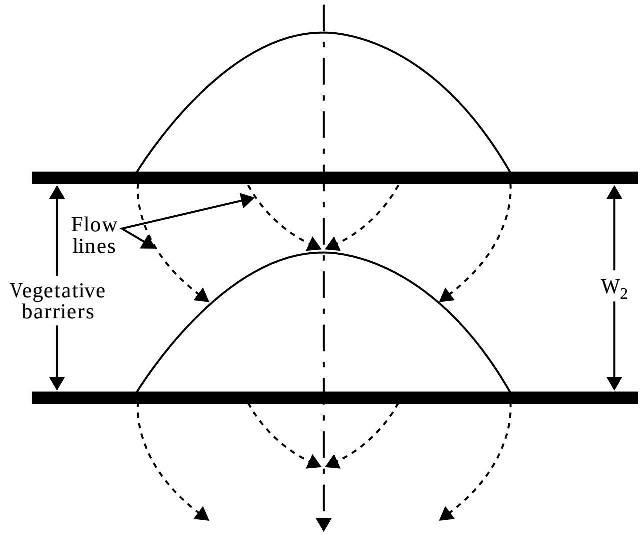


Figure 3i–4 Top view showing spacing of barriers, backwater, and reconcentration of flow downslope of barriers



Note: In situations where rows are bedded, flows reconcentrate more rapidly than shown and backwater should extend all the way to the next barrier to prevent further ephemeral gully development.

series of barriers spaced at a VI of 2 feet may serve as an inexpensive alternative to small drop pipe structures where bank slopes do not exceed 100 percent (1:1) and where shading by woody vegetation will not restrict vegetative barrier growth. Vegetative barriers used as field borders should be a minimum of 3 feet wide. There is no maximum crop strip width or slope length.

Increasing the efficiency of other conservation practices

Contour buffer strips: These strips are similar to vegetative barriers except they are wider, have less stringent alignment criteria, and require sediment accumulations to be periodically removed and redistributed on the land. Vegetative barriers, established just up-slope or in the upper 3 feet of the field strip where they cross concentrated flow areas, can disperse these flows so more of the runoff goes through, rather than over, the vegetation in the strips.

Filter strips: Filter strips are areas of vegetation located along streams, waterbodies, field borders, terraces, or diversions used to entrap sediment and improve water quality. Vegetative barriers incorporated into the upslope portion of filter strips improve uniformity of runoff flows entering the filter and increase filter strip longevity by promoting sediment deposition above the filter strip. Vegetative barriers can also be placed in filter areas to promote ponding and infiltration.

Field borders: Field borders are areas of vegetation located along field edges or boundaries to provide wildlife habitat or access to the field. Vegetative barriers incorporated into the upslope portion of borders on the low side of the field increase field border longevity by promoting sediment deposition above the field border. Vegetative barriers also provide additional wildlife cover in borders of predominantly sod-forming grasses.

Riparian forest buffers: Riparian forest buffers are similar to filter strips, but include woody as well as herbaceous vegetation. Vegetative barriers could be used on the upslope edge of the vegetation zones to disperse flow and provide more complete removal of nitrate from ground water.

Grassed waterways: Waterways are designed to remove water from a field under controlled conditions. In some cases high flow velocities make establishment of grass difficult. Vegetative barriers can help stabilize waterways, much like the use of hay bales, when established at designed intervals across concentrated flow channels. Their uniform dispersal and slowing of runoff, together with their root systems, make established vegetative barriers more effective than hay bales.

Diversions and terraces: Diversions and terraces are designed to intercept water flowing down a slope and direct it across the slope to a stable outlet, such as a grassed waterway or underground outlet. Vegetative barriers established above the diversion and terrace channels increase their longevity by promoting sediment deposition above the diversions and channels. Barriers established on top of terraces may provide additional stability; however, barrier vegetation should not be allowed to become established within the terrace channel area.

In all practice modification with vegetative barriers, ensure that the barrier vegetation does not direct sediment deposition into areas that would impair the function of the associated conservation practice.

Plant material information

Species selection

Vegetative barriers should be planted to vegetation with sufficient stem strength and density to trap sediment and detain water. The stems of the vegetation should have the ability to remain upright during runoff flow events.

Herbaceous and woody species may be used if they have proven ability to retard flow velocity and trap sediment. Cultivars of individual species with known superior stem strength will be used, for example, “Shelter Switchgrass” in the Northeast. Care should be taken not to select vegetation that is known to be invasive or that is a host for insect and disease pests in the region.

Vegetation should be established that has a density of at least 50 stems per square foot in all barriers. Barriers should be at least 3 feet wide. If barrier vegetation is so tall-growing that mowing is needed to minimize crop shading, barriers may be made wider to accommodate available mowing equipment. Mature barrier design width may also be wider than the amount of vegetation initially planted (fig. 3i–1).

The steepness of a stable backslope of the mature bench (S_1, fig. 3i–1), which depends on local soil and vegetation characteristics, determines the required design barrier width. The final steepness of the cropped interval (S_2, fig. 3i–1) is reduced to a fraction of the initial slope.

Grass species native to the contiguous United States that possess desired characteristics include: switchgrass (*Panicum virgatum*), coastal panicgrass (*Panicum amarum var. amarulum*), eastern gamagrass ( ), basin wildrye (*Leymus cinereus*), and big sacaton (*Sporobolus wrightii*).

The following exotic grasses desirable characteristics are: tall wheatgrass (*Elytrigia elongata*), altai wildrye (*Leymus angustus*), mammoth wildrye (*Leymus racemosus*), Chinese silvergrass (*Miscanthus sinensis*), and Vetivergrass (*Vetiver zizanioides*).

Method of establishment

Vegetative barriers may be established vegetatively or from seed. Vegetatively propagated barriers trap more sediment immediately and are not as subject to establishment failure from washouts or burial by sediment. Seeding requires less material and labor and, therefore, is less expensive.

Barriers established vegetatively should be planted at a spacing sufficiently dense to ensure a functional hedge in one growing season. This spacing needs to be closer in areas that have limited rainfall. While planting a continuous vegetative strip would be best, experience in Texas indicates that planting a single row of bareroot seedlings, cuttings, or divisions at a 3-inch spacing can create a functional hedge in 1 year, while planting at a 6-inch spacing takes 2 years. In more humid areas, 6- to 12-inch spacing has proved effective in 1 year. Even where gaps between transplanted clumps are still distinguishable, crop residue bridges these gaps and makes the hedge effective in slowing runoff and trapping sediment. In concentrated flow areas, a double row of continuous vegetative strips, or of rows planted with 6- to 8-inch spacing of 4-inch diameter clumps, with rows 12- to 18-inches apart, is recommended.

Barriers established from seed should be sown using the best available technology for establishing a stand with little risk of failure. In most cases this mandates the use of a drill to place the seed at the precise rate and depth recommended. Optimum seeding dates for the species are used. Irrigation should be used if it is part of the standard establishment procedures for the species. Seed should be sown in a strip at least 3 feet wide.

Establishment by plants or seed may be enhanced by installing straw bales, burlap silt fences, biologs, or fiber rolls immediately downslope of the barrier location in concentrated flow areas. This reduces scour and promotes water conservation for the young plants.

Seedbed and planting bed

Poor site preparation is a major cause of stand failures. Therefore, site preparation should be planned and initiated well in advance of planting. No-till planting can be ideal provided weeds are adequately controlled before planting. Seeds should be placed at optimum depth, and the seedbed packed after seeding.

Tilled seedbeds should be packed before seeding to create a firm surface for sowing and to ensure precise seeding depth control. Seedbeds should also be packed after planting to ensure good seed-to-soil contact. Plants to be established vegetatively may be planted into a loose bed, but the soil should be well packed after planting.

Planting dates

Vegetative plant material are best transplanted when dormant or during periods of abundant rainfall in early spring. Seeded plant material should be sown at optimum seeding dates for the species, soil, geographic location, and irrigation potential.

Fertility

Lime, phosphorus, and potassium should be applied before planting. Their application should be according to soil test recommendations. Nitrogen, on the other hand, should not be applied at planting. Instead, it should be applied at recommended rates when the planted species have emerged and are competing well with weed species present.

Weed control

Weeds should be controlled with an integrated control strategy using cultural, mechanical, and chemical methods.

Planning considerations

Need for tile drainage

Where barriers cross low areas, sediment deposition results in reduced slopes and loose, unconsolidated sediment. Wheel ruts in this sediment, combined with residue trapped on the barriers, have been observed to significantly impede surface drainage, thus interfering with field operations and lowering the area's productivity. Because the barriers and associated tillage marks tend to redirect runoff, wet spots may be created where they never before existed. Farmers seeing this problem may be tempted to cut water furrows through the barriers to facilitate drainage. Subsurface tile installed perpendicular to grass barriers under the concentrated flow areas avoid these difficulties (see case study). Feeder tile lines buried under the hedge and connected to the perpendicular main tile further alleviate wet areas and decrease surface runoff and amounts of crop protection chemicals leaving the field.

Barriers as alternatives to a waterway

Waterways are designed to remove water from a field under controlled conditions. In some situations grass barriers can perform the same function even though their alignment is perpendicular to the direction of runoff flow. Barriers “step” water down the slope, relying on tillage and deposition of sediment to cause progressive leveling that disperses and slows runoff. Where flow conditions do not exceed barrier strength, a suitable merging of these technologies may be to leave small sodded areas below each hedge to control local erosion on hedge backslopes while allowing crop production and tillage above each hedge that is accompanied by downhill soil movement and results in benching.

Application to construction sites

Vegetative barriers offer an attractive and effective alternative to silt fences and hay bales on construction sites. The high value of the area being protected and the need for immediate sediment control make vegetative establishment practical. Vegetative barriers are most effective if established in advance of construction. While vegetative barriers are easy to kill or remove after construction is completed, a more efficient approach would be to cut areas close to final grade prior to barrier establishment from stiff-grass sod strips and to allow the barriers and trapped sediment to remain as part of the permanent landscape.

Operation and maintenance

Any vegetative erosion control practice requires maintenance. However, vegetative barriers generally require less maintenance than waterways, buffer strips, or filter strips because sediment deposits do not need to be redistributed throughout the field. Also, repair of washouts is restricted to a narrow width of vegetation. Where barriers are established from seed, washouts are more likely to occur in concentrated flow areas during the establishment year. These areas can be repaired by overfilling the damaged area and transplanting vegetation the following year. Barriers in concentrated flow situations should be inspected annually and any gaps, such as may be created by animal burrows, should similarly be repaired early in the spring. Maintenance must be done in a timely manner to prevent further damage.

Another maintenance issue concerns training farm workers to distinguish barrier vegetation from weeds, such as johnsongrass. Young barrier grass should not be killed because it is mistaken for a weed. Remove weedy species that could be invasive to the cropped areas adjacent to the barriers. This can frequently be accomplished by using wick application of nonselective herbicides after a height differential has been developed following barrier mowing.

If wetness develops in sediment deposited upslope of barriers, farmers may be tempted to cut water furrows through the barriers to facilitate drainage. This damages the vegetative barrier system and should not be done. Tile drainage can avoid this problem.

Tall-growing barrier grasses must be mowed to minimize shading of adjacent crop rows. Mowing produces barriers of denser, but finer stems; therefore, it is undesirable in concentrated flow areas if large stem diameters are desired. Selecting barrier species that do not require mowing, but that have dense thick stems, reduces maintenance and permits barriers narrower than mowing machine widths.

Burning may stimulate growth of some hedge grasses, but is not a desirable practice in concentrated flow situations if tillage will soon follow and maximum sediment trapping effectiveness is needed.

Case Study

In 1992, Dillaha and Hayes presented an analysis of the application of filter strips to an irregular field (fig. 3i–5). These authors determined sediment trapping from a 10-year return interval design storm. According to them, the filter strip design they presented (fig. 3i–6) trapped at least 97 percent of all sediment greater than 0.01 mm and 58 percent of clay-sized sediment. The authors stressed that trapping of silt-sized sediment was greatly reduced if filter strips were not extended above points **d** and **e** as illustrated because depths of concentrated runoff exceeded 4 inches.

In 1995, Dabney and fellow researchers used this field in an example exercise to show how buffer strip, vegetative barrier, and hybrid systems might be designed. The systems developed are illustrated in figures 3i–6 to 3i–10. A comparison of the five systems is presented in table 3i–1.

While the original vegetative filter strip design (fig. 3i–6) does a good job of reducing sediment yield, it does nothing to reduce sheet and rill erosion within the cropped portion of the field and it removes the greatest amount of land from production.

Based on RUSLE calculations, the contour buffer strip design (fig. 3i–7) reduced sheet and rill erosion in the field by about 25 percent. This is inadequate by itself as an erosion or sediment control system because of significant deviations of the strips from the contour at several points. This practice also removed a relatively large area of the field from crop production.

The contour vegetative barrier design (fig. 3i–8) removes less cropland from production than the filter strips or buffer strips and affords the greatest degree of in-field erosion control of any of the alternative vegetative systems studied. This system however, is also the most complex to design and establish and it provides less trapping of fine sediment than the filter strip design.

The vegetative barriers provide a guide for contour tillage. Tillage marks parallel to the barriers intercept flow and redirect it in the same way that terraces redirect water. This reduces effective slope length. RUSLE calculations of this system indicate that with this reduction in slope length and contouring benefits, sheet and rill erosion may be reduced by 75 percent compared to no treatment of this cropped field. Runoff diverted to local depressions is carried downslope through the barriers under controlled conditions that prevent ephemeral gully development. Tile drainage is provided to avoid wet spots within the field where barriers have directed runoff water.

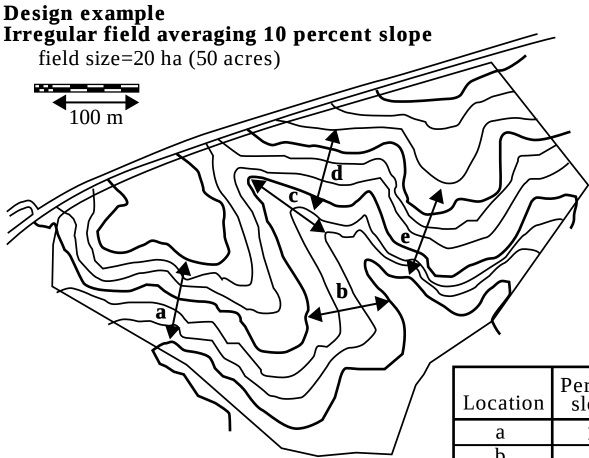
It should be noted that extra barriers are established on the more gently sloping part of the field to maintain contour alignment on the steeper part to the north. In this arrangement, planting direction is reversed around the end of each extra barrier, and no point rows are created.

The discrete vegetative barrier system (fig. 3i–9) can control ephemeral gullies within fields, but like filter strips, does not control sheet and rill erosion throughout the field. This system removes the least amount of land from production of all the systems compared, but could create problems with row alignment unless planting is done with a grain drill.

The hybrid system (fig. 3i–10) combines a filter strip, one continuous vegetative barriers to serve as a guide for row directions, and discrete vegetative barriers to control ephemeral gullies. This system has several advantages.

- Sediment trapping of all but dispersed clay will be nearly equal to that of the original filter strip design while taking less than half as much land out of production.
- Ephemeral gully erosion is controlled within the field.
- The upslope of the filter strip includes a vegetative barrier that protects the filter strip from inundation with concentrated flow during large storms.
- Most of the sand and aggregated sediment in runoff will deposit within the cropped part of the field. This helps maintain field productivity and extends the life of the filter strip. An optimized runoff and erosion control system is created by combining the hybrid system with crop residue management to control sheet and rill erosion in the field.

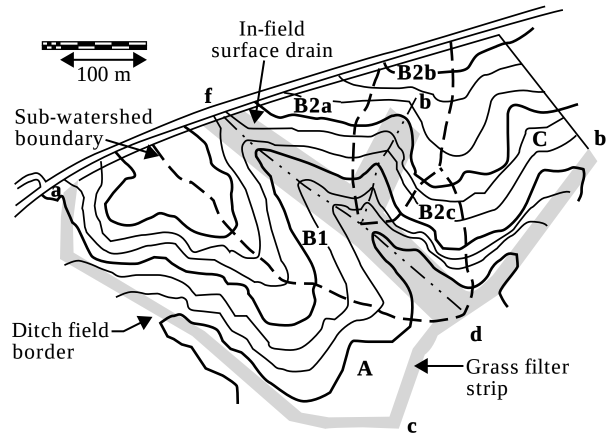
Figure 3i–5 Irregular 50-acre field averaging 10 percent slope, but ranging from 4 to 16 percent



Location	Percent slope
a	12
b	6
c	4
d	10
e	16

Note: Fields such as this one result in complex designs requiring extra barriers on less steep portions of the field to maintain contour alignment. Contour interval is 6 feet (2 m).

Figure 3i–6 Filter strip design that traps 97 percent of sediment greater than 10 microns in diameter



Note: This system does not control infield erosion.
Source: Dillaha and Hayes (1992)

Figure 3i-7 Contour buffer strips sometimes deviate significantly from the true contour when applied to such irregular fields, reducing their erosion control effectiveness

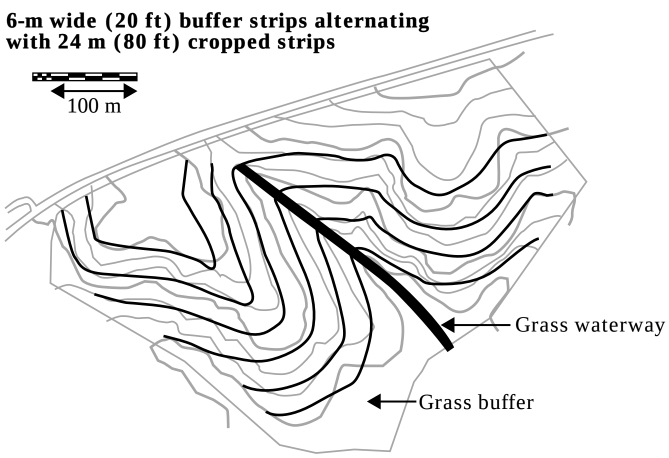
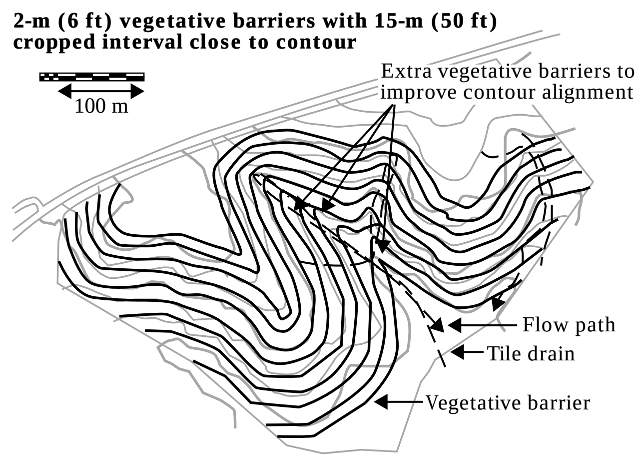


Figure 3i–8 Extra parallel barriers added on the south-west part of the field and terminated near the drainage way in the center of the field help maintain contour alignment in this irregular field



Note: The subsurface tiles help to avoid development of wet spots from flow redirected by the barriers.

Background research

Vegetative barriers have potential for reducing sheet, rill, and ephemeral gully erosion and trapping sediment on cropland. Conventional grass buffer strips and filter strips often fail where flow concentrates because the force of the flow flattens the grass, which is then submerged and often buried under deposited sediment. Stiff, erect grasses extend the range of conditions where grass strips can control runoff and sediment yield by withstanding higher flow rates and deeper sediment deposits.

Figure 3i–9 The discrete barrier sections can control ephemeral gully development; however, the irregular spacing could create row alignment problems if cultivation or directed spraying is needed

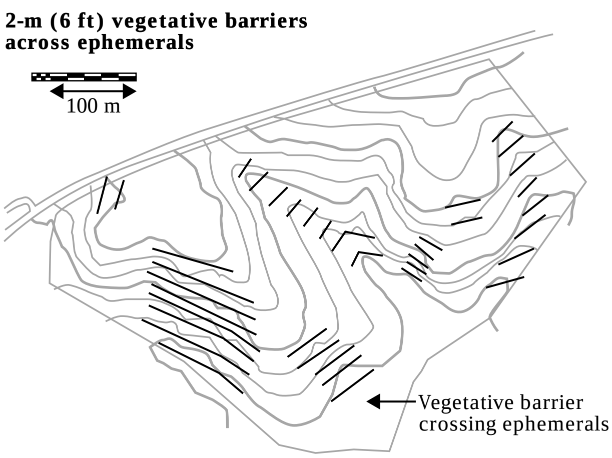
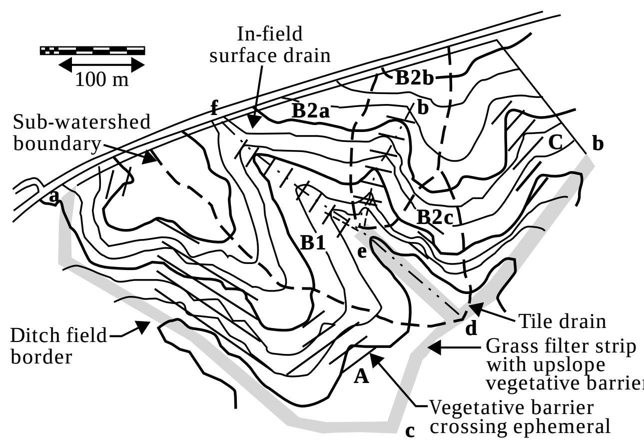


Figure 3i–10 This hybrid system uses a filter strip to reduce sediment yield and discrete vegetative barriers to control ephemeral gullies.



Note: This system is most effective and practical when used in combination with crop residue management to control sheet and rill erosion.

Table 3i–1 Comparison of land use and impact of alternative vegetative erosion and sediment control systems in case study example

	Area in vegetative system (ha)	Percent in grass (%)	Sheet and rill controlled?	Gully erosion controlled?	Sediment yield controlled?
Filter strip	3.6	18	no	waterway	yes
Buffer strip	2.4	12	some	waterway	yes
Contour hedge	1.4	7	yes	yes	yes
Discrete hedge	0.5	2	no	yes	yes
Hybrid system	1.7	8	no	yes	yes

Stage-discharge relationship

In 1996, Dabney reported an equation to predict backwater depth as a function of flow and grass barrier characteristics. Strips from 0.15 to 0.50 meter wide were studied in specially designed flumes. Backwater elevations were determined for clearwater flows ranging from 0.01 to 1.0 cubic foot per second per foot of barrier, typical of those occurring in upland runoff channels. Vetivergrass and switchgrass had the greatest ability to stand against high flows; 1-foot-wide barriers of each stood against backwater depths as great as 15 inches. The increased water depth at the upstream edge of a grass was bimodal function of flow, being nearly a linear function of flow up to 0.13 cubic foot per second per foot of barrier and proportional to the square root of flow rate at higher flows. Backwater depth was also a fractional (0.17) power function of stem density, stem diameter, and hedge width. In flows with sediment, backwater depths were found to be increased by the introduction of soil into the flow as the barriers became loaded with plant residue and duff from the soil (Meyer et al., 1995; Dabney et al., 1995b).

Sediment trapping

Deposition of sediment upslope of the grass is the primary mechanism for trapping sediment by vegetative barriers (Dabney et al., 1995b). Barriers do not filter sediment because they have relatively large flow spaces. Only large material, such as fibrous plant residue is trapped by filtration. Sediment trapping efficiency depends on the ponded depth (hedge density and flow rate), backwater length (slope), flow rate, and sediment size and density.

On hillslopes without concentrated flow, barriers trap about two-thirds of the sediment generated on small plots (McGregor and Dabney, 1993; Dabney et al., 1993; McGregor et al., 1998). Where flows concentrate, slope has a major impact on the length of the ponded area and hence on sediment trapping. Meyer (1995) showed that for 5 percent slope and flows up to 0.5 cubic foot per second per foot of barrier, trapping efficiency of effective barriers was above 90 percent for sediment particles larger than 125 μm diameter and about 20 percent for sediment smaller than 32 μm. Between these sediment sizes, trapping effectiveness decreased with increasing flow rates. The 20 percent trapping of sediment finer than 16 μm reported by Dabney (1995b) was greater than predicted by settling theory, suggesting some unidentified mechanism was operative in removing fine sediment. Trapping of fine sediment is increased greatly if flows are dispersed and so slowed, or if benching reduces slope and so increases settling distance (Dabney et al., 1995b; Dabney et al., 1996).

Hedge failure prediction

A barriers strength, its ability to remain erect, is related to its stem density and individual stem strength. The product MEI (where M is stem density, E is stem modulus of elasticity, and I is stem moment of inertia that is proportional to the fourth power of stem diameter) has been suggested as an indicator of hedge strength and is the basis for the barrier strength criteria provided earlier. Dunn and Dabney (1996) found that modulus of elasticity of stems of several grasses increased with stem age. Vetivergrass barriers develop strength from a high density of large diameter stems, whereas switchgrass barriers are strong because of the high modulus of elasticity, similar to that of oak, of their intact mature stems.

Landscape evolution

The soil conservation effectiveness of a well-maintained system of vegetative barriers increases with time. As soil is removed downslope of barriers and sediment is trapped upslope, the steepness of the cropped interval and ephemeral slope is reduced. This slows runoff, reduces erosion, and increases potential water infiltration and crop productivity. Where soil is tilled and sediment loads are high, deposition upstream of barriers can significantly flatten concentrated flow areas over time, further spreading and dispersing runoff (see fig. 3i–3). The ability to survive and thrive as sediment is deposited in and around them enables stiff grass barriers to maintain their trapping capacity after each deposition event. In fact, as sediment deposits as a delta, depth of rooting increases, as does the ability of the soil to store the supplemental water carried to swale areas with runoff. These conditions commonly facilitate more plant growth than occurred previously. This increasing vegetative growth adds to the stability of the barrier, further slowing flow through it and allowing more sediment to settle.

Enhanced soil productivity immediately upslope of the barrier may be associated with a decline in productivity immediately downslope of the barrier where topsoil has been removed by tillage and erosion. The consequence is that substantial gradients of soil fertility and other soil properties may develop across the benches (Turkelboom et al. 1997). The suitability of a site for benching depends on subsoil characteristics and the ability of a farming system to overcome constraints imposed by subsoil exposure. Application of lime, manure, crop residue, fertilizer, and deep tillage may ameliorate any problem that develops in progressive areas.

Tillage translocation

Recent research has indicated that soil movement by tillage, termed tillage translocation, may be more significant than has been commonly recognized (Lindstrom et al., 1992; Govers et al., 1994; Lobb et al., 1995). Water erosion is more visible than tillage translocation and is often the dominant means of transport in areas where concentrated ephemeral flow occurs. However, the ability of tillage to make the gullies that form in these areas ephemeral proves that tillage can move just as much soil. Recent European studies (Quine et al., 1994; Govers et al., 1996) have reported that tillage accounts for 50 to 70 percent of total soil movement in conventional tillage agriculture on soils with gradients of 0.15 to 0.20.

Tillage erosion at a point depends on the balance of soil translocated into the control volume compared to the amount translocated out of that volume. If slopes are uniform, there are equal additions and removals in the control volume, so change at that point is zero and tillage translocation goes unseen. On continuous slopes, tillage translocation causes visible changes only where slope gradients change. It causes degradation on convex slopes and aggradation on concave slopes. Tillage translocation is also evident at field boundaries, which are lines of zero flux. This is why vegetative barrier systems, by creating a large number of discontinuities and field boundaries and shortening slope length, amplify the impact of tillage translocation on landscapes (Dabney et al., 1998). Tillage, by moving soil and by predisposing the soil to water erosion, is the predominant factor causing benching between vegetative barriers. Little landscape benching occurs in no-till situations.

Modeling difficulties and conservation credit

Current generation erosion models, including RUSLE and WEPP, do not reflect any changes in slope over time and so cannot predict long-term conservation benefits. They also do not account for tillage translocation.

Observation of field plantings indicate that barriers and associated parallel tillage marks cause considerable redirection of runoff flows to localized low areas. As noted, this redirection can cause development of wet areas that require drainage. However, redirection also reduces runoff immediately downslope and so reduces effective slope length for nonflow areas. Current generation erosion models cannot account for partial redirection of runoff. Consequently, determination of effective slope length becomes a matter of judgment. In planning, if one assigns the credit expected with the current slope after vegetation is well established, the design should be very conservative because performance should improve with time if the barrier is properly maintained. If in the future the conservationist observes that slopes have been reduced or that flow is being redirected by the barriers behaving as terraces, it would then be appropriate to take additional credit by altering the modeled slope length and steepness.

Information needed to fill in job sheet

The job sheet provides information for the design of a vegetative barrier. The following is guidance in how to complete the specification sheet for the landowner's use.

Landowner

Enter the name of the landowner planning the vegetative barrier.

Field number

Enter the field number or numbers from the conservation plan, job sketch, or plan map. A field name is sometimes more commonly used. Correspond the field identification with the job sketch on the back of the job specification sheet.

Purpose

Check the appropriate purpose or purposes that the vegetative barrier will serve.

Location and layout

Cropped strip width—Using the field slope and vertical interval for the set of vegetative barriers determine the spacing between each barrier. Cropped strip width is the distance between each barrier on the slope. The area between barriers is considered the cropped area. Refer to figure 3i–1. Make necessary adjustments for soil conditions, equipment size, and irregular slopes and drainageways.

Barrier width—The thickness of the vegetative barrier is measured by the width that the vegetation will occupy in the cropped area.

Rows per barrier—Determine the number of rows for each barrier. Infield barriers generally have only one or two rows. Barriers crossing drainageways have two or more rows. Barriers may be solid, seeded in row widths from 12 to 36 inches wide. Wider barrier widths are sometimes used to correct point rows on irregular slopes.

Barrier length (feet)—Determine the length of each barrier across the landscape. Length is measured perpendicular to the flow direction of water across the field. Some vegetative barriers only cross drainageways while others may traverse the entire slope.

Barrier acres—Calculate the total acreage established in vegetative barriers. This is the width of each individual barrier multiplied by the length of that barrier. Barrier acres determine seeding requirement.

Field slope—Measure the percent slope between each barrier. This percentage is used to calculate the vertical interval.

Plant material information

Provide the vegetation species and/or cultivar planned to be planted in each vegetative barrier. Acceptable species are listed in the Field Office Technical Guide. The seeding rate or transplanting distance, planting date, and any recommendations for soil amendments and fertilizer are also given. Soil is applied according to a soil test or following the guidance in conservation practice standard for critical area treatment. Follow recommended timings of soil and fertilizer amendments.

Site preparation

Site preparations follow normal seeding and transplanting guidelines from conservation practice standard Critical Area Treatment (342). Additional guidance can be given in Additional specifications and notes on the back page of the job sheet.

Planting method(s)

Specify the seeding depth or transplant spacing. Generally grass seeds are planted shallow (top 0.25 inch) in a firm seedbed. Give the amount and placement of mulch material, if used. Planting methods guidance is given in conservation practice standard Critical Area Treatment (342). Use this same guidance to recommend planting grain cover or nurse crop.

Operation and maintenance

In this section provide guidance for any routine operations that are necessary to maintain the function of the vegetative barrier. Provide weed control methods based on vegetation tolerance to herbicides, tillage, mowing, and/or burning. Program tillage and mowing to maintain row width and row height. Recommend fertilizer according to crop and barrier needs. Give reminders to repair gaps in the barriers and where to obtain seedlings for repair. Caution against using herbicides in the cropped areas that will damage the vegetation in the barrier. Use Additional specifications and notes on the back page for providing the information to the landowner.

Job sketch

Draw a sketch on the back page that shows field locations of each vegetative barrier. Number each barrier. Show all drainageways where the barrier will be realigned and planted to additional rows. Show field boundaries, barrier widths, and slope direction. Also show any other conservation buffer practices that may be planned for the field.

Additional reading

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Vegetative Barriers 1/

Conservation Practice Job Sheet *(Interim)*

Natural Resources Conservation Service (NRCS) *April 1997*

Landowner____

Definition

Vegetative barriers are narrow, permanent strips of stiff stemmed, erect, tall, dense perennial vegetation established in parallel rows and perpendicular to the dominant slope of the field.

Purpose

Vegetative barriers provide erosion control on cropland and offer an alternative to terraces where the soil might be degraded by terracing.

In addition, the following benefits are provided:

- Facilitate benching of sloping topography.
- Retard and reduce surface runoff by promoting detention and infiltration.
- Disperse concentrated flow and reduce ephemeral gully development.
- Divert runoff to a stable outlet.
- Entrap sediment-borne and soluble contaminants and facilitate their transformations.
- Provide wildlife habitat.

1/ Applicable where the states have developed an interim practice standard.

Where used

- On cropland fields where water or wind erosion is a problem or where water needs to be conserved.
- Where a suitable outlet can be provided.
- Where adapted perennial vegetation can be expected to become established before the field is damaged from erosion.
- On slopes less than 10 percent.

Conservation management system

Vegetative barriers are normally established as part of a conservation management system to address the soil, water, air, plant, and animal needs and the owner's objectives. For this practice to be fully effective, it is important to plan the conservation crop rotation, nutrient and pest management, crop residue management, and other cropland practices.

Wildlife

Vegetative barriers provide excellent opportunities to improve wildlife habitat for some species by creating travel lanes that connect important habitat areas or in-field escape cover. For wildlife objectives, select native species or other adapted species that provide wildlife food and cover. Practices, such as wildlife upland habitat management, provide guidance for applying vegetative barriers that meet wildlife objectives.

Specifications

Site-specific requirements are listed on the specifications sheet. Additional provisions are entered on the job sketch sheet. The following general specifications apply to this practice:

- Minimum width of barrier strip is 12 inches.
- Maximum vertical and horizontal spacing of barriers is determined using the terrace spacing equations.
- Barriers are aligned as near contour as practicable with minor adjustments to accommodate farming operations.

Operation and maintenance

Vegetative barriers must be inspected periodically to assure no voids develop in the protective strips of vegetation. Shape and replant washouts and rills as necessary to maintain plant density. Control spreading of barrier plants into cropped areas. Control weeds and fertilize to maintain plant vigor. Control grazing and equipment traffic as necessary to protect barriers.

Vegetative Barriers – Specifications Sheet

Landowner V.G. Barrier Field number 8

Purpose (check all that apply)	
☑ Reduce sheet and rill erosion	☐ Reduce runoff
☐ Reduce pollution from runoff	☐ Provide wildlife habitat
☑ Reduce ephemeral gullies	☐ Other (specify)

Location and Layout	Strip 1	Strip 2	Strip 3	Strip 4
Barrier width (in)	36	36	36	36
Rows per barrier	2	2	2	2
Barrier length (ft)	3,000	2,800	2,600	1,800
Barrier area (acres)	0.2	0.19	0.18	0.12
Field slope (%)	2	2	3	3

Plant Materials Information				
Species/cultivar by row number	Seeding rate (lb/acre)	Seeding date	Recommend lime (tons/acre)	Recommend fertilizer $N\text{-}P_2O_5\text{-}K_2O$ (lb/acre)
Strip #1				
1 Switchgrass (Alamo	10	May 10	0	20-40-90
2				
3				
Strip #2				
1 Switchgrass (Alamo	10	May 10	0	20-40-90
2				
3				
Strip #3				
1 Switchgrass (Alamo	10	May 10	0	20-40-90
2				
3				
Strip #4				
1 Switchgrass (Alamo	10	May 10	0	20-40-90
2				
3				

Site Preparation

Prepare firm seedbed. Apply lime and fertilizer according to recommendations.

Planting Method(s)

1. Drill seed 0.25 inches deep uniformly down the row. Establish stand of vegetation according to recommended seeding rate.
   If necessary, mulch newly seeded area with Ø tons per acre of mulch material.
   May seed small grain as a companion crop at the rate of 100 pounds per acre, but clip or harvest before it heads out.
2. If seedlings are used, adjust column labels accordingly in above table.

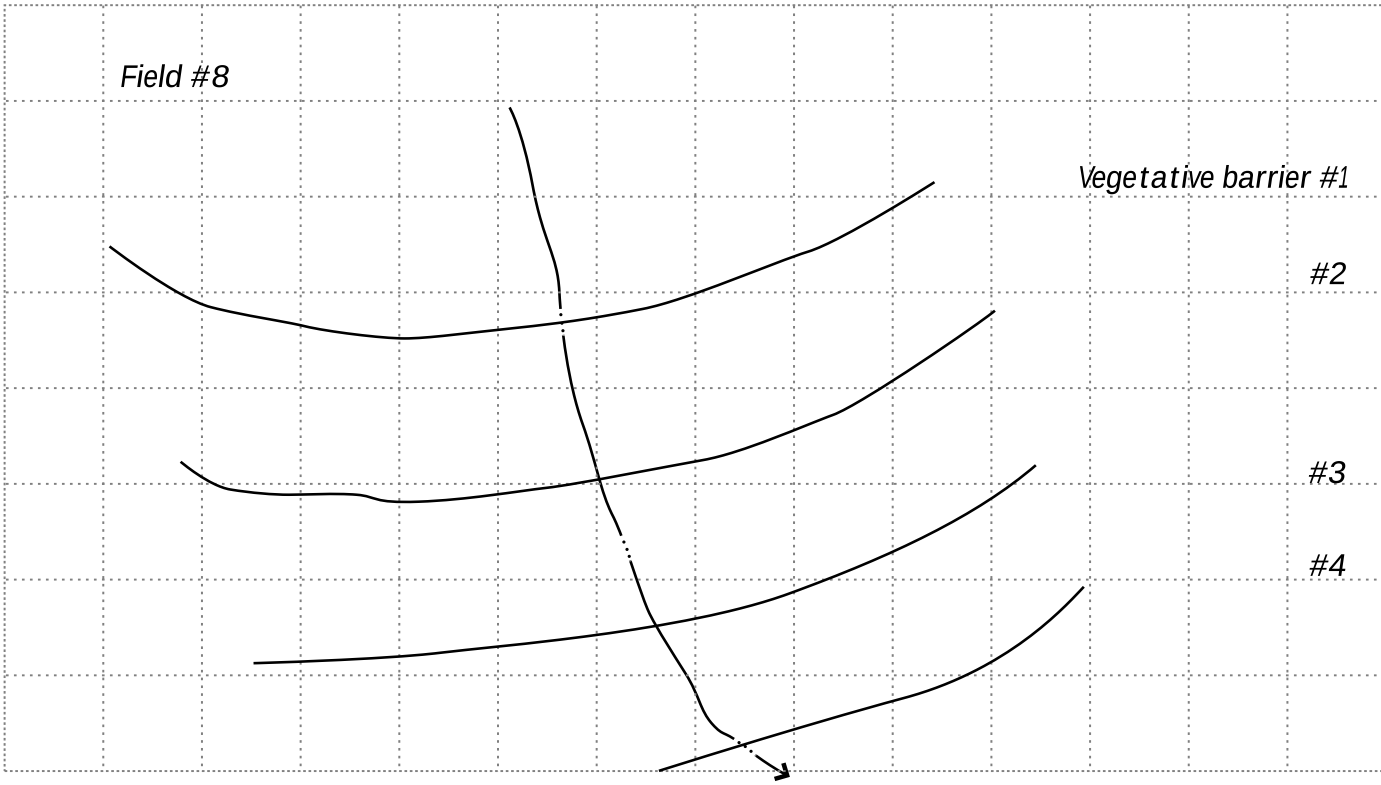
Operation and Maintenance

Vegetative barriers must be inspected periodically to assure no voids develop in the protective strips of vegetation. Shape and replant wash-outs and rills as necessary to maintain plant density. Control spreading of barrier plants into cropped areas. Control weeds and fertilize to maintain plant vigor. Control grazing and equipment traffic as necessary to protect barriers.

Vegetative Barriers – Job Sketch

Field sketch showing field boundaries, barrier widths, runoff direction arrow, and field layout. Other relevant information, such as adjacent field conditions including structures, crop types, and complementary practices, may also be included.

Scale 1"= 660 ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")



Additional Specifications and Notes:

Apply nitrogen fertilizer to switchgrass barriers after established at ratio of 50 lbs per acre.

Control weeds with herbicide 2, 4-D after plants established.
Avoid using 2, 4-D when sensitive crops planted in field.

Chapter 3j Windbreak/Shelterbelt

Definition of windbreak/ shelterbelt

A windbreak is defined as any barrier (natural or artificial) that reduces troublesome winds by creating a wind shadow to the leeward (downwind) side.

For this publication, windbreaks or shelterbelts are defined as single or multiple rows of trees or shrubs that are established for one or more environmental purposes. The terms windbreak and shelterbelt are used interchangeably.

Purposes

Windbreaks offer a variety of potential benefits to a farm or ranch enterprise and the rural community, both environmental and financial. They include:

- **Improve crop production and quality** by modifying the microclimate and reducing wind erosion.
- **Protect crops from insect pests** by reduced crop visibility, dilution of pest hosts resulting from plant diversity, interference with pest movement, and creation of environments less favorable to pests and more favorable to beneficial insects.
- **Manage snow drifting** to either maximize use of the moisture in the snow for crops or minimize snow blockages across roads or around buildings and livestock areas.
- **Improve air quality** through windspeed reduction and the physical capture of airborne particulates including dust, smoke, and pesticide droplets.
- **Enhance wildlife habitats and corridors** by adding tree, shrub, and herbaceous cover.
- **Provide aesthetic diversity** by adding trees on an agricultural landscape including living screens to separate incompatible uses.
- **Improve water quality** through interception of sediment and interception, sequestration, and decomposition of agricultural chemicals by tree, shrub, and herbaceous root environment.
- **Improve irrigation efficiency** by reducing evaporation losses.
- **Reduce energy consumption** by reducing air infiltration into buildings resulting in less heat loss and by reducing the amount of snow removal from roads and around buildings.
- **Improve livestock production** by increasing feed efficiency and weight gains, improving survival of newborns, and increasing milk production.
- **Provide potential for secondary farm products** from the windbreak, such as fruit, nut, or wood products.

Limitations

Although windbreaks have many potential benefits, there are also some limitations. They include:

- Require a more intensive management system including specialized equipment for the long-term tree and/or shrub management to maintain their protective values.
- Remove land from annual crop production and may not provide a financial return from the protection provided by the trees for several years.
- Hinder the use of large farm equipment and center pivot irrigation systems because smaller fields are separated by windbreaks.
- Serves as a potential source of harmful pests including insects and weeds.

Functions

Agroforestry practices, including windbreaks, tend to be more ecologically complex compared to a land use with a annual cropping. This is mainly because of the physical and biological interactions that occur when trees or shrubs are integrated with crops, livestock, or human activities. Some key functions of these more ecologically complex systems are described here.

Microclimate modification

Windbreaks reduce wind velocity, changing soil and air temperature, evapotranspiration rates, and relative humidity levels within the sheltered area.

Water management
Windbreaks alter the hydrologic cycle by reducing evaporation and transpiration losses from soils and plants in the sheltered zone especially under irrigated conditions. They distribute snow to either effectively use the moisture for crops or accumulate in a small area for slow release.

Soil quality
Windbreaks reduce wind erosion by interrupting the saltation process and reducing the unsheltered distance while adding organic material to soil from leaf drop and root growth.

Economic diversity
Enhanced growing conditions in sheltered zones increase crop and livestock production levels and add potential products directly derived from the tree/shrub component (wood, nuts, fruit, foliage).

Energy use cycle
Windbreaks alter the heat loss cycle from structures by reducing air infiltration and increasing shade.

Nutrient cycling
Windbreaks utilize nutrients from the deeper root systems of the trees.

Pest management
Windbreaks provide habitat and increase populations of insects, diseases, or weed pests. They also interrupt pest cycles.

Waste management
Windbreaks intercept, adsorb, and biodegrade organic sediment, nutrients, pesticides, and other biological pollutants.

Landscape diversity
Biological diversity is increased by adding trees/shrubs. The separation of competing uses is enhanced (e.g., confined animal feeding operations and rural residences or highways and living areas).

Wildlife habitat
Windbreaks provide food, cover, nesting sites, and travel lanes for a variety of wildlife species.

Not all of these functions may exist with each windbreak application. The function is dependent upon the way the plant components are manipulated in the design process. All the different interactions that occur with the different combinations of tree/shrub/herbaceous (annual and perennial) plants are not understood. For example, information is not sufficient to evaluate all the different pest interactions to positively say that beneficial insects will be favored and the harmful pests will be reduced. As different systems are designed, the best knowledge available must be used and the systems must be monitored for different interactions.

Design considerations

Several key components of windbreaks need to be manipulated for functions to occur. These components include determining the purpose, site evaluation, and location and layout.

Determining the purpose

A windbreak can have a variety of purposes ranging from crop protection to snow management. The design of the windbreak is dependent upon the purpose desired. To determine the purpose requires understanding the desired objectives of the landowner and the physical site characteristics. The first step in design is to interview the landowner to ascertain his/her objectives or purposes for the windbreak. A probing questioning strategy can be effective. Questions can include:

- From which direction(s) does the wind cause the most problem(s)?
- How do you want to manage the snow? Do you want to make use of the moisture from the snow? Are there any potential drainage problems associated with snowmelt?
- What structures need wind protection?
- Are you interested in providing wildlife habitat with the windbreak? If so, what kinds of wildlife do you want to favor?
- Are you interested in selecting species and a design that will add beauty to your home?
- When do your livestock need the most wind protection? Do you need to be concerned with summer air movement in the livestock area?
- Have you had any crop damage or loss from the wind or blowing soil? If so, when did it occur?
- Are you currently using any conservation measures (e.g., crop residue management, stripcropping, crosswind trap strips) to reduce the wind erosion impacts? If so, what is your management approach?
- Is the crop irrigated? If so, what method is used?
- Do you have any preferences about the amount of land that could be used for wind barriers or their placement in the field? What are the sizes of

field equipment you will be using to prepare, plant, maintain, and harvest your crops between the wind barriers?
- Do you have any species preferences for a wind barrier system? Are you aware that a wind barrier system can be designed using not only trees, but also shrubs, tall grasses, or annual crops?
- Do you have any long range plans to change your crop sequence or equipment which that affect windbreak layout?

After the landowner interview, the planner can proceed with developing design alternatives based on the purposes identified.

Site evaluation

The next step is to evaluate the site conditions that may affect windbreak design and application. These site conditions can include:
- Identify all areas needing protection based on the troublesome wind direction(s) (fig. 3j–1).
- Inventory the soils, paying close attention to inclusions of difficult soils, such as high/low pH salts or poor drainage. Begin a starter list of species adapted to the soils.
- Observe the topography to determine any runoff concerns either into or away from the windbreak (especially snowmelt and feedlot runoff).
- Locate property lines, overhead and underground utilities (electric, telephone, gas, and/or sewer), and existing trees or shrubs that may be within or adjacent to the proposed windbreak.
- Identify any access roads or lanes that could cause breaks in the windbreak.
- Locate the windbreak to avoid obstructing the winter sun, picturesque views, or oncoming traffic near driveways.
- Identify potential cold air drainage concerns to prevent frost problems with home orchards or gardens.
- Identify protection needs for the windbreak; e.g., fencing from livestock.
- Inventory existing wildlife habitat and wildlife species in the area so the windbreak may complement.
- Observe any existing plant species that may be alternate hosts for pathogens, e.g., cedar-apple rust.
- Record present agronomic wind erosion control efforts; e.g., tillage operations, crop sequence.

Location and layout

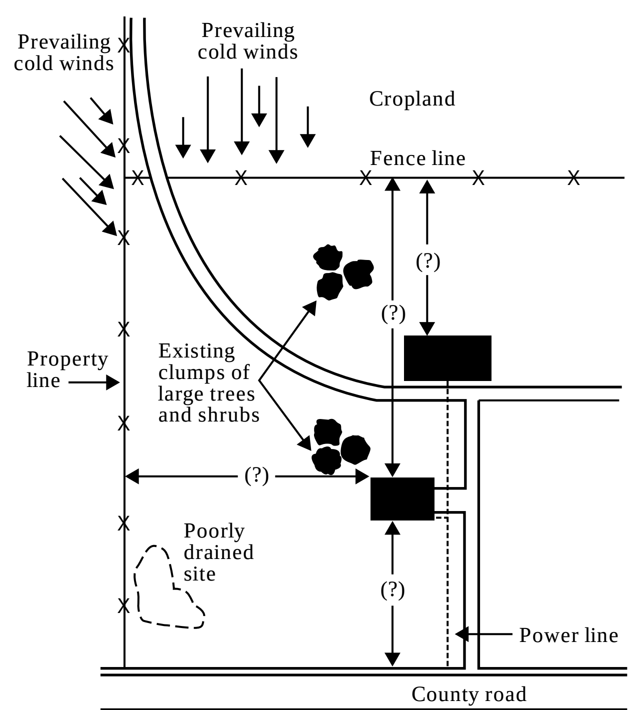
Height

A windbreak must be 2.5 feet or higher to have a significant effect. Windbreak height (H) is the most important factor determining the downwind area of protection. Windbreaks reduce wind speed for two to five times the height of the windbreak (2H to 5H) on the upwind side and up to 30H on the downwind side of the barrier. The area protected is a direct proportion to the height; e.g., a 20-foot windbreak will reduce wind speed up to 100 feet upwind and 600 feet downwind (fig. 3j–2) compared to a 40-foot windbreak, which doubles the area of influence (200 feet upwind and 1,200 feet downwind).

Density

Windbreak density is the ratio of the solid part of the barrier to the total area of the barrier. Wind flows through the open portions of a windbreak, thus the more solid the windbreak, the less wind passes through. By adjusting windbreak density, different windflow patterns and areas of protection are established (fig. 3j–3).

Figure 3j–1 Site evaluation includes key landmarks and critical distances to use in the planning process.



The dynamics of windflow around solid objects and through porous structures in relation to wind in the open can be manipulated to improve air quality. Designing windbreaks as a conservation buffer requires the planner to be able to manipulate the different structural components of a windbreak to achieve the desired buffering effect. Climatic and physical effects, such as wind speed, apparent air temperature, snow deposition, and evapotranspiration, are modified as a result of the structural characteristics of the windbreak.

Orientation

Windbreaks are most effective when oriented at right angles to prevailing or troublesome winds. The best orientation for each windbreak depends on the objectives for the windbreak. A key point to remember is that although the troublesome wind may occur primarily from one direction, it rarely blows exclusively from that direction. As the wind changes direction and is no longer blowing directly against the windbreak, the protected area decreases (fig. 3j–4).

Figure 3j–2 Leeward distance of wind protection is proportional to height of the barrier

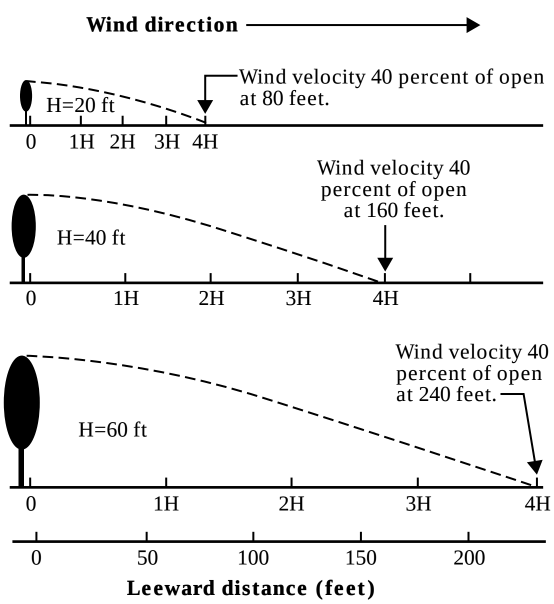
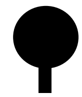


Figure 3j–3 Wind speed reduction to the lee of windbreaks with different densities, (A) density of 25 to 35 percent, (B) density of 40 to 60 percent, (C) density of 60 to 80 percent, (D) density of 100 percent.

(A)



Open wind speed 20 mph
Deciduous 25-35% density

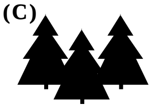
H distance from windbreak	5H	10H	15H	20H	30H
Miles per hour	10	13	16	17	20
Percent of open wind speed	50%	65%	80%	85%	100%

(B)

Open wind speed 20 mph
Conifer 40-60% density

H distance from windbreak	5H	10H	15H	20H	30H
Miles per hour	6	10	19	15	19
Percent of open wind speed	30%	50%	60%	75%	95%

(C)



Open wind speed 20 mph
Multi row 60-80% density

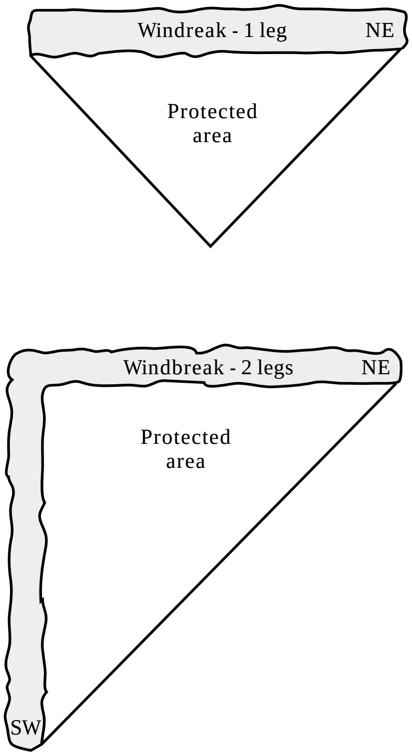
H distance from windbreak	5H	10H	15H	20H	30H
Miles per hour	5	7	13	17	19
Percent of open wind speed	25%	35%	65%	85%	95%

(D)

Open wind speed 20 mph
Solid fence 100% density

H distance from windbreak	5H	10H	15H	20H	30H
Miles per hour	5	14	18	19	20
Percent of open wind speed	25%	70%	90%	95%	100%

Figure 3j–4 In areas with variable winds, multiple-leg windbreaks or windbreak systems provide greater protection to the field or farmstead than single-leg windbreaks



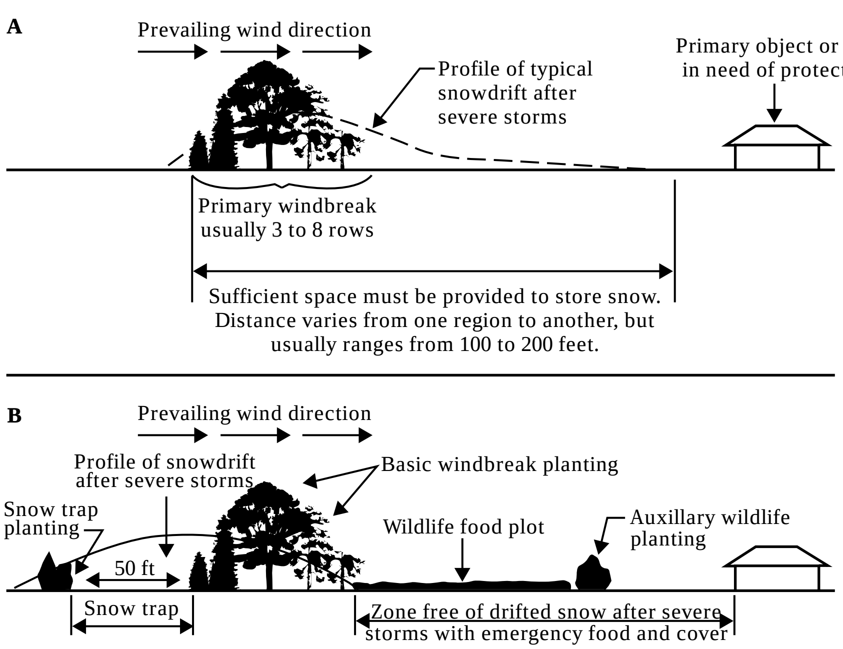
Length

Although the height of the windbreak determines the extent of the protected area downwind, the length of a windbreak determines the amount of total area receiving protection. For maximum efficiency, the uninterrupted length of a windbreak should exceed the height by at least 10:1. This ratio reduces the influence of end-turbulence on the total protected area.

Windbreak for structural protection (farmstead, feedlot, roads, buildings)

- For wind protection only, the tallest row needs to be 2 to 5H (H = planned height of the tallest row) from the primary area needing protection. However, for wind and snow protection, the most windward row needs to be 100 to 200 feet from the windward edge of the primary protection area. Once that critical distance is met, check to see if the area needing protection is still in the 2 to 5H zone; i.e., a livestock feedbunk. Areas and objects more than 10H from the windbreak will receive little wind protection (figs. 3j–5 and 3j–6).
- To protect structures, the windbreak should have a density ranging from 60 to 80 percent during the period requiring maximum protection. To achieve the minimum level of this porosity range, plant at least three rows of trees and shrubs with at least one row being a conifer.

Figure 3j–5 Basic farmstead windbreaks

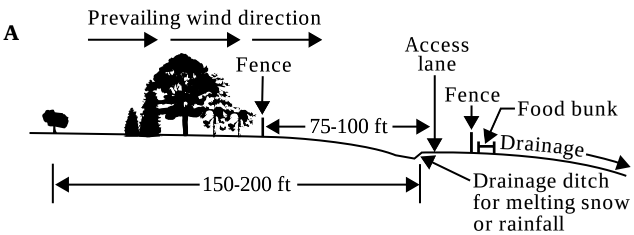


(A) A basic farmstead windbreak consists of three to eight rows of both conifers and deciduous trees and shrubs. Conifers or shrubs should be located to the windward side with tall deciduous species in the center. A row of shrubs on the interior or leeward side completes the design.

(B) In areas with frequent, heavy snows consider adding a row or two of shrubs 50 feet to the windward side to trip snow before it reaches the main windbreak.

Figure 3j–6 Cross-section of a feedlot windbreak designed for wind and snow protection (distance between the area needing protection and the windward row varies with the amount of space needed for snow storage)

(A) Traditional multirow windbreak with a trip-row of shrubs on the windward side.



(B) Modified twin-row, high density windbreak

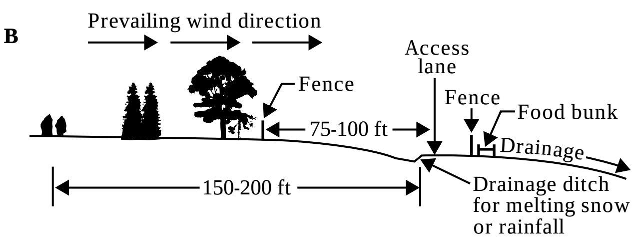


Figure 3j–7 Locate lanes and roads adjacent to windbreaks to avoid typical snowdrift pattern at end of windbreak

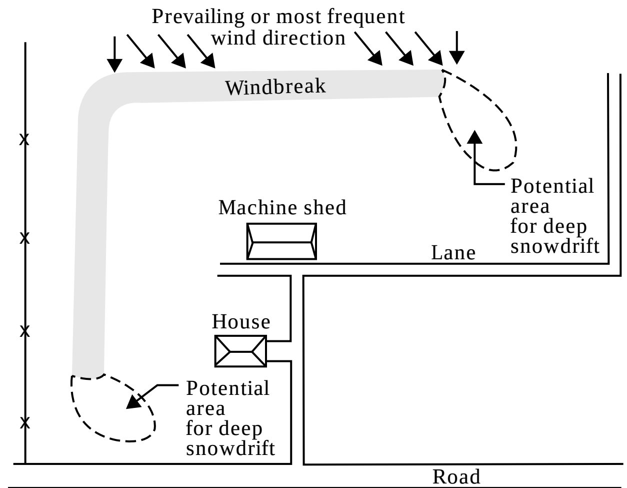
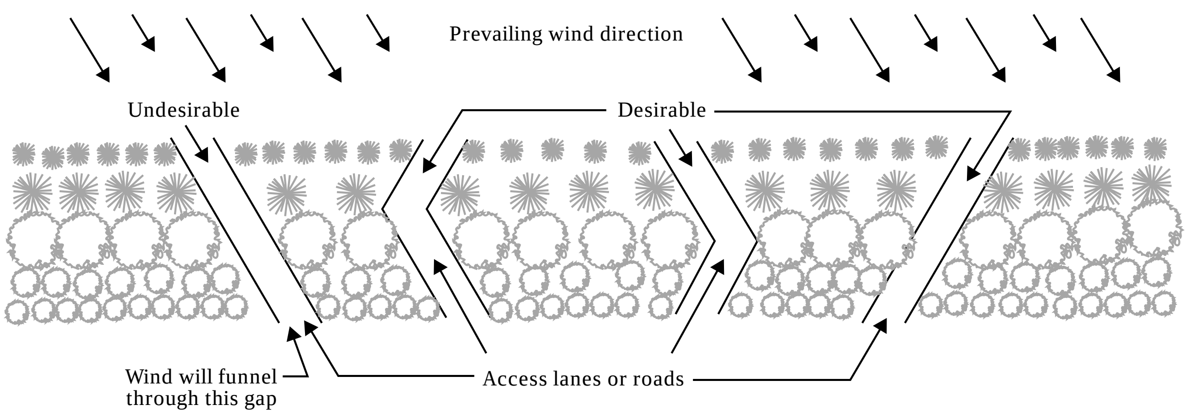


Figure 3j–8 Access lanes shoud be at an angle to troublesome winds

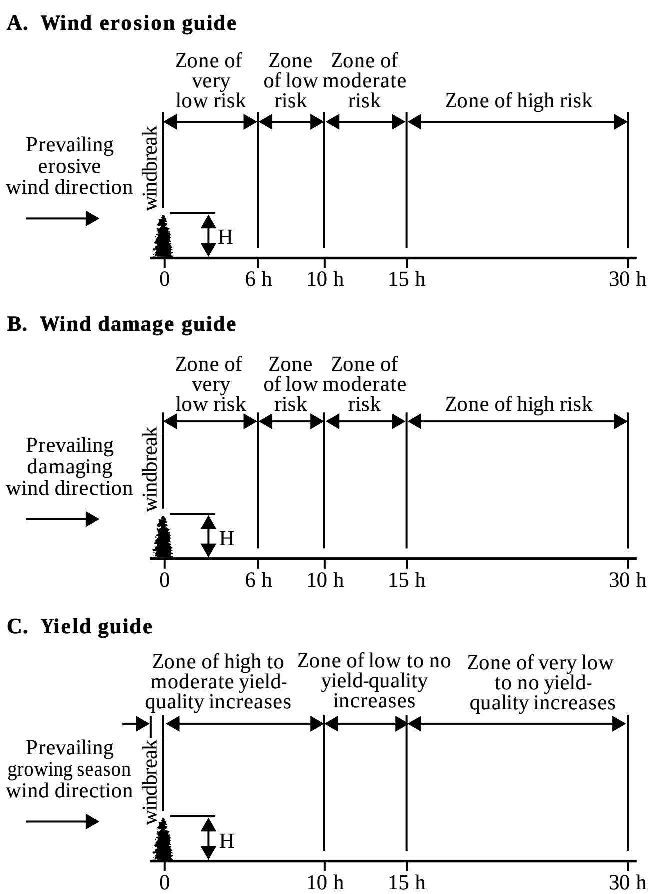


- Extend the windbreak a minimum of 100 feet past structures needing protection to accommodate wind turbulence at the end of the windbreak and end-drifts of snow.
- Locate access roads from 100 to 500 feet from the ends of the windbreak. If a lane must cut a windbreak, it should cut through the windbreak at an angle to prevailing winds to prevent funneling of wind and snow drifting (figs. 3j–7 and 3j–8).

Windbreak for field protection (crops, soil)

- Use a conservation plan map or photo to identify fields in need of protection, existing windbreaks, soil problems, utilities, direction of prevailing erosive winds, property lines, roads, and access lanes.

Figure 3j–9 Risk and yield guide for very low tolerance crops



- A windbreak density of 40 to 60 percent provides the greatest downwind area of protection and provides excellent soil and crop protection. The design density should be achieved during the time period when maximum protection is needed. A single row of conifers and a single row of deciduous trees (in full leaf) having crown closure can achieve this level of density. A single row of deciduous trees without leaves may be at the lower end of the range depending on the species and the spacing used.
- For crop protection and production and/or uniform snow distribution, wind break-to-windbreak intervals for most crops should be about 15 to 20H. This is especially true if a network of wind breaks are applied. When field windbreaks are applied in a series across the field, the 2 to 5H area of reduced wind speed windward of the windbreak can be credited. Economic evaluations of windbreak systems using the Windbreak Economic Model (WBECON) show that up to 5 percent of the field may be occupied by windbreaks and still provide a positive net gain in production.
- For crops highly susceptible to damage from wind or windblown soil, a spacing interval of 6H to 10H provides a high degree of protection (fig 3j–9 and table 3g–1 in Chapter 3g, Herbaceous Wind Barriers).
- For erosion control purposes, the Natural Resources Conservation Service uses a rule-of-thumb of no erosion out to 10H leeward. This would lead to a windbreak-to-windbreak interval of 10H plus the distance protected by the agronomic (standing crop, residue, cropping pattern, ridging) system. Windbreaks can be combined with other buffer practices (e.g., herbaceous wind barriers and cross wind trap strips) to provide greater flexibility (fig. 3j–10).

Spacing of windbreaks should be based upon the use of the wind erosion equation (WEQ) or other acceptable wind erosion prediction technology. *(Refer to Chapter 3g, Herbaceous Wind Barriers for a comprehensive example of determining the interval.)*

- "One-leg" windbreaks are sufficient if winds come from one direction only, but a network of windbreaks are needed when winds deviate throughout the windy season.
- Windbreak length should be long enough to provide the needed zone of protection for the field.

Windbreak for snow management

Design the density of your windbreak to manipulate snow drifting to meet landowner objectives (fig. 3j–11).

- To achieve even snow distribution across a field resulting in maximum water infiltration into the soil, the windbreak density should range from 25 to 35 percent. This would be roughly equivalent to a single row of deciduous trees without leaves at a wide spacing (15 to 20 feet). Additional conservation measures will be needed if soil erosion is a potential problem during the time the windbreak is at this density level (fig. 3j–11E).
- To achieve maximum snow accumulation, the windbreak density should range from 60 to 80 percent. The most windward row should be a minimum of 100 feet from the area being protected to prevent inappropriate snowdrifts. This distance will vary (100 to 300 feet) depending on the location and severity of winters. A trip row of shrubs or dense conifer can be located 50 to 100 feet windward of the main windbreak to create a snow trap (fig. 3j–11 F and G).
- When protecting roads, allow plenty of room for the leeward drift by locating the windward row of the windbreak 200 to 300 feet from the center of the road.

Figure 3j–10 Entire field is protected by two field windbreaks and eight herbaceous wind barriers

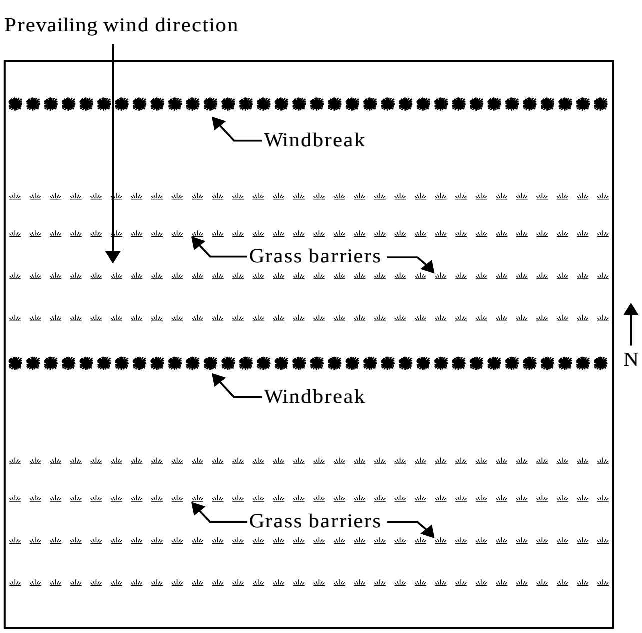
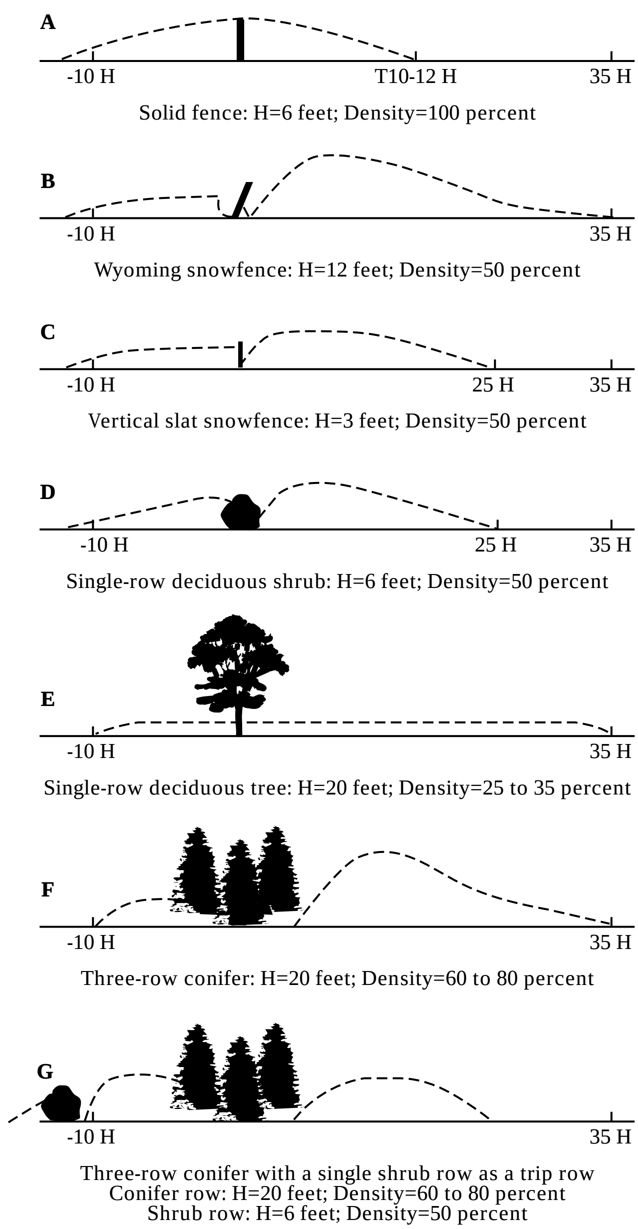


Figure 3j–11 The height and density of the snowfence or windbreak will determine how much snow can be stored in the system



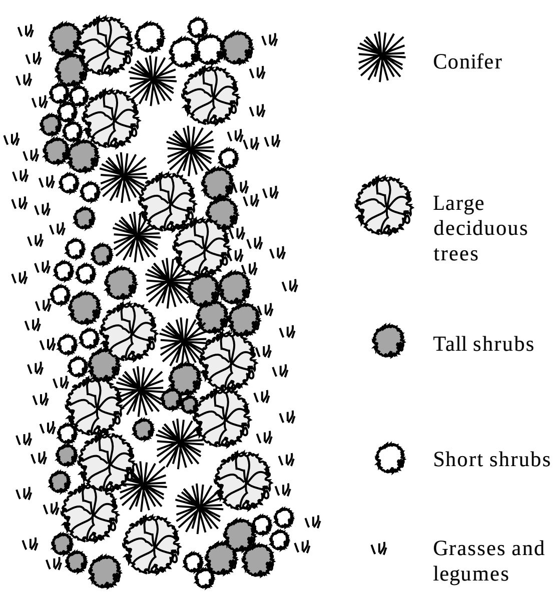
Windbreak for wildlife

- Include a variety of trees and shrubs in the windbreak. This gives a more natural landscape appearance, improves wildlife values for more species, and reduces the chances of disease and insect pest problems (fig. 3j–12).
- Where appropriate, select a site that connects to a larger habitat block, such as a river corridor, woodlot, wetland, woody draw, or similar area.
- Consider planting or leaving herbaceous vegetation, such as a mixture of grasses and legumes, standing grain, or crop residue as a border (20 to 50 feet wide) along the edges of the windbreak. If grasses or legumes are used, then they should be separated from the new tree planting to avoid competition. This strip of cover can provide nesting, loafing, and foraging cover for several species.
- Consider adding a shrub row 50 to 100 feet windward of the main windbreak as a snow trap resulting in greater wildlife protection on the leeward side of the main windbreak.

Windbreak as a living screen

- Establish noise screens as close to the noise source as possible.
- Locate visual screens as close to the observer as possible.

Figure 3j–12 Windbreaks can be given a more naturalistic look and still provide excellent wildlife habitat and wind protection



- For both noise and visual screens, choose plant material that will result in a very high density; e.g., conifers (spruce and juniper). The chosen plants should then be spaced as close together as practical to form a tight barrier.
- Windbreaks may moderate the impacts of older odor.

Design considerations for all windbreak purposes

- Avoid subsurface drain lines and irrigation pipelines—species such as willows and poplars, with aggressive root systems should not be planted within 100 feet.
- Avoid locating rows beneath power or telephone lines, allow for lateral spread of the mature crown plus 10 to 15 feet when planting next to utility lines.
- Locate new rows at least 50 feet from existing windbreaks (outside of the root influence area of the older trees and shrubs).
- Do not locate trees closer than 200 feet from road corners or intersections to allow traffic visibility.
- Access lanes or roads that cut through multiple-row windbreaks should be at an angle to prevailing winds to prevent funneling of wind. Lanes or roads through single-row barriers should be avoided. Locate them from 100 to 500 feet from the ends of the windbreak (figs. 3j–7 and 3j–8).

Woody plant material information

All species of trees and shrubs do not grow at the same rate nor do they grow to the same mature height. Likewise, adapted species vary in their growth on different soils within a geographical area. The amount of available soil moisture during the growing season and soil aeration are two important factors affecting tree and shrub growth. These factors are largely determined by soil texture and depth and by climate.

Conservation tree and shrub suitability groups have been developed as a guide for selecting species best suited to different soils and climates, predicting height growth at 20 years, and measuring effectiveness. They can be used to select plant material for windbreaks. These guides are available in the NRCS Field Office Technical Guide. Information about different plants can also be obtained from the PLANTS data base (http://plants.usda.gov), which also includes VEGSPEC software that assists in designing vegetative practices including windbreaks.

In addition to selecting plants adapted to the climate and soil, plants need to be selected that have the greatest potential for meeting landowner objective. The primary objective is to select plants that provide the desired level of wind protection in a reasonable length of time (within 10 years). This means selecting species that give the appropriate level of density and optimum height for the site. For example, conifers need to be considered if optimum year-round wind protection is desired. If wildlife enhancement is desired, species with attributes especially desirable for the desired wildlife species should be selected.

Site preparation and planting methods

Site preparation is an important first step to ensure successful survival of the trees and shrubs in the windbreak. The goal is to maximize the amount of moisture at the site and to minimize the potential for weed competition. The type of site preparation used depends on the soil and existing vegetation at the site. With sandy soils, care must be given to avoid wind erosion problems. On sloping sites, precautions must be taken to prevent water erosion. Site preparation can be accomplished either mechanically (e.g., tillage equipment including chiselplow, disc, rototiller, or scalper), chemically (pre and/or post-emergent herbicides), or a combination of both.

For grassland sites, the grass needs to be completely destroyed at least in the area of the tree planting. This should be done the year before planting. This can be accomplished either with cultivation or herbicides, or a combination of both. On cropland sites, light tillage or a herbicide application is usually needed to control annual weeds. If any problem weeds (such as perennial weeds) exist on the proposed site, they need to be destroyed the year before planting.

Tree planting methods include using either a tree planting machine or hand planting tools. For both methods, some key techniques need to be followed. They include:

- Prevent roots from drying out.
- Do not plant on hot, windy days.
- Do not plant when the temperature is freezing or below.
- Plant seedlings in a vertical position with root collar 1" below soil surface.
- Prepare a trench or hole deep and wide enough to permit roots to spread out naturally; avoid J rooting.
- Prune roots as needed to prevent J roots.
- Pack soil firmly around roots to eliminate air pockets.

For additional information refer to Chapter 4 - Establishing Conservation Buffers.

Operation and maintenance

All buffers need to have an operation and maintenance plan to assure they continue to function as desired. These items need to be included in the plan for windbreaks as described in this section.

Weed control

Weeds need to be minimized usually for the first 3 to 5 years in a band about 3 to 4 feet on each side of the rows of trees or shrubs. The area between the rows can be planted to an annual cover crop (e.g. grain/ forage sorghum, oats, corn, millet, wheat, rye, or sunflowers) to help control weeds, provide wildlife cover, and protect young tree seedlings from soil or wind abrasion. Sod-forming grasses should not be planted between the rows because they compete for moisture.

If mechanical cultivation is used (sweep, disk, spring tooth, rototiller), several cultivations may be needed each year depending on the geographic area. If cultivation is used, the tillage depth should be shallow (2 to 4 inches) to avoid excessive damage to surface tree roots. Specially designed implements that operate on a hydraulic arm can cultivate in the row. These implements need to be operated carefully to avoid damage to the seedlings. Discontinue cultivation in early fall to allow plants to harden off for winter.

Chemical weed control (pre- and/or post-emergent herbicides) can be a relatively inexpensive approach with a single treatment generally lasting longer than mechanical methods. Approved herbicides for trees come and go, and checking with the Extension Service, state forester, or other certified/licensed herbicide specialist is recommended. Be sure the sprayer is calibrated correctly.

A third weed control alternative for the trees is to use some type of mulch. Synthetic woven plastic weed barriers are available commercially. These synthetic mulches range from 4-foot squares to continuous rolls 6 feet wide. Most of these mulches biodegrade over time. These materials have the advantage of not only controlling weeds, but also conserving moisture. Initial cost is significant, but some of the mulch products do not degrade for 5 years or beyond. Organic mulches, such as wood chips, could also be used if a ready supply is available. Research is being done examining potential living mulches, such as clovers, that could provide not only weed suppression, but also some nitrogen fixation.

Pest control

Insects and diseases can be significant factors in reducing the health and vigor of the windbreak and the adjacent crop. Periodic inspection of the crops and trees is recommended to detect and identify possible pests. These inspections and, in some cases, the use of pheromone traps help determine when corrective action is warranted. The corrective action can include chemical controls and/or cultural or mechanical controls. Action taken should minimize the impacts on beneficial insects. Care needs to be taken when applying herbicides to adjacent crops to minimize damage to the windbreak.

Supplemental irrigation

Irrigation (hand, drip, sprinkler, furrow or flood) is not a substitute for good site preparation and weed/grass control. Irrigation should be used when soil moisture conditions are extremely dry at planting time or during prolonged drought after planting. Where pre-emergent herbicides are used for in-row weed control, irrigation should be used sparingly to prevent leaching of herbicide into the tree root system. Irrigation should be considered only a temporary maintenance practice used to ensure survival. Tree plantings should be weaned from irrigation within 3 to 5 years after planting. In arid regions of the country, permanent irrigation systems may need to be designed to ensure adequate survival and growth. For drip systems, clean filters and emitters, repair damaged or split pipe, and make sure water is not toxic. For other systems also clean filters, repair any malfunctioning spray heads or pipes, and clean furrows for unimpeded flows. Discontinue irrigation in the fall to slow plant growth and allow hardening off before winter

Replanting

To fill in the gaps in the windbreak, replant all trees and shrubs that have failed. Replant annually for at least 3 years after the initial planting and continue until a full stand of trees is attained.

Fertilization

Generally, fertilization of windbreaks is not recommended. It is not practical, economical, or feasible in most cases. The only situation where fertilization may be justified would be a small, high valued windbreak planted on soils that have obvious soil nutrient deficiencies. Apply fertilizer and other soil amendments according to soil test results.

Protection from sun, wind, and fire

Protect plants from desiccation by sun and wind (any season) by placing shingles or commercially available tree shade cards on the south and west sides of the individual seedling. Bales of straw can provide a mini-windbreak, but may attract rodents. Establish firebreaks 10 feet to 20 feet wide (mowed or tilled strip) around the planting.

Protection from large and small animals

Trampling and browsing damage from livestock or wildlife may be a concern for the trees. The damage may occur directly on the trees or through soil compaction to the root systems. Establish appropriate fencing to prevent livestock damage and repair broken fences promptly. Jackrabbits, cottontails and mice often damage trees and shrubs by chewing on the bark, girdling branches or the main stem or gnawing the plant completely off above ground line. For control, use repellents, traps, special fencing, seedling protectors (photodegradable plastic tubing or mesh netting). Consult with local and state game/wildlife specialists for control measures.

Storm damage and pruning

Hail, wind, or snow storms often cause breakage of limbs and sometimes the main trunk(s) of the trees and shrubs. Remove broken limbs and tops.

Pruning techniques

- *Limbs*—undercut halfway through damaged or dead limb (this is done a short distance from the fork or main bole). Remove limb with an overcut just outside of the undercut. Remove the stub at the top of the branch collar.
- *Main bole*—Remove the stem with several cuts to prevent bark strippage. Position the cuts well above the fork of live limbs below (desiccation of live wood will occur several inches below the cut–if too close to the fork, live limbs could die). Make sure the final cut angles the surface so that water is drained off.

Information needed to fill in job sheet

A specifications sheet should be filled out for each windbreak site for use by the farmer. Indicate the landowner's name and the field number corresponding with the conservation plan map. Check off those purposes that apply to the particular site based on the objectives of the landowner.

Under the section Location and Layout, complete the planned width and length of the actual windbreak. The area of the windbreak can be calculated by multiplying the length and width. The total area protected is calculated by multiplying the length of the windbreak times the distance that will be protected (10 to 15 times the height of the windbreak using the 20-year projected height) by the windbreak. Under Additional requirements, enter any critical distances for locating the windbreak, such as distance from the windward row of the windbreak and the building or road being protected or the distance between a series of field windbreaks.

For each tree/shrub row as shown on the sketch, list the species (including specific cultivars) in the woody plant materials information section. Explain what type of planting stock is planned using the symbols in the footnote (BA=Bareroot, CO=Container, CU=Cutting) as well as the size of the desired stock. Complete the recommended planting date for the trees/shrubs. Record the distance between the individual plants in the row in the next column. Based on the estimated length of the row, estimate the number of plants needed for each row. In the final column, fill in the spacing between individual rows.

Spacing information for individual plants in the windbreak should be available in the local NRCS Field Office Technical Guide. The following information is provided for general guidance:

A. Between rows: generally 12 to 20 feet (tillage equipment plus 4 feet). Some designs (twin-row high-density) may extend beyond 20 feet.

B. Between plant spacing in the row (based on a 20-year height)

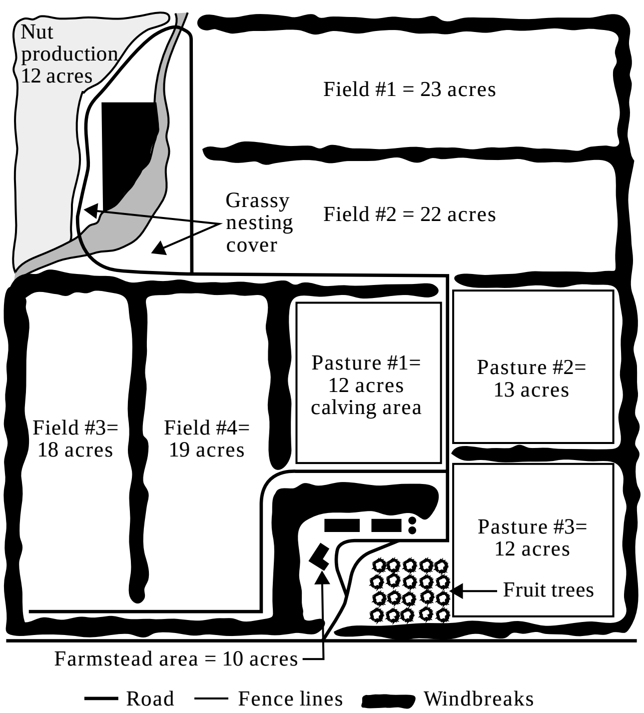
	Single row (feet)	Multiple row (feet)
Low shrubs (<10 feet)	3-5	3-6
Large shrubs (>10 feet) Small evergreen trees (<25 feet) Deciduous columnar trees (any height)	5-8	6-8
Low deciduous trees (<25 feet)	6-10	8-14
Tall evergreen trees (>25 feet)	8-12	8-16
Tall deciduous trees (>25 feet)	8-12	10-18

C. Spacing should allow for crown closure within about 10 years without undue competition between adjacent plants in later years.

On the back of the specification sheet, complete a sketch for the planned windbreak (fig. 3j–13). For field windbreaks, indicate the orientation of the windbreak(s) in relation to field borders including critical distances, such as the interval between multiple windbreaks or distance to a road. For windbreaks protecting structures, show the orientation of the windbreak and the critical distances to areas being protected. Include key landmarks that help locate the windbreak properly, such as buildings, fences, roads.

Under the additional specifications and notes, provide any specific details needed for the correct installation of the planting.

Figure 3j–13 An example of a 160-acre farm designed to take full advantage of windbreaks and other woody plantings



Additional reading

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United States Department of Agriculture, Natural Resources Conservation Service. 1996. Windbreaks for conservation. AIB-339.

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Windbreak/Shelterbelt

Conservation Practice Job Sheet 380

Natural Resources Conservation Service (NRCS) *January 1998*

Landowner____

Definition

Windbreaks or shelterbelts are plantings of single or multiple rows of trees or shrubs that are established for environmental purposes. The height of the tallest row and overall density of foliage and branches of an individual planting greatly influence the size of the nearby area that is protected or sheltered.

Purpose

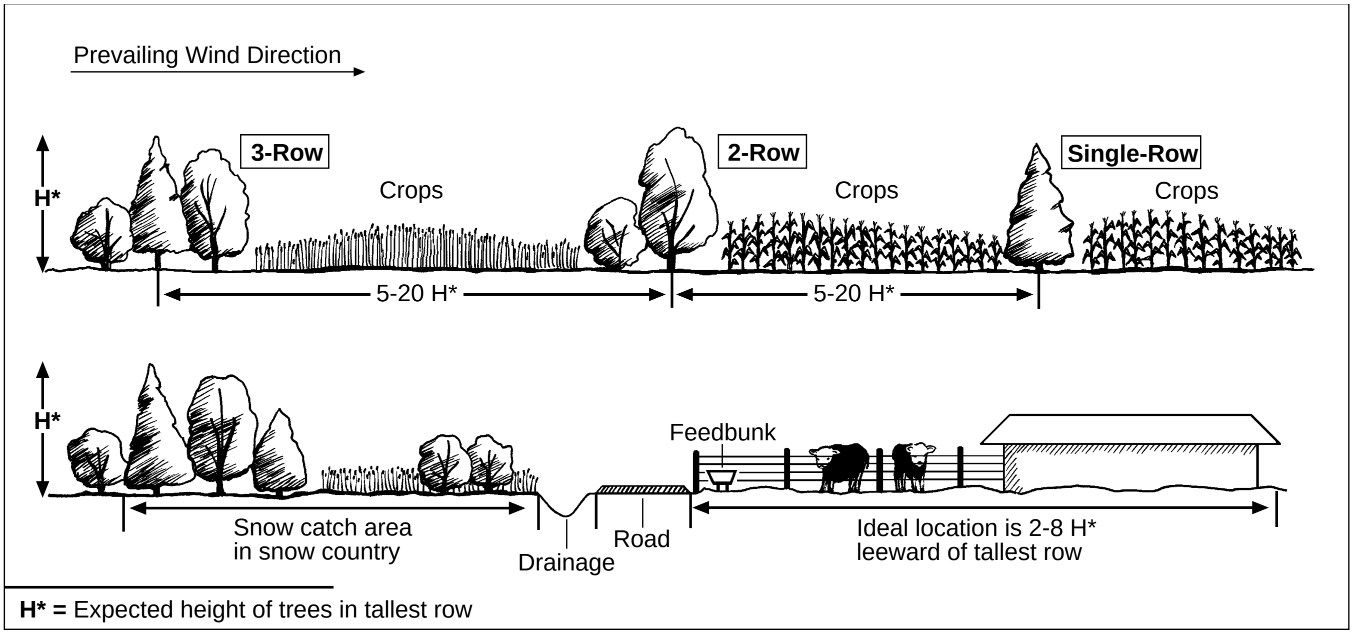
Windbreaks or shelterbelts are generally established to protect or shelter nearby leeward areas from troublesome winds. Such plantings are used to reduce wind erosion, protect growing plants (crops and forage), manage snow, and improve irrigation efficiency. Windbreaks also protect structures and livestock, provide wildlife habitat, improve aesthetics, and provide tree or shrub products. Also, when used as a living screen, windbreaks control views and lessen noise.

Where used

Windbreaks are “environmental buffers” that are planted in a variety of settings, such as on cropland, pasture, and rangeland (sometimes referred to as “living barns”), along roads, farmsteads, feedlots, and in urban areas.

Conservation management system

Windbreaks and shelterbelts are normally established concurrently with other practices as part of a conservation management system. For example, proper crop rotations and tillage techniques and management of residue in fields (conservation crop rotation and residue management) work with windbreaks to control wind erosion.



A windbreak or shelterbelt usually consists of multiple rows, with shrubs in the outer rows and taller trees in the interior. Complementary practices work with these environmental buffers to further control wind erosion and snow deposition and modify site characteristics for habitat and screening purposes. For comprehensive protection of a field, windbreaks are placed in a series across the area (typically spaced at intervals of 5 to 20 times the height of each windbreak), with individual windbreaks running parallel to one another, but perpendicular to prevailing winds.

Wildlife

For plantings to function properly, access by livestock and certain wildlife must be managed year-round (use exclusion and fencing). Connecting shelterbelts with existing or planned perennial vegetation, such as woodlots and woody draws (tree/shrub establishment) or riparian areas (riparian forest buffer), provides additional benefits for wildlife and aesthetics. Select native or adapted species that provide wildlife food or cover.

Operation and maintenance

Trees and shrubs in the windbreak or shelterbelt need periodic maintenance and, later on, possible renovation (tree/shrub pruning and windbreak/shelterbelt renovation). In arid areas windbreaks may need supplemental water or water harvesting techniques for successful establishment.

Specifications

Site-specific requirements are listed on the specifications sheet. Additional provisions are entered on the job sketch sheet. Specifications are prepared in accordance with the NRCS Field Office Technical Guide. See practice standard Windbreak/Shelterbelt Establishment code 380.

Multiple-row windbreak protects farmstead and provides wildlife habitat.

Windbreak/Shelterbelt – Specifications Sheet

Landowner____ Field number____________

Purpose (check all that apply)	
☐ Reduce wind erosion	☐ Provide wildlife habitat
☐ Protect growing plants (crops, forage, other)	☐ Provide a living screen (view and noise control, other)
☐ Manage snow	☐ Improve aesthetics
☐ Provide shelter for structures (farmstead, house, other)	☐ Improve irrigation efficiency
☐ Provide shelter for livestock	☐ Other (specify):

Location and Layout	
Width (ft ; include widths of maintenance areas next to outer rows):	
Length (ft):	Area (ac):
Total area of zone protected/sheltered (ac.; based on expected height and density of the windbreak/shelterbelt):	
Additional requirements:	

Woody Plant Materials Information					
Species/cultivar by row number	Kind of stock[1]	Planting dates	Plant-to-plant distance (ft) within row	Total number of plants for row	Distance (ft) between this row and next row[2]
1					
2					
3					
4					
5					
6					
7					
8					

[1]BAreroot, COntainer, CUtting; include size, caliper, height, and age as applicable. [2]Adjusted for width of maintenance equipment.

Site Preparation
Remove debris and control competing vegetation to allow enough spots or sites for planting and planting equipment. For plantings requiring supplemental moisture, prepare and ready applicable materials for installation. Additional requirements:
Temporary Storage Instructions
Planting stock that is dormant may be stored temporarily in a cooler or protected area. For stock that is expected to begin growth before planting, dig a V-shaped trench (heeling-in bed) sufficiently deep and bury seedlings so that all roots are covered by soil. Pack the soil firmly and water thoroughly.
Planting Method(s)
For container and bareroot stock, plant stock to a depth even with the root collar in holes deep and wide enough to fully extend the roots. Pack the soil firmly around each plant. Cuttings are inserted in moist soil with at least 2 to 3 buds showing above ground. Additional requirements:

Windbreak/Shelterbelt Maintenance
The planting must be inspected periodically and protected from damage so proper function is maintained. Replace dead or dying tree and shrub stock and continue control of competing vegetation to allow proper establishment. For plantings requiring supplemental moisture, install and begin operation of the irrigation system. Periodically prune trees and shrubs to repair environmental damage and maintain plant health and vigor. Additional requirements:

Windbreak/Shelterbelt – Job Sketch

If needed, an aerial view or a side view of the windbreak/shelterbelt shown below. Other relevant information, such as complementary practices and adjacent field or tract conditions including structures and crop types, and additional specifications may be included.

Scale 1"=________ ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")

Additional Specifications and Notes:

Chapter 4 Establishing Conservation Buffers

All the time spent planning and designing a conservation buffer can end in failure if inadequate time is devoted to assuring correct installation of the plant material. The information that follows gives some basic guidance on site preparation and planting of woody and herbaceous plants. Most states have job sheets or other guidelines for establishing woody and herbaceous plants. That information can be substituted or added to the following general information.

Woody plant establishment

Site preparation

Site preparation is an important first step to ensure successful survival of trees and shrubs. The preparation shall be sufficient for establishment and growth of selected species and be done in a manner that does not compromise the intended purpose. The goal is to optimize the amount of moisture at the site and to minimize the potential for weed competition. Site preparation can be accomplished either mechanically (e.g., tillage equipment), chemically (e.g., herbicides), or a combination of both. The type of site preparation used depends on the soil and existing vegetation at the site. On sandy soils care must be given to avoid wind erosion problems. On sloping sites precautions must be taken to prevent water erosion. Avoid sites that have had recent application of herbicides harmful to woody species to be planted. If herbicides are used, apply only when needed and handle and dispose of properly and within Federal, State, and local regulations. Follow label directions and heed all precautions listed on the product label. If fabric mulch is to be installed, a light tillage in the spring before planting helps level the site.

Tillable sites with loamy clayey soils

Sod and deep-rooted perennials sites

Sod and deep-rooted perennials need to be killed 1 year before planting the trees or shrubs. This can be accomplished by one of the following:

- Till (plow, disk-plow, rototiller, or similar equipment) the site in the year before planting the stock. A cover crop may be used where needed to control erosion.
- Apply a nonselective herbicide the year before planting the trees or shrubs. Plant the stock in the residue. On clayey soils, tillage may be needed to achieve a satisfactory soil/root contact if a tree planting machine is used.

Small grain or row crop sites

- If the site is in row crops, lightly till (disk, field cultivator, or similar equipment) strips where the trees will be planted. This should be done either in the fall or spring before planting. If the site has a plowpan or hardpan in the subsoil, a fall ripping of the soil where the trees will be planted may be necessary to allow better root development. A cover crop may be used where needed to control erosion.
- If the site is in small grain stubble, the stock may be planted in the spring without further preparation.
- Tillage on steep slopes must be on the contour or cross-slope. A cover crop between the rows may be necessary to control erosion and sediment deposition on planted stock.

Tillable sites with sandy soils

Sod and deep-rooted perennial sites

Any of the following methods may be used to prepare the site:

- Kill the sod with a nonselective herbicide the year before planting. Plant trees or shrubs in the residue.
- Till (disk, rototiller, or similar equipment) strips where the trees will be planted and plant to a spring cover crop (corn, grain, sorghum) the year before planting the trees. Leave a stubble cover in which to plant.
- When hand planting, scalp or strip an area at least 3 feet in diameter and 2 to 4 inches deep. Place plants in the center of the scalped area.

Small grain or row crop sites

- If the site is in small grain, corn, or similar clean tilled crop and it is reasonably free of weeds, plant stock in the stubble without prior preparation. A narrow strip may need tilling to kill weeds or volunteer grain or to prevent stalks and other residue from clogging the tree planter. If fabric mulch is used, a light tillage may be needed to level the site. A cover crop or stubble may be needed between the rows to protect the planting from water or wind erosion.

Nontillable sites and/or erosive sites (including sites with undesirable brushy or herbaceous species)

On sites where equipment is not practical or possible, where tillage of the site will cause excessive erosion, or where tillage is impractical, the following methods may be used:

- Machine or hand scalp an area at least 36 inches in diameter with subsequent plant placement in the center of the scalped area.
- Rototill a strip at least 36 inches wide the year before tree planting with subsequent plant placement in the center of the tilled strip.
- Kill the vegetation in a 36-inch diameter or larger area or in a 36-inch or wider strip with a nonselective herbicide the year before planting and plant in the center or along the centerline of the treated area.

Sites with undesirable brush need initial treatments that physically remove and kill the brush species. This facilitates planting of desired stock and prevents re-encroachment of the brush. Suitable methods include handcutting and removal, brush hogging, brush-blading, or other equivalent procedure with repeated treatment or use of herbicides to control resprouting.

Handling/storage

Store seedlings in a cool, moist environment (e.g., 34 to 40 degrees Fahrenheit and 80 to 100 percent humidity) or heel them in until planting time. Keep roots moist and cool during handling. Seedlings that have been allowed to dry out, heat up, or begin root growth should not be planted. Tree roots should never be subjected to freezing conditions or submerged in water longer than 6 hours. Poor quality, damaged, or undersized stock should be discarded.

Planting stock types and quality

The following information is based on *The American Standard for Nursery Stock*, published by the American Association of Nurserymen, ANSI 260.1, 1996.

When planning a conservation buffer with trees or shrubs, determine the planting stock that best suits the buffer objectives. Planting stock can affect the cost, survivability, and expected growth rate. The stocktype indicates how the plant type was grown and delivered. Plants are generally labelled according to their type designation, age, and cultural treatment while in the nursery.

The designation codes are:

C	=	Cuttings
U	=	Unrooted cuttings
G	=	Grafted
L	=	Layered
S	=	Seedling
M	=	Micropropagated or tissue cultered
D	=	Division

Cultural designation codes are:

R	=	Root pruned
P	=	Pot or container grown
T	=	Transplanted (one per time)
B	=	Bed grown
O	=	not transplanted
Coll	=	Plants collected from the wild
Age	=	Sum of numbers following the type and cultural codes

Thus a SITI is a 2-year old planting stock grown 1 year as a seedling (s) in a nursery bed and 1 year as a transplant (t).

There are four common ways plants are prepared in the nursery for shipment and planting. They are:

Bare-root (BR)

They are generally smaller seedlings or rooted cuttings from which the soil or growing medium has been removed. All bare-rooted trees and shrubs shall have a well branched root system characteristic of the species. Bare-rooted seedlings specification may be designated by planting stock type or by caliper and root stem ratios.

Container-grown (P)

These are plants grown and marketed in a container. All container grown trees shall be healthy, vigorous, well rooted, and established in the container in which they are grown. They shall have healthy tips of good quality and be in a healthy growing condition. All container-grown trees shall be graded by plant and container size.

Balled and burlapped (B & B)

These are larger trees and shrubs which have been prepared for shipping and planting by digging so that the soil immediately around the roots remain undisturbed. The ball of earth containing the roots of the plant is then wrapped in burlap or similar fabrics. The ball sizes should always be of a diameter and depth to encompass enough root system as necessary to assure full recovery of the plant.

Cuttings

Branches and stems of some species can be harvested and directly planted. The size of cuttings vary depending on the intended use and type of species. Refer to the NRCS Engineering Field Handbook, Chapter 16, Streambank and Shoreline Protection, and Chapter 18, Soil Bioengineering for Upland Slope Protection and Erosion Reduction, for a list of species that can be established by live cuttings.

For more information contact the American Association of Nursrymen, 1250 I Street N.W., Suite 500, Washington, D.C., 2005 (202-789-2900).

Planting methods

Planting methods vary depending on the type of plant material used. Bare root, container, ball and burlap, or cutting are the primary types of plants used. The following general guidelines are for all types of tree plantings:

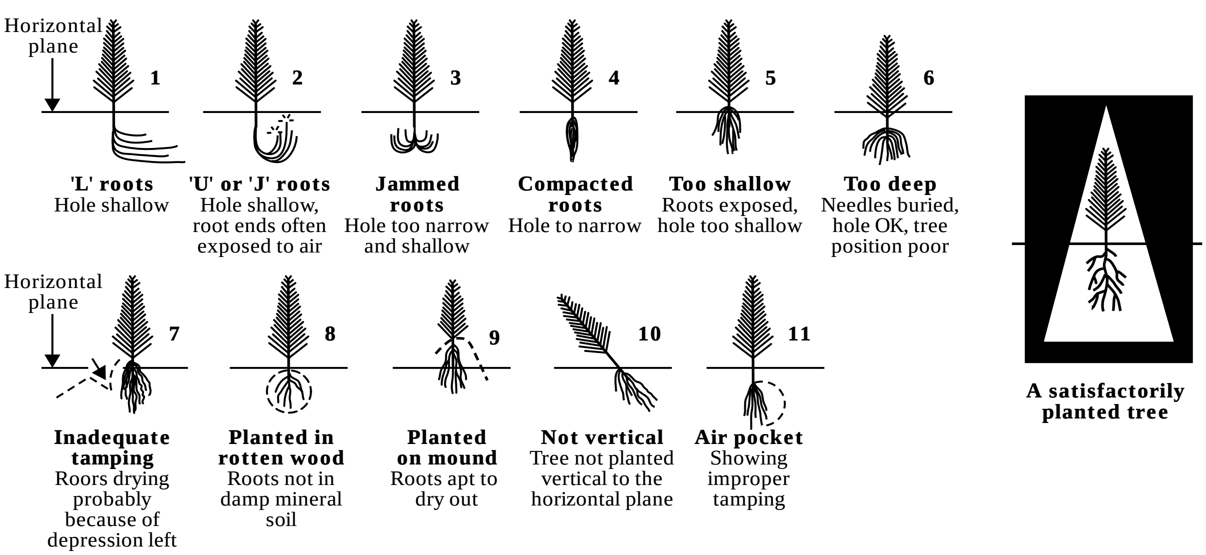
- Do not plant on hot, windy days.
- Do not plant when temperature is freezing or below.
- Do not plant when the soil is frozen or dry.

Bare root plants

Bare root planting methods include using either a tree planting machine or hand planting tools. Figure 4–1 illustrates satisfactory and unsatisfactory planting methods for bare root plants. Some key techniques need to be followed for both methods.

- Prevent roots from drying out by placing in a water-soil (mud) slurry, peat moss, superabsorbent (e.g., polyacrylamide) slurry, or other equivalent material.
- Plant seedlings in a vertical position with root collar even with or 1 inch below soil surface.
- Trench or hole must be deep and wide enough to permit roots to spread out naturally.

Figure 4–1 Drawings 1 through 11 illustrate ways that trees should not be planted; drawing 12 is an ideal planting



- Root pruning may be necessary to prevent improper root placement, such as "J" roots.
- Pack soil firmly around roots to eliminate air pockets.

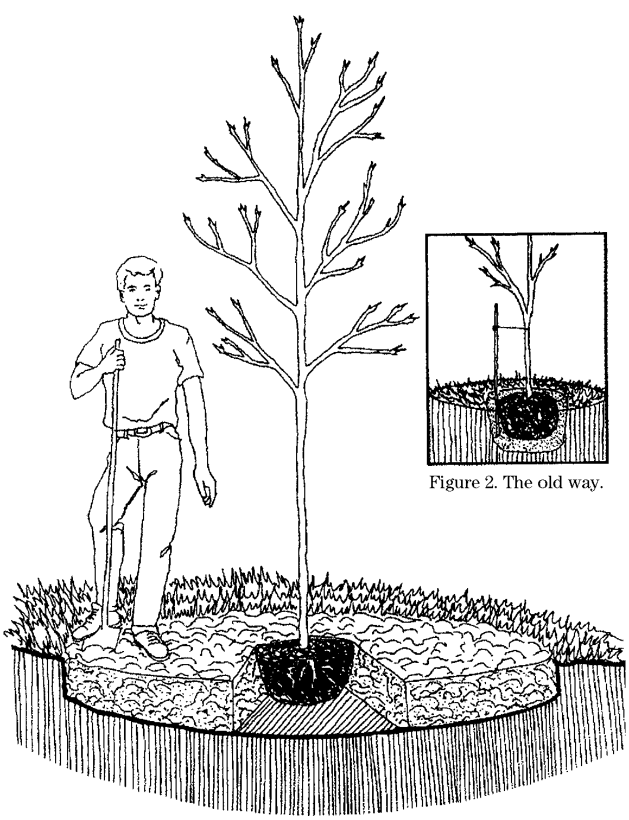
Container or ball and burlapped plants

Planting methods for these types are: container—Cut away the container and gently separate any pot bound roots. Any roots that are growing in a circle should be cut.

Ball and burlap plants—Place the tree into the hole, cut the string holding the burlap, and remove the burlap from around the root ball.

Figure 4–2 illustrates the proper way to plant ball and burlap plants. The preparation of the planting area is critical to tree survival and vigorous growth. Rather than digging a hole, prepare a planting area five times the diameter of the root ball. Set the tree on undisturbed solid ground in the center of the area so that the upper surface of the root ball is level with the surrounding soil. Cut or remove all wires or rope holding the burlap in place. Preferably, the tree should not be staked and protective tape should not be wrapped around the stem. Use water to pack or settle the soil around the root ball, and apply a 2- to 4-inch layer of mulch over the entire area. Do not create a water-holding berm by mounding the soil at the outer edge of the planting area.

Figure 4–2 The new way to plant balled and burlapped plants



Live cuttings

The following method is used for live cutting:

- Try to plant the cuttings the same day they are harvested. When this is not possible, store the cuttings in a cool, moist environment.
- Pretreat stored cuttings with several days of soaking just before planting.
- Insert cuttings to the depth required to reach adequate soil moisture and still have at least two to three buds aboveground.
- Pack soil around each cutting firmly to eliminate air pockets.

Post-establishment care

Fabric mulch may be used for weed control and moisture conservation for new plantings on all sites, particularly those with pronounced growing season moisture deficits or invasive, weedy species. Refer to the mulching standard and specification in the NRCS Field Office Technical Guide (FOTG) for installation procedures.

Planting grasses, forbs, and legumes

Site preparation

Site preparation for herbaceous buffers is dependent on the species selected and the site characteristics, such as soils, topography, and climate. Guidelines should be available or referenced in the local FOTG. General guidelines for perennial barriers of grasses and forbs include a seedbed that is firm and free of weeds. Many grass and legume seeds should be planted no deeper than 0.5 inch and must have good seed/soil contact. Record specific site preparation instructions in the Additional Specifications and Notes section of the specifications sheet.

Seedbed preparation for annual barriers of crop species can generally be completed in a fashion that is common and appropriate for the crop.

The runoff entering the buffer strips must be diffused and uniform. Any small gullies or channels that exist on the slope should be smoothed before seeding. Noxious weeds should be eliminated along with any debris, stones, or other obstructions that will effect the establishment, function, or maintenance of the buffer strip.

Methods of site preparation and planting must conform to local FOTG guidelines. Minimum surface disturbance is desirable to reduce the risk of erosion and runoff. Control weeds before filter strip establishment to avoid vegetation competition.

Planting methods

Generally, seeding is the preferred method of buffer strips establishment. If land is coming out of the Conservation Reserve Program or other land retirement program, existing vegetation can sometimes be left in the areas designated as buffer strips. Lime and fertilizer should be applied according to soil test recommendations before seedbed preparation. A firm seedbed about 4 inches deep should be prepared, and the seed drilled or broadcast and lightly covered. In some cases a no-till drill or direct seeder are used to seed buffer strips.

Record the planting method information in the space provided on the specifications sheet. Consider the use of mulching or a cover crop to aid with herbaceous buffer establishment. Identify the desired type of drill, such as disk opener or deep furrow, and the desired seeding depth. Guidelines should be available or referenced in the local FOTG.

Chapter 5 Marketing and Program Implementation

Getting conservation buffers on the ground

Establishing conservation buffers on privately owned lands through voluntary action is no easy task. Getting conservation buffers on the ground requires an understanding of how decisions are made by landowners and collaborative groups. Understanding why conservation buffers are adopted by some and rejected by others is fundamental to creating successful implementation strategies.

Basically people will adopt some practice, technology, behavior, or idea if they are both able and willing. A landowner's ability to adopt buffers is greatly influenced by the amount and type of technical information that are provided during planning. Willingness to apply buffers involves human behavior requiring the planner to be able to persuade and motivate landowners.

Several factors influence a landowner's *ability* to apply conservation, including:

- awareness
- access to appropriate information
- supporting assistance
- resources availability
- management skills

Factors affecting a landowner's *willingness to adopt* conservation include:

- inconsistent or conflicting information
- irrelevant solution or unrelated to landowner's needs
- ignorance of new technology
- perceived as too complicated
- too much risk and uncertainty

If buffers are not being adopted because of the landowner's lack of ability, then it is a technical problem. If the reason for not adopting is related to the landowner's willingness, then it is a social problem. Marketing provides a strategy to address both ability and willingness by addressing human behavior and perceptions.

Marketing conservation buffers

The goal of marketing is to meet people's needs or solve their problems while, at the same time, meeting the Agency's objectives. Marketing conservation is different from traditional business marketing because as public servants we have a mission and obligation to achieve a specific goal of resource management. A business sells/markets whatever the customer wants. Conservationists sell/market those things that meet the resource management objectives of the Agency and hopefully the objectives of the landowner. Conservation marketing attempts to persuade and motivate landowners to adopt and apply wise resource management strategies.

Traditionally, the strategy for getting conservation adopted was to find a key individual that would apply conservation and influence other individuals in the community to adopt the technology. This approach emphasizes the learning and communication processes of adoption. Recent approaches focus on the social, economic, political, and psychological environment rather than the role of the individual adopters. Thus the emphasis shifts to **marketing the innovation by meeting the needs of the adopter**.

Importance of marketing

Things have changed in the agricultural community. Landowners are a less homogeneous group than 50 years ago. The number of female landowners, part-time farmers/ranchers, absentee landowners, and other unique groups has increased. There are fewer middle-sized farms, while corporate farms, and small farms have increased. Farmers and ranchers are better educated and expect up-to-date information. Technical assistance by government agencies is declining as a result of limited and declining budgets. Marketing provides a framework to deal with the increased diversity of the agricultural community. Using marketing techniques to apply conservation buffers can save you time.

A marketing approach

The three key elements to conservation marketing are:

- Understanding what is important to the landowner and attaching a conservation behavior/practice to that value.
- Identifying and meeting the needs of the landowner.
- Providing solutions to landowner's problems.

Decisions are based on what is valued. If the landowner does not value it, it will not be adopted. People do things when they believe it is in their best interest, either economically or socially. Marketing provides a mechanism to influence or change what people perceive to be in their best interest. Economics are important to most people, but not always the strongest driving force. By identifying what is important to the landowner, conservation buffers can then be marketed to meet those needs and help solve problems.

Why people act for the public good

Landowner behavior to adopt conservation buffers is influenced by a variety of positive and negative mechanisms referred to as *social control*. One mechanism involves the internalization of goals and long-term perspective on the need for adoption. People must want to adopt the practices, be convinced of their benefit, and know how to find support and appropriate technologies.

Another mechanism involves peer pressure. Adoption may be based on fear that they will be criticized if they do not do it—(or if they do do it). Economics is another mechanism, either because it is profitable or because they may be fined. A fourth mechanism may be force. Regulation may cause fear of having someone come on their land and doing it to them or shutting them down.

The positive economic, peer pressure, and internalization mechanisms are viewed as voluntary, while the negative economic and force mechanism are viewed as regulatory. Even though both voluntary and regulatory mechanisms can be part of the overall implementation strategy, marketing relies solely on voluntary participation.

People do not buy things, they buy good feelings, solutions to their problems, self-respect, a secure future, and happiness. When marketing buffers, do not sell people a plan, sell them pride in ownership, security, self-respect, independence, or whatever their need might be. If people can be convinced conservation buffers can meet their needs, they will plant buffers.

Listen to landowners and focus on their values, needs, and problems. Attach conservation buffers to that which is important to them, not to you or the Agency. Conservation buffers need to be marketed as a way to meet their needs or as a solution to one of their problems.

Steps in developing an implementation marketing plan

Develop a local team of interested agencies and organizations
Select representatives from the planning area that have similar interests in resource conservation.

Establish goals and objectives
Know exactly what you want to do. Set a goal. Keep it realistic and achievable within a reasonable time.

Identify target clientele
Identify who needs to do something for you to meet your goal. This is your target audience for conservation buffers implementation or marketing plan.

Identify clientele needs and characteristics
Get to know your target audience. At minimum, you must learn:

- their primary problems, needs, or concerns;
- where they get resource management information;
- who they trust; and
- how they make decisions.

Evaluate the conservation buffer technology for social desirability

Determine if the buffer technology meets the following criteria:

Relative advantage—The landowner must perceive conservation buffers to be better than what they are presently doing.

Compatibility—Conservation buffers must be compatible with the landowner's problems or needs, existing values, past experiences, and management ability.

Complexity—The value of conservation buffers must be clear and the landowner must perceive conservation buffer technology as easy to master. Planting and maintaining conservation buffers must be shown to be relative to their benefits.

Testability—Conservation buffer technology should be demonstrated as a practice that can be experimented with on a limited basis. The potential of conservation buffers to be tried on limited basis reduces the risk associated with trying many new or innovative conservation practices.

Visability—Being able to see conservation buffer technology and its benefits greatly enhances the ability to persuade landowners to plant and maintain buffers. On-the-ground demonstrations have proven effective. Success is also possible using videos with image processed technology to show future benefits.

Develop a marketing plan for action

Link the conservation buffer technology to that which is important to the landowner. Convincingly demonstrate to the landowner how planting buffers will solve one of his or her problems, meet one of his or her needs, or address one of his or her concerns.

Ideas to help market buffers

- Organize workshops and field tours with landowners
- Send targeted mailings
- Seek speaking opportunities at organizational meetings and schools
- Perform onfarm visits and one-on-one consultation with targeted landowners
- Send news releases to the local newspaper
- Have the newspaper do a feature story
- Establish a demonstration site
- Air radio spots
- Do television interviews
- Sponsor a trivia contest on the radio with the winners to receive trees
- Develop a slide show
- Develop a model buffer demonstration to use at fairs, field days, or other such activities
- Solicit volunteers to help promote buffers
- Develop a coloring book for young people
- Develop a brochure
- Award locals for establishing buffers
- Put together a self-guided buffer tour
- Promote cost share opportunities
- Cooperate with other organizations in promotion of buffers
- Develop community education course at local college
- Develop a photo album of before and after pictures and success stories
- Send mass mailings to rural landowners
- Post fliers locally
- Feature buffers on radio news show
- Ask FFA chapter to demonstrate and promote buffers

Assuring success of a marketing plan

Provide prompt technical assistance. Timelines are the key to getting conservation buffer technology on the ground once the landowner indicates a willingness to apply. Marketing should not begin until prompt technical assistance can be provided. Partnerships and alliances are effective ways to leverage resources and provide timely assistance.

Building alliances

At the national level the conservation buffer initiative has a National Conservation Buffer Team consisting of members from Federal agencies, national agribusiness, associations of state conservation and agricultural agencies, environmental groups, and professional societies. However, contact with the landowner and community occurs at the local level. If the buffers are to receive wide spread support, local conservation buffer alliances should be considered. The organizational structure may already exist in a county conservation committee, a local environmental or farm organization, or other mechanism. An alliance may need to be developed specific to your marketing needs. The makeup of the buffer alliance could begin with those agencies and organizations that are mirrored in the National Conservation Buffer Team.

An effective alliance pulls agriculture and the community together for common goals. It increases resources, creates solutions, spreads the workload, and creates a broader awareness, recognition, and support for the value of conservation buffers. Its grass roots nature should also encourage support from state and regional sources.

The alliance should have well defined and supported tasks that each alliance member will support. Every member of the alliance should be an active participant in some aspect of the initiative.

Keys to successful partnerships

Establish a sense of need and direction—All partners need to know they are working toward a worthwhile purpose. They also need to know what is expected of them.

Select partners based on existing and potential skills, not personalities—Partnerships need technical or communications, problem-solving, and interpersonal skills.

Pay particular attention to early meetings and activities—First impressions mean a lot. People are often skeptical at the first meeting and may be suspicious of other partners.

Set some ground rules—The group probably needs to set specific ground rules related to meeting participation, discussion, confidentiality, constructive feedback, and expected contributions.

Start with a few short-term tasks that have a good chance for success—Be sure that early projects are realistic and will be seen as “winners” in the eyes of the partners.

Challenge the group regularly with fresh facts and information—New information (that you will be gathering as a partnership) helps to better understand your situation and improve your effectiveness.

Spend time together—It takes time to get the partnership working effectively. Spend time (outside of meetings if possible) to get to know each other.

Use the power of positive feedback, recognition, and reward—People respond to positive incentives in the partnership setting just as they do as individuals.

From: *Know Your Watershed,* Conservation Technology Information Center

Trees Forever
Iowa Buffer Initiative

Water quality is an important issue to every Iowan, and Trees Forever is working with several partners (over 12 public-private partners) on a revolutionary, first-of-its-kind program~~the~~ Trees Forever Iowa Buffer Initiative. The goal of the Iowa Buffer Initiative is to increase awareness and utilization of long-term land management practices and their impact on water quality, soil erosion, landscapes, and wildlife. The initiative will focus on establishing 20 demonstration sites for riparian buffers and other buffers in Iowa each of the next 5 years. The demonstrations will use riparian management technology developed by the Agroecology Issue Team of the Leopold Center for Sustainable Agriculture based at Iowa State University. This riparian buffer technology will improve water quality for all Iowans. The initiative has also trained over 100 conservation professionals through intensive workshops on buffer planning and implementation. Additional outcomes planned include:

- Trees as buffers around livestock confinement operations
- A recognition program for landowners who protect streams and waterways with grass and tree buffers
- Field days for farmers, rural landowners, and youth to increase awareness of the value of buffers

Trees Forever was founded in 1989 by two volunteers. An Iowa-based not-for-profit, Trees Forever has been the catalyst for projects in all of Iowa's 99 counties and in over 400 communities. Trees Forever is supported by individuals, corporations, foundations, and government .

Programs

Conservation buffers can be successfully applied with or without the use of specific programs. However, programs can be a valuable component of a marketing plan by offering economically attractive incentives to install and maintain conservation buffers. Many Federal, State, and local programs are available to assist in the application of conservation buffers. Some Federal programs are described here.

The Conservation Reserve Program (CRP) continuous signup

The continuous signup makes the use of conservation buffers economically attractive for landowners. This program allows certain conservation buffer practices to be established on cropland and marginal pasture. The land can be enrolled in the CRP at any time without having to go through the process of submitting a competitive offer. Check eligibility requirements.

CRP opportunities—Producers who have land under expiring CRP contracts that will go back into crop production can leave conservation buffers in place and enroll those buffer acres under the continuous CRP signup. The continuous CRP signup requires no competitive offer by landowners. All offers of land are automatically accepted if all eligibility requirements are met and the landowner is willing to accept the prescribed rental rate and whatever incentive might be available for a certain buffer practice. Rental rates are based on the productivity of soils and cash rent for comparable land in a county. Cost sharing is allowed for the establishment of conservation buffer practices under the continuous CRP signup. In many locations, other public or private programs will pay additional cost share. Filter strips, riparian forest buffers, grassed waterways, and windbreaks may receive additional incentive payments.

Environmental Quality Incentives Program (EQIP)

This program provides technical, financial, and educational assistance in designated priority areas. Half of the resources is targeted to livestock-related natural resource concerns and the set-a-side for other significant conservation priorities.

Wildlife Habitat Incentives Program (WHIP)

This voluntary program develops and improves wildlife habitat on private land. It provides both technical assistance and cost sharing to help establish and improve fish and wildlife habitat.

Wetlands Reserve Program (WRP)
This voluntary program helps landowners restore and protect wetlands. It provides an opportunity for landowners to receive financial incentives to enhance wetlands in exchange for retiring marginal agricultural land.

Stewardship Incentive Program (SIP)
Teamed with the Forest Stewardship Program, SIP provides cost sharing for improved management of private forest land through multiple practices and programs including tree-based conservation buffers, planning, tree planting, wildlife and fish habitat, recreation, riparian restoration, soil erosion control, and forest improvements.

Many state supported assistance programs support the National Conservation Buffer Initiative, and some private conservation organizations are making financial assistance available. Other groups may provide labor to help with vegetative establishment.

Technical support for implementation

Technical assistance providers also need good technical information to provide timely and accurate assistance to landowners. This publication provides a valuable technical reference. Other valuable sources of information are on the Internet at the following Web sites:

National Handbook of Conservation Practices and Buffer Job Sheets
http://www.ncg.nrcs.usda.gov/nhcp_2. html

Selecting and Sizing Buffer Practices for the Conservation Buffer Initiative
http://www.ftw.nrcs.usda.gov/tpham/buffer/akey.htm

Natural Resources Conservation Service Homepage
http://www.nrcs.usda.gov

Conservation Technology Information Center (CTIC)
http://www.ctic.purdue.edu/ctic/ctic.html

VegSpec
http://mimosa.itc.nrcs.usda.gov/NetDynamics/vegspec/pages/HomeVegspec.htm

Selected Agricultural Best Management Practices to Control Nitrogen in the Neuse River Basin
http://ces.soil.ncsu.edu/net/

National Agroforestry Center
http://www.unl.edu/nac/

Grazing Lands Technology Institute
http://www.ftw.nrcs.usda.gov/glti/homepage.html

Association for Temperate Agroforestry
http://www.missouri.edu/~afta/afta_home.html

Sustainable Farming Connection
http://sunsite.unc.edu/farming-connection/index.html

Greening Australia
http://www.greeningaustralia.org.au/

Riparian Zone Bibliography
http://www.serc.si.edu/serc_web_html/pub_ripzone.html

Sylvan Nursery Links
http://www.sylvannursery.com/links.html

American Nursery and Landscape Association
http://www.anla.org/

American Nursery and Landscape Association Publications
https://secure.resultsdirect.com/anla/publications/

Chapter 6 Economic Considerations—Buffer Practices

Introduction

The economic considerations of conservation buffers vary among regions, crops, individual farms, and types of production systems. The economics of buffer systems are affected by:

- acreage of revenue producing crops removed from production
- the number, spacing, and species of woody material
- livestock considerations
- the necessity of tree shelters
- site preparation

Table 6-1 lists potential effects, pluses (+) and minuses (–), of installing a riparian buffer system on most agricultural operations. Effects are separated into economic, social, and resource groupings.

To a particular landowner, any one of these potential effects could be the critical factor for deciding whether or to install a conservation buffer. The importance that producers will give each of these effects in the decisionmaking process depends on their particular resource setting and their own value judgments.

Table 6–1 is not an all-inclusive list nor is it meant to be limited to any one particular set of circumstances. For example, buffers designed to lower stream temperatures or provide streambank stabilization would not necessarily provide flood control benefits.

The above information can be used as a framework for the evaluation of a buffer system. After determining which effects will occur on a particular operation, quantitative values can be estimated.

Table 6–1 Summary display of effects of conservation buffers

Pluses +	Minuses –
Economic effects	
Potential future timber harvest	Loss of crop production/revenue
CRP rental payment and cost-share financial assistance	Maintenance costs
Reduced production cost	Installation cost
Increased potential residential value	Potential increased wildlife damage
Enhanced fee hunting/fishing opportunities	Potential need to relocate livestock
Potential flood damage reduction	
Social effects	
Aesthetic value (beautification of farmstead)	Change farming/cropping pattern
Perception from surrounding community as a conservation farmer	Uncertainty with management/maintenance
Resource effects	
Improve water quality	Limited use of certain pesticides on cropland
Lower stream temperatures	
Reduce gully erosion	
Increase terrestrial wildlife habitat	
Decrease sedimentation to stream	
Improved fish habitat	
Decreased turbidity	
Reduced potential of hoof disease for livestock	

Example case scenario

A 500-acre farm with a confinement hog operation has recently purchased a 160-acre unit. The new unit will provide an area for additional waste application. The crop rotation is a corn, soybean, and wheat system.

The onsite resource problems include erosion, worn out gradient terraces, and grassed waterways with erosion problems. Trees and shrubs have encroached onto the waterway. The farmer's objectives include replacing the terraces and tile and eliminating some of the waterways. An offsite water quality issue in the reservoir downstream has received increasing local attention from the community. The producer is interested in an economic evaluation of adding riparian forested buffers using the continuous signup feature of the Conservation Reserve Program (CRP).

The producer is considering a 35-foot wide buffer on each side of the stream. Even though all the 35 feet will be planted to grass, the first 15 feet will be planted to hardwoods. This will translate into 10 acres of hardwood seedlings, planted at a rate of 330 per acre, along with 24 acres of grass. The local forester has recommended that 50 percent of the trees be protected against wildlife damage with a plastic tube and a wooden stake. This percentage can vary greatly with local conditions and can greatly affect the final total installation cost of the buffer.

An efficient way of organizing and analyzing effects identified above is partial budget analysis. Partial budget analysis identifies and quantifies items that change (table 6-2) and then groups positive and negative effects in four main categories: added returns, reduced costs, added costs, and reduced returns (table 6-3). This section will briefly explain these four categories, with an emphasis on how they relate to conservation buffers and our case scenario.

Added returns

Added returns include those items that will increase income to the landowner. For conservation buffers, the landowner receives an annual CRP rental payment from the USDA based on soils information for the buffer acres.

Reduced costs

Reduced costs typically include variable production costs for the foregone crop production. Variable costs change as production is changed. If it goes up, these costs go up; if production goes down, these costs will go down. These types of costs would include all the material inputs that went into the crop production, such as tillage, seed, fertilizer, and machinery operating costs, including fuel and labor.

Fixed costs, which are those costs that do not change regardless of the amount of production, will remain the same. These costs would include the costs of owning farm machinery, buildings, and other capital that will not be affected by installation of the buffer. Examples are interest on a loan taken out for the equipment or insurance and taxes.

This type of information can be obtained from crop budgets, which typically break out these types of production costs on a per acre basis for several crops and types of conditions.

Reduced returns

Reduced returns include those items that will decrease the landowners revenue, and consist primarily of the income lost by the crop production foregone on buffer acres. This information can be obtained from crop budgets as well if estimates of crop price and yield are not available from the producer.

Special attention should be paid to the productivity of the land to be taken out of production. Productivity can vary quite extensively from overall farm or even field averages. In many areas, edges of fields can be the least productive ground to farm, because of more extensive wildlife damage, lower soil productivity, or periodic flooding. For this example, slightly lower yields are assumed for the cropland now set aside for the buffers.

Added costs

Added costs include those items that increase the cost to the landowner and are primarily made up of the buffer installation cost. Depending on the acreage, spacing, and necessity of tree shelters, forest buffers can be quite expensive to install. In this scenario, the landowner installed the buffer and obtained cost share assistance to help defray installation costs. Maintenance costs will also be incurred over time. CRP offers a flat reimbursement for annual maintenance costs that reduces the cost to the landowner.

Present values versus annual values

The installation costs for riparian forest buffers tend to be incurred at one time, typically in the initial year of establishment. However, some of the other costs and revenue changes occur annually rather than all at once, such as CRP rental payments, crop production costs and revenues, and buffer maintenance expenses.

To compare accurately these costs and benefits all values need to be converted to either average annual amounts, or one time, present value amounts. Average annual values are used in this example.

Conclusion

The analysis for this scenario indicates installing a riparian forest buffer to catch the onfarm sheet erosion and help solve the offsite water quality problem can be accomplished for an added cost of $1,449 (table 6–3) to the operation, or about $60 per acre per year. In this example the reduced returns and added costs are greater than the added returns and reduced costs. However, the other, noneconomic impacts should be considered as well. A potential client may decide that $60 per acre for the 24-acre buffer may be well worth the money in order to achieve any or all of the social and resource impacts that might occur.

Table 6–2 Data for economic evaluation of installation of riparian forest buffer

Reduced variable production costs calculation

	Corn		*Soybeans*		*Wheat*	
Cost Item	Conventional tillage ($/ac)	No-till ($/ac)	Conventional tillage ($/ac)	No-till ($/ac)	Conventional tillage ($/ac)	No-till ($/ac)
Machinery operating	1.68	0.67	1.48	1.36	1.97	1.49
Power unit operating	6.53	1.48	4.99	1.32	4.48	1.53
Labor	9.00	2.73	7.14	2.41	6.46	3.20
Materials	100.19	94.97	55.43	82.75	38.12	49.48
Manure spreading	2.80	2.80	2.80	2.80	2.80	2.80
Crop drying	15.72	15.72	—	—	—	—
Total	**135.92**	**118.37**	**71.84**	**90.64**	**53.83**	**58.50**

Reduced revenue calculation

Crop	Yield (bu/ac)	Price ($/ac)	Revenue ($/ac)
Corn	120	2.08	249.60
Soybeans	30	5.45	163.50
Wheat	50	3.31	165.50

Composite acreage calculation

Crop	Acres	Percent of total acreage	Variable production costs ($/ac)	Revenue ($/ac)
Corn	280	100%	135.92	249.60
Soybeans	280	100%	71.84	163.50
Wheat	100	36%	53.83	165.50
Total	**660**	**236%**	**226.99**	**472.21**

Forest buffer installation cost calculation

Item	Unit	Unit cost	Amount	$/acre
Seedlings	each	1.80	330	594.00
Tree shelters	each	3.10	165	511.50
Grass	acre	41.00	1	41.00
Total				**$1,146.50**

Note: All unit costs include labor and materials.

In many cases the land placed into the buffer area is less productive than the average for the field. If the revenue loss from the cropland placed in the buffer is $140 or less, installing the buffer would be economically profitable.

In many situations, the environmental benefits to the public offset the reduction in monetary benefits to the producer, suggesting that some public support may be worthwhile.

Table 6–3 Riparian forest buffer partial budget analysis

This situation is evaluated over a 10 year CRP contract period at 8 percent interest.

Added returns
Each year a CRP payment of $85.00 per acre is received for the 24 acres.
24 acres x $85.00 per acre = **$**2,040

Reduced costs
Each year the producer will not incur production cost for the land enrolled in CRP. A composite per acre cost (the percentage of each crop in the rotation) is $96.30/ac.
24 acres x $96.30 per acre = $2,311

The total of added returns and reduced costs = $4,351

Reduced returns
The producer will no longer receive the income for the crop production on the 24 acres. The composite acre is also used for this calculation.
24 acres x $200 revenue per acre = $4,800

Added costs
The producer will incur the cost of installing the buffer treatment components. There will be 24 acres of warm-season grass plantings at $41 per acre and 10 acres of mixed hardwood plantings at $1,147 per acre. The total installation cost is $12,454. The producer will receive 50 percent cost share, or $6,227. This will leave the producer with a responsibility of $6,227. For comparison purposes, this will be amortized over the 10-year evaluation period at 8 percent interest, for a total installation cost of $928.

The annual maintenance cost is $8 per acre. A management payment of $5 per acre reduces the producers cost to $3 per acre or $3 x 24 acres = **$**72.

Total of added costs = $1,000

The total of the reduced returns and added costs is $5,800.

The net change for the operation is $4,351 – $5,800 = – $1,449.

Glossary

Absorb
To take one substance into another.

Access roads
A vehicular travel way constructed to provide entry to an area.

Adsorb
To attach one substance onto another.

Agroecosystem
A managed or modified ecosystem that is used for agricultural production.

Alley cropping
Single or multiple rows of trees or shrubs with agronomic, horticultural, or forage crops grown in the alleys between the rows of woody plants.

Alternative farm income
Income not traditionally derived from the common agricultural enterprise.

Bareroot
A seedling whose roots are freed from the soil when lifted from the nursery. They must be dipped or packed in a moisture conserving medium.

Barrier porosity
The area of a barrier that is not occupied by vegetative material as viewed from the direction of the wind.

Berms
1. An elongated mound in a naturally level land area or one made artificially by a landscaper to gain privacy or interest in a private or public area. 2. A shelf or mound that breaks the continuity of a slope.

Best Management Practices (BMPs)
Management practices, such as nutrient management, or structural practices, like terraces, designed to reduce the quantity of pollutants, such as sediment, nutrients, pesticides, pathogens, salts, or heavy metals that are carried by wind or water energy from their intended area toward adjacent sensitive areas, such as surface water, urban areas, and ground water.

Biological control
1. Using living organisms to control other living organisms that cause detrimental impact to man's objective; i.e., insects, fungus, and diseases. 2. A method of controlling pest organisms by means of introduced or naturally occurring predatory organisms, sterilization, the use of inhibiting hormones or other methods rather than chemical or mechanical means.

Buffer width or flow length
The distance that wind- or water-borne sediment, nutrients, and runoff have contact with the vegetated buffer area.

Canopy
The more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent plants above the ground. Canopy cover is above the soil surface.

Companion crops
Two or more species of vegetation grown in the same field at the same time. Generally, one species has a primary function while the other performs a second tunction. As an example, a crop grown to reduce wind erosion damage to newly established wind barrier.

Conservation buffers
Areas or strips of land maintained in permanent vegetation to help control pollutants and manage other environmental problems.

CRP
Conservation Reserve Program; Federal land retirement program starting with the 1985 farm bill.

Container grown seedlings
Seedlings that are grown in small pots or tubes and planted with soil or growing media intact around roots.

Contaminant
A material contained in another substance that would no longer make that substance pure.

Contour buffer strips
Strips of permanent vegetation alternated with wider cultivated strips that are farmed on the contour.

Contour line
An imaginary line on the land connecting points of the same elevation; an elevation line on a map.

Critical area planting
1. An area that because of its size, location, condition or value must be treated with special consideration because of inherent site factors and difficulty of management. 2. A severely eroded sediment producing area that requires special management to establish and maintain vegetation.

Crop tolerance
The capability of a crop to withstand stress caused by the environment, competition, or human applied inputs.

Cross wind trap strips
Areas of herbaceous vegetation resistant to wind erosion and grown in strips perpendicular to the prevailing wind direction.

Cuttings
A short length cut from a young, living stem, branch, or root for propagating, i.e., for producing a whole new plant in soil or other media.

Denitrification
The process by which nitrate-nitrogen is converted to nitrogen gas by soil organisms under anaerobic conditions.

Deposition
The settling out of soil and organic particles by forces of gravity against the forces of wind and water energy.

Desiccation
The drying out or loss of moisture from the aerial parts of a plant or other material.

Detachment
The process of a soil particle or chemical compound breaking free from its position on the soil.

Detritus
Fragments of organic or rock material that is partly disintegrated and deposited by gravity in low-lying areas.

Drainage ways
Constructed or natural concentrated flow path of water off the landscape.

Ecological (ecology)
The relationship of plants and animals to their environment.

Ecological function
A collection of physical, chemical, and biological processes that act to create a landscape condition.

Electrostatic charges
Stationary electrical particles that form on the surface of material and react to static electricity.

End row
The rows along the edge of the field usually perpendicular to the majority of the rows in a field. Also known as headlands.

End-turbulence
In reference to a windbreak, it is the tumbling of the wind as it whips around the ends of a windbreak or shelterbelt reducing its zone of protection.

Entrapment
The stopping of movement by physical, chemical, or biological forces as one substance passes through another.

Ephemeral gully
A shallow concentrated flow path that develops as a response to a specific storm and disappears as a result of tillage or natural processes.

Eutrophication
The enrichment of a body by influx of nutrients and energy.

Evapotranspiration
The conversion of water, whether open, as soil moisture, or within plants, by evaporation or transpiration into water vapor that is released into the atmosphere.

Field border
A band or strip of permanent vegetation established on the edge of a cropland field.

Filter strip
An area of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants from runoff and to maintain or improve water quality.

Filtration
The physical stopping of movement of one substance as it passes through another. Relative size differentials (one substance too big to pass through the other) accounts for most filtration.

Function
A process or mechanism performed because of physical, chemical, or biological conditions or actions that usually results in a product.

Furrows
Narrow grooves made in the soil surface by mechanical equipment.

Gradients
Change of elevation, velocity, pressure, or other characteristics per unit length; slope.

Grassed waterway with vegetated filter
A natural or constructed vegetated channel that is shaped and graded to carry surface water at nonerosive velocity to a stable outlet or that spreads the flow of water before it enters a vegetated filter.

Ground cover
Plants used to cover the ground generally for the purpose of preventing erosion.

Ground water
The water that occurs beneath the Earth's surface between soil and rock particles and that supplies water to wells and springs.

Headland
The rows along the edge of the field, usually perpendicular to the main rows in the field, used to turn equipment and travel along the field border. Also known as endrows.

Herbaceous wind barrier
Tall grass and other nonwoody plants established in 1- to 2-row narrow strips spaced across the field perpendicular to the normal wind direction.

Hydrologic cycle
The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Infiltration
The movement of water or other substances from the free surface of the soil into the soil profile.

Integrated approach
A means to identify, blend, and balance all of the desired conditions of the landowner and other stakeholders into a buffer design. It helps managers consider and account for multiple desired conditions and the ecological functions that affect each condition.

Intercropping
1. The planting of field crops among trees. 2. The planting of several crops together on the same land.

Interface
The line between the contributing area upgradient from the buffer area and the buffer itself.

Inundation
Covering over with water.

J-rooting
A term used to describe the root development when bare rooted seedlings are improperly planted causing the roots to bend upward in the planting hole forming a J or L.

Landscape diversity
A landscape with multiple land uses and plant cover types.

Leeward
Downwind.

Loading
The influx or movement of pollutants into a particularly body, whether it be a water bodyor vegetated buffer.

L-rooting
See J-rooting.

Main bole
The primary stem of a multistem tree or shrub.

Microclimate
The climatic conditions of a small area resulting from the modification of the general climatic conditions by local differences in elevation, exposure, or vegetation.

Migration
To move from one location to another.

Mineralization
The conversion of soil organic matter and other organic material into inorganic substances by microbial breakdown.

Natural regeneration
Reproduction, revegetation using existing parent species on the site to re-establish a stand. Most commonly used with trees or annual grasses or forbs.

Neotropical migrant birds
Birds that fly south of the United States border each winter and return in the spring.

Nitrification
The oxidation of ammonia to nitrites and nitrates.

Nonselective herbicides
Weed control chemicals that have no specific tolerant vegetation.

Noxious weeds
Weeds that are designated by State and local authorities to have severe economic and health impacts on the environment.

Nurse trees
Trees used to train, develop, or protect more valued crop trees. Used to increase the growth rate and improve the form of the high value interior tree row.

Nutrient
Chemicals needed by plants and animals to develop growth and produce products.

Nutrient cycling
The movement and transformation of nutrients through various chemical, physical, and biological processes.

Nutrient management
The management of the form, rate, timing, and method of application of nutrients, including nutrients from biosolids, being applied to the soil in a manner that provides adequate plant nutrition, but minimizes the environmental impact of these nutrients.

Overstory
The portion of the trees in a forest stand forming the upper crown cover.

Percolation
The movement of water or other substances, usually downward by gravity force, within the soil profile.

Pest management
Managing pests including weeds, insects, diseases, and animals.

Pollutant
A level of contaminant material in a substance that would impair the use of that substance.

Ponding
The buildup of water levels in depression areas.

Purpose
The action or process desired by a specific practice or series of practices. The end result of the purpose is usually a benefit to production or the environment.

Residue management
The production, distribution, and final deposition of crop residue to enhance soil carbon, wildlife, and soil moisture, and to reduce soil erosion.

Riparian Ecosystem Management Model (REMM)
A computer model designed to predict the effectiveness of riparian vegetation in protecting water quality.

Riparian forest buffer
An area of trees and shrubs located adjacent to streams, lakes, ponds, and wetlands.

Root collars
The area that separates the stem from the root of a tree and is usually found at the soil line and distinguishable by a small callous-like ring around the seedling.

Runoff
Water that is not absorbed by the contributing area, but rather drains off by surface or subsurface flow onto the area of other land and waterbodies.

Run-on
Water that is received from the contributing area onto a land area, such as a vegetated buffer.

Saltation
The bouncing of soil particles along the soil surface by the forces of wind.

Secondary functions
Functions that are derived from practices and can be designed for the primary purpose, but are not the main purpose for which the practice was installed to address.

Sediment
Particles or aggregates of soil or organic material that are transported from one location and deposited in another.

Sequestration
To capture and make unavailable for biological processes.

Setbacks
Distances from sensitive areas where normal operations are modified, even eliminated, and other management practices and techniques are implemented.

Silt fences
A fabric or other material put up to serve as a barrier for the expressed purpose to trap sediment.

Skidding of trees
A loose term for hauling loads of logs by sliding, not on wheels, as from the stump to the deck or other landing.

Spawning
Reproductive activity of fish.

Spoil
Soil or rock material removed from ground excavation and surplus to or unsuitable for immediate or ultimate requirements.

Stakeholders
People who have a vested interest in any particular activity.

Surface creep
The rolling movement of soil particles along the soil surface caused by the forces of wind.

Suspended solids
Organic and inorganic particles that are suspended and carried by wind or water.

Total phosphorus enrichment ratio (PER)
The ratio of total P contained in sediment eroded from a field to the total P contained in the soil of the field.

Trainer trees
Outside rows of hardwood species will tend to bend toward the light in the alleyway thus reducing their wood value except for chips. See nurse trees.

Transformation
The changing of substances by physical. chemical, or biological processes into another substance or substances.

Translocation
1. The movement of solutes within and between the tissues of a living tree. 2. The movement of carbohydrates and other organic substances within the phloem.

Upgradient
The area or surface of material that lies above or upslope from another.

Vegetative barrier
Narrow, permanent strips of stiff stemmed, erect, tall, dense, perennial vegetation established in parallel rows and perpendicular to the dominant slope of the field.

Vegetative biomass
The total organic production of plants above and below ground in a particular habitat.

Vertisols
Clayey soils with high shrink-swell potential that have wide deep, cracks when dry. Most of these soils have distinct wet and dry periods throughout the year.

Volatilization
The transport of substance by vapor.

Wick application
The application of pesticides, particularly herbicides, by a braided fiber.

Windbreak/shelterbelt
Plantings of single or multiple rows of trees or shrubs that are established to protect soils from wind erosion, protect sensitive plants, manage snow, improve irrigation efficiency, protect livestock and structures, and create or enhance wildlife habitat.

CORE4 Key Conservation Practices

Practice Integration

Buffer Design Considerations for Fish and Wildlife

Conservation buffer practices are useful in addressing a variety of natural resource concerns on the agricultural landscape, including fish and wildlife benefits. However, additional attention to fish and wildlife considerations is needed to maximize benefits realized through installation of buffer practices. Although the principles addressed in this section are presented to apply to conservation buffers, they can also be applied to fish and wildlife considerations in conservation tillage, nutrient management, and pest management planning.

Fish and wildlife habitat

The welfare of fish and wildlife depends on the availability of habitat.

Habitat is the term used to describe the ecosystem in which a species lives. Each species responds differently to physical variables in the ecosystem including the pattern of patches, corridors, and the dominant cover type, or matrix. For example, wildlife differ in their ability to disperse. Some species, such as reptiles, have physical limitations; others have behavioral or physiological limitations. Most species are not limited in their ability to use linear habitats, but experience high levels of mortality dispersing across open landscapes and other areas of unsuitable habitat.

Each individual species has a unique set of habitat requirements. In this sense, the term *habitat* is most useful when linked with a species, or in some cases, a group of species that share similar habitat requirements (e.g., grassland nesting birds).

Habitat consists of three primary components that, combined with space to live, are required for survival.

Food—Most species have specific plant or animal food preferences, while others consume a wide variety of food items.

Cover—All fish and wildlife species need various types of cover to survive. Escape cover allows individuals to avoid predators. Thermal cover is needed to regulate body temperature, particularly critical in winter for many species. Cover is needed for breeding, nesting, and rearing young (reproduction cover) as well as for resting, loafing, and roosting.

Water—Access to water in some form is necessary to sustain life. Most wildlife need free water access within their home range throughout all seasons of the year.

While food, cover, and water are the essential elements of fish and wildlife habitat, these different components must be distributed on the landscape in a manner that provides reasonable access.

Populations cannot be sustained if food is abundant for an individual species, but there is no cover in which to hide, nest, or rear young.

Likewise, what may appear good habitat in one season may be unsuitable to sustain species populations during other seasons of the year. Thus, for nonmigratory species, all habitat components must be available in all seasons.

For migratory species, such as neotropical migratory songbirds, numerous fish species, and waterfowl, habitat that supports reproduction on the breeding grounds, successful wintering, and migration back and forth must be available to sustain healthy populations.

Instream aquatic habitat

Habitat quality for fish and other aquatic organisms associated with stream systems relies on several factors.

Shading—Many fish species, especially salmonoids and other cold-water species, cannot tolerate elevated water temperatures. Riparian areas that are heavily vegetated can moderate stream temperatures by shading the stream in summer and providing a buffer from extreme cold in winter.

Large wood—Riparian forests are sources of large wood that, when it falls into the stream, provides structural complexity to stream channels. Instream wood often results in the development of pools that can slow streamflow and provide fish refuge from high velocity water, hiding cover and over-wintering habitat. Also, instream wood increases the retention time of smaller organic detritus by capturing leaves and twigs in branches and roots. This allows more time for aquatic invertebrates to break down the detritus, supporting the food chain that sustains fish and other vertebrate species. Instream wood is also habitat to some aquatic insects.

***Organic matter input*—**In upland streams that are shaded by streamside forests, as much as 75 percent of the organic food base is supplied by dissolved organic compounds or detritus, such as fruit, limbs, leaves, and insects that fall from the riparian canopy. Benthic detritivores, the stream bottom bacteria, fungi, and invertebrates that feed on the detritus form the basis of the aquatic food chain. They pass on this energy when they are consumed by larger benthic fauna and eventually by fish.

***Minimum sediment load*—**Riparian ground vegetation acts as an efficient filtration system by removing sediment and other suspended solids as well as sediment-bound nutrients and pesticides from surface runoff. This function is critical for maintaining good water quality.

***Nutrient assimilation*—**Streamside riparian areas function as a sink when nutrients are taken up by plants and stored in plant tissues. In wetter areas, nutrients in leaf litter may be stored for long periods as peat. Also, sediment filtered out by vegetation remains in the riparian sink to become incorporated into riparian soils.

Fish and wildlife challenges

Habitat loss

Habitat loss and degradation is probably the greatest influence on fish and wildlife populations today. Loss of some original habitats illustrate this point:

- 90 percent of the native grasslands east of the Mississippi River are gone.
- 90 percent of Iowa's original wetlands have been removed.
- 80 percent of Indiana's forests have been eliminated.
- 85 percent of inland water surface area is artificially controlled

Habitat losses of this magnitude permanently displace many species and dramatically depress the population levels of others. It forces remaining species into the few remnant patches available, increasing competition, crowding, stress, and the potential for disease outbreaks.

Habitat fragmentation

Habitat fragmentation results in reduced habitat patch size and increased edge. As remnants of native habitats become smaller, they are less likely to provide food, cover, and the other resources necessary to support the native fish and wildlife community. Small patches are also more susceptible to catastrophic disturbance events, such as fire or severe weather that can decimate local populations. Although an increase in edge (the boundary between two plant communities) resulting from fragmentation may benefit some species, some researchers believe that increasing edge may be detrimental to the protection of native biodiversity.

Exotic and invasive species

Introduced exotic and invasive plants and animals place an additional stress on native ecosystems. In some instances, invasive weed species may completely replace native vegetation relied on by native wildlife for food and cover. Non-native species threaten as much as two-thirds of all endangered species. These species are now considered by some experts to be the second most important threat to biodiversity, after habitat destruction.

Predators and nest parasites

Edges act as barriers on fragmented landscapes, causing some predators to travel along them. High predator densities along edges can result in higher mortality for edge dwelling prey species or species moving through narrow corridors. Nest parasitism by brown-headed cowbirds also appears to be higher in species nesting in edge habitat.

Environmental contaminants

Exposure to environmental pollutants places additional stressors on fish and wildlife populations. Use of pesticides and other agricultural chemicals has contributed to significant impacts to fish and wildlife populations in the past (e.g., DDT), making proper application critical.

Urbanization

Urbanization of rural landscapes and encroachment of human developments continue to place pressure on many fish and wildlife populations. Significant habitat loss is attributed each year as rural areas are developed for housing and other urban uses. Wildlife losses to free-ranging house cats and dogs associated with suburban areas are also significant. In addition, millions of migrating songbirds are lost annually to collisions with radio towers and similar artificial structures.

Modification of natural disturbance

Modification of natural disturbance regimes has also contributed to loss of habitat quality in many ecosystems that evolved under periodic disturbances, such as fire and flooding. Where fire, flooding, and other natural disturbances are suppressed, native plants are frequently unable to regenerate, gradually shifting community structure unsuitable for many wildlife species.

Conservation buffers—habitat restoration opportunities

The interest in establishing 2 million miles of buffers through the National Conservation Buffer Initiative provides an excellent opportunity to address many challenges facing fish and wildlife on the agricultural landscape today. By consciously considering the needs of fish and wildlife, a landscape fabric that supports both healthy fish and wildlife populations and productive agricultural operations can be established.

Buffer practices can be used to address specific fish and wildlife habitat objectives. Examples include establishing forest riparian buffers along waterways to restore degraded fish habitat, and establishing field borders and vegetated barriers to provide habitat and travel ways for upland wildlife.

Buffer practices specifically directed at resolving other natural resource problems, such as soil loss, nutrient management, and crop protection, may also provide substantial fish and wildlife benefits with a little additional planning. In most cases, certain fish and wildlife species are desired by the landowner or targeted by local planners to be featured. The habitat requirements of these species need to be considered in designing buffer practices. In addition, adjacent land uses also need to be considered in designing buffer practices to benefit fish and wildlife.

Considering the habitat needs of fish and wildlife help meet the wildlife objectives of the Farm Bill programs support onservation buffers establishment.

Buffer design principles for fish wildlife

Develop reliable food sources

The types of wildlife foods vary by the targeted species and the native plant community. Plants that produce fleshy fruits and berries are commonly used by a wide variety of birds, mammals, and aquatic species.

Vegetative bude, grass seeds, and annual forbs are common food items for a variety of species. A diverse herbaceous structure supports insects and other invertebrates fed upon by many birds and mammals.

The key to providing adequate wildlife food is maximizing the variety of food sources available on the farm and in the surrounding area.

Wildlife food plants should be selected based on the food requirements and preferences of the wildlife species targeted and local soils, topography, climate, and other considerations. Selection of plant materials must also consider the soil conservation, instream habitat, water quality, or other objectives of the buffer practice being established. Native plant materials should be used wherever feasible to support restoration of native floral and faunal communities.

Develop horizontal structure

Horizontal structure refers to the arrangement of different habitat types. Components of horizontal structure would include forests/woodlands, shrubby areas, grasslands, cropland, urban areas, lakes and streams, and wetlands. The intricacy with which these different features are woven together or interspersed affects the overall habitat quality of the landscape. For example, grasslands afford certain benefits to wildlife when they exist on their own. The same is true for a windbreak and a wetland. However, when these three habitats are arranged in proximity to each other, the overall habitat value for many species is greater than the sum of the parts. Wildlife can move safely in each habitat type, exploiting the benefits offered by each.

In developing horizontal structure, the number and types of vegetation clumps should be maximized within the buffer zone. This will support small mammals and other wildlife species needing a variety of vegetation types in a relatively small area.

Develop vertical structure

Vertical structure refers to the layers of different plant forms and sizes in the plant community. Complex forested plant communities may have five or more layers; from top to bottom, they are the canopy, understory, shrub layer, herbaceous layer, and forest floor. At the other extreme, a wheat field for example, generally has only one layer—wheat.

Vertical structure has a significant influence on the diversity of wildlife species present in the community. Different layers offer food, water, cover, shelter, or breeding sites to different species, resulting in a rich diversity of wildlife using one habitat type. Each species fills a niche, or specialized position, in the community. However, some species that evolved in grassland habitat, such as the lesser prairie chicken, require simple vegetative structure with diverse plant species composition. Depending on the buffer practice being implemented, vertical structure should be maximized wherever possible.

The structure of streamside plant communities also affects aquatic species by contributing organic material to the aquatic food web, shading the water surface, providing cover along the banks, and influencing bank and channel structure through input of wood.

Maximize buffer width

Buffer width is associated with several landscape functions: habitat, conduit, source and filter, and barrier.

Habitat functions**—**Buffer practices serve as corridors of habitat for wildlife populations moving through them. The longer it takes a species to move through the corridor, the more important its habitat function becomes. Wider corridors reduce area and edge effects within the corridor. Thus, a broader range of species, including interior species, is more likely to use a wider corridor. Where streams are present, wider buffers provide more organic matter to the aquatic ecosystem.

Conduit functions**—**Wider corridors reduce edge effects for individuals and populations moving through them. Optimum width is determined by the strength of the edge effect and species requirements. Narrow corridors may be associated with higher levels of predation and nest parasitism than wider buffers.

Source functions**—**Wider buffers are more likely to act as a population source (adding individuals) than as a sink (removing individuals).

Filter and barrier functions**—**Wider buffers provide more effective filtering of surface sediment, nutrients, and pesticides. This is especially important in areas next to waterbodies.

Landscape placement

Buffers planned to benefit fish and wildlife should be viewed from a landscape perspective. Home range size of target species should be considered to ensure that all three basic habitat elements of food, cover, and water are reasonably accessible by individual animals.

Vegetation established within the buffer should be compatible with the native ecosystem in which the practice is being established. For example, establishment of exotic conifer trees in a native prairie grassland ecosystem may be counterproductive to restoration of native grasslands.

Wherever possible, buffer practices should be linked across land ownership boundaries to support populations within the watershed. This is particularly important in stream restoration efforts.

Provide travel lanes

Buffers should be viewed in the context of providing travel corridors for wildlife that connect patches of habitat on the landscape. Maintaining historical connections between patches is essential in maintaining species diversity and population viability within a watershed. Preventing fragmentation of existing corridors that connect patches is less expensive than restoring connections. In many cases, however, it may be necessary to restore historical connections between patches. Establishing buffers can serve this need. Historical vegetation (the vegetation that existed before fragmentation) should be used in restoring corridor connections.

Where feasible, consider developing parallel or alternate wildlife corridors linking habitat patches on the landscape. If multiple paths exist for an animal to get from one point to another, the animal is more likely to complete the journey. The fact that animals may not recognize a corridor as a conduit to a destination should be considered. They recognize it as a continuation of attractive habitat, and once inside, their movement is restricted and channeled by the corridor's linearity. It is usually a chance occurrence that they make it from one end of the corridor to the other. The more chances there are for that movement to occur, the more likely it is to occur.

Multiple corridor connections between habitat patches also safeguard the system from disturbances resulting from periodic management actions and natural disasters.

Optimize vegetation diversity.

The key to providing good wildlife habitat in most settings is maximizing the diversity of vegetation. Use native plant materials where possible. In some cases where seed source is available onsite, natural regeneration may provide suitable habitat. Consider year-round food and cover needs of the target wildlife species to ensure the habitat can support viable populations throughout the year.

Management and maintenance

Mimic natural disturbance**—**Fish and wildlife species evolved under natural disturbance regimes, and maintenance of good habitat quality frequently relies on periodic disturbances, such as fire, wind, ice storms, floods, and grazing and browsing by wildlife. Natural disturbances may occur at a localized scale or may affect broad regions of the landscape.

In many instances, humans have modified natural disturbance patterns that result in long-term habitat degradation. One example of this is fire suppression on prairie and other ecosystems that rely on fire to sustain ecosystem health.

Managers need to recognize natural disturbance regimes and incorporate them into the landscape wherever feasible to sustain native fish and wildlife habitats. Where natural disturbance regimes have been altered, wildlife habitat can be established and maintained by using such practices as timber harvest, cultivation, prescribed burning, and prescribed grazing. Use of these practices should mimic natural disturbance regimes to the extent possible.

Buffer areas can be managed and maintained so that fish and wildlife are benefited while meeting other buffer practice objectives.

Consider landowner and other conservation objectives—When establishing a maintenance protocol to maximize fish and wildlife habitat value, landowner objectives should be considered to ensure that disturbance actions are compatible with the farming or ranching operation. Disturbance actions should be tied to local climate conditions; for example, prescribed burning may not be conducted during times of drought. Any disturbance action taken to maintain or improve wildlife habitat conditions must also consider how it affects water quality, erosion, and other buffer practice objectives.

Along with the traditional tools for management, there are emerging technologies that enhance managers' ability to maintain vegetation in a particular successional stage. One method recently developed is the "weed sweep" method of applying herbicide to shrubs and taller vegetation to maintain areas in early successional stage without mowing or other practices that remove a majority of the vegetation. Using weed sweep technology can enable landowners to maintain functional field borders while providing cover for terrestrial wildlife.

Specific buffer practices—wildlife considerations

Contour buffer strips

Contour buffer strips are composed of herbaceous, perennial vegetation. The state standard for the practice establishes guidelines for establishment, where layout is dictated by cropping regime, slope, soil texture, climate, equipment used to crop the field, and other factors. However, efforts can be made to maximize wildlife benefits within state standards and specifications.

Plant materials should be selected to benefit wildlife. Where sod-forming grasses are called for to slow water and sediment movement downslope, grasses that allow wildlife movement near the ground should be selected. These grasses include switchgrass, bluestems, and other native grasses. Where feasible, legumes and other forbs should be encouraged to maximize diversity within the contour buffer strip.

Residual cover left standing over the winter can provide critical thermal and escape cover for wildlife within otherwise barren agricultural fields.

Where mowing is required to maintain the practice, it should be delayed until after the nesting season for most grassland nesting birds in the area. Mowing dates sensitive to the nesting season range significantly throughout the country.

Field borders

Field borders can be used to effectively link buffer practices and other wildlife practices and habitats on the landscape in a flexible manner. Since the purpose of the field border is to provide turning areas for farm equipment and buffer adjacent areas that may be sensitive to agricultural operations, a greater variety of plant materials may be selected.

As with contour buffer strips, plant materials should be selected that provide food and cover for the wildlife species of interest. Native grasses and forbs that provide residual cover in winter are most beneficial for a variety of wildlife.

Where needed for maintenance, mowing should be delayed until after the nesting season for the area.

Alley cropping

Alley cropping systems are designed primarily to grow crops between rows of high value trees. These systems can be modified slightly to benefit wildlife. Rather than keeping the ground clear beneath the trees through tillage of herbicide application, use ground covers that provide wildlife food and cover. Nitrogen-fixing legumes, such as clovers, aid in tree growth while providing wildlife habitat.

Plant fruit-bearing shrubs between or adjacent to the trees. Plants with fruit lasting long into winter provide necessary winter wildlife foods.

Instead of a single tree row, plant two of three rows of trees, creating wider strips of trees between crop alleys. This adds to the cover capability of the planting. With proper planning, the tree rows can be used as travel lanes to connect other food, cover, or water resources. The added shrub rows and ground cover enhance wildlife habitat quality.

Alley cropping is an intensively managed system that benefits wildlife. With a little planning, adding native plant components can increase the attraction of desired wildlife species.

Vegetative barriers

Vegetative barriers is a new practice that can be used alone or in combination with other practices to control soil erosion. Wherever possible, native vegetation that maximizes wildlife food and cover in the area should be used.

Filter strips

Filter strips provide an opportunity to establish travel corridors and permanent vegetative cover for wildlife. While the primary purpose of filter strips is to reduce nonpoint source pollution, maximizing vegetative diversity within the filter strip also provides fish and wildlife benefits. As with other buffer practices, plant materials selected should provide food and cover to local wildlife where possible while still serving to adequately filter runoff entering the filter strip from adjacent cropland.

Mowing should be delayed until after the nesting season, or alternate means of maintenance of the filter strip, such as use of the weed sweep technique, should be used to minimize impacts on nesting wildlife. Likewise, residual cover should be maintained through the winter to provide winter habitat for birds and mammals.

Field windbreaks/shelterbelts

The diversity of ecological niches and weather protection afforded wildlife by windbreaks are particularly important in agriculturally dominated landscapes. Windbreaks provide food, nesting, brooding, loafing, thermal, and escape cover for many species of birds and mammals. They are also used as travel lanes by both migratory and nonmigratory species. Windbreaks are important resting stops for songbirds during spring and fall migration. At least 108 species of birds are known to use shelterbelts for foraging, nesting, or resting.

When designing a windbreak for wildlife, include plant species and arrangements that provide food and cover for desired wildlife species. Where feasible, connect planted windbreaks to other planted or natural sources of cover and water sources, such as wetlands, streams, and ponds. If the windbreak cannot be positioned to connect with these areas, vegetative barriers or other buffer practices may be established to provide travel corridors between the windbreak and other habitats.

Several rows of crop left standing adjacent to the windbreak may provide additional fall and winter foods. Alternatively, a strip along the windbreak may be tilled, but not planted to release annual forbs. This provides additional wildlife food and cover.

Mix plant species and lifeform within the windbreak to maximize habitat diversity. Planting types of plants in a clumped distribution increases heterogeneity and quality of habitat. Snags should be left in the windbreak to provide foraging sites for woodpeckers and cavity trees for cavity nesters.

Wider windbreaks generally provide better wildlife cover. A single row windbreak has far less value to wildlife than a multiple row planting.

If drifting snow is a problem, plant a trap row of shrubs 50 to 100 feet away on the windward side to help keep snow out of the windbreak.

Herbaceous wind barriers

Herbaceous wind barriers should be used to link areas of more natural habitats wherever possible to provide wildlife travel ways across open land. Native vegetation that provides food and cover for local wildlife should also be used.

Cross wind trap strips

Cross wind trap strips provide an additional opportunity to provide wildlife habitat on the agricultural landscape. Native grasses and forbs should be selected that provide food and cover to local wildlife. Wherever feasible, these buffer areas can be linked with other habitat to provide travel corridors.

Mowing should be delayed until after the ground nesting bird nesting season, and winter residual cover should be made available in these areas wherever possible.

Riparian forest buffers

Riparian forest buffers should be established along streams to provide upland wildlife habitat as well as to improve aquatic habitats both within the affected stream reach and in downstream lakes, rivers, and estuaries.

As with other buffer practices, a diversity of native trees, shrubs, and forbs should be encouraged. Tall, streamside trees with spreading canopies should be encouraged to provide shade, organic matter input, and large wood to the stream.

Riparian forested buffers are vulnerable to adverse impacts caused by upland management practices. The best place to address these impacts is not at the edge of the riparian corridor, but at the point of origin —in the uplands. Conservation practices that reduce the amounts of sediment, fertilizer, and other pollutants leaving the field in runoff and erosion will support healthy riparian corridors. They vary by region and land use, but generally include the following recommendations:

- Cease cultivation of highly erodible soils on steep slopes.
- Use contour farming, stripcropping, and other such practices to reduce erosion on long slopes.
- Be flexible with crop choices. Match the crop with a suitable soil type.
- Employ minimum tillage systems: no-till, mulch-till, ridge-till, for example.
- Practice crop rotation.
- Use rest-and-rotation grazing systems.
- Promote selective logging.
- Use effective waste management practices.

Riparian buffers contain three primary habitat zones that run parallel to the stream.

Zone 1 is next to the stream. This zone should support large native trees and shrubs that provide overhead shading to moderate water temperatures and provide a source of organic matter input (leaf fall, twigs, insects) and large woody material to the stream. Fast-growing species, such as willows, should be established in areas void of streamside vegetation.

Zone 2 is in the middle of the buffer. This zone should be composed of slower-growing hardwood trees and conifers and shrubs to provide diverse habitat for numerous wildlife species and additional nutrient and sediment removal from runoff and subsurface water traveling toward the stream.

Zone 3 lies farthest from the stream on the outside edge of the buffer. This zone should be comprised of a herbaceous filter strip adjacent to cropland or pasture. It should be dominated by tall, residual grasses, such as switchgrass or other native grasses. Forbes and legumes should be included in the seeding mix to maximize habitat quality.

Often the first step in establishing riparian forest buffers along severely degraded streams is to exclude livestock. Initial response of herbaceous vegetation provides food and cover for early successional wildlife species including songbirds, amphibians, and small mammals.

Where virtually no woody cover exists onsite, live fascines or other rooting stock may be needed to establish vegetation in zone 1. Native plant materials, such as dogwood or willow, adapted to the area should be selected to allow for quick regeneration.

Where deer or rodent populations are high, additional measures may be needed to protect tree seedlings in zone 2 until they are established.

Native grasses and forbs in zone 3 provide a natural transition between agricultural fields and the riparian forested buffer habitat.

Artificial nest structures, such as wood duck boxes, bat houses, and bird houses, can be installed in the buffer area to enhance wildlife habitat quality and nesting productivity.

Where the opportunity presents itself, flood plain wetlands should be restored within riparian forests and other buffer practices. Wetlands restored on the flood plain should be linked hydrologically to the adjacent stream to maximize restored wetland function. Restored wetlands add to the variety of fish and wildlife habitats available in a given area.

Riparian herbaceous cover

Riparian herbaceous cover provides an opportunity to provide habitat for wildlife in close proximity to water. As with other buffer practices, diversity of native vegetation should be maximized within this area.

Native grass-legume mixes should be selected where possible, and mowing or other disturbance of the area for maintenance should occur well after the nesting season for local species.

Riparian herbaceous cover can be combined with other riparian and stream restoration practices, such as streambank stabilization, through various bioengineering methods.

Grassed waterways

Grassed waterways are typically seeded in a monoculture of exotic grasses along surface drainageways that traverse agricultural fields. However, they are important habitats for many ground nesting species and species that prefer early successional vegetation. Fourteen bird species were observed nesting in grassed waterways in one Iowa study. Nest densities of over 1,100 nests per 250 acres of grassed waterways were reported. These nest densities exceed densities found in no-till and cropped fields. Dickcissel daily survival rates when nesting in grassed waterways were the same as those reported for old fields and prairie remnants. Research suggests that grassed waterway habitats could be even more productive if seeded with a mix of native grasses and forbs.

Maintenance of grassed waterways should be done such that mowing is conducted after the ground-nesting bird nesting season.

Other considerations

Weeds

Extreme care should be taken when planning buffer practices to prevent the release or stimulation of exotic invasive plants, particularly plants considered noxious weeds in the area.

Knowledge of local noxious weeds and practices that discourage their spread is essential. Many noxious weeds are responsible for degrading wildlife habitat as well as presenting serious problems for agricultural production.

Crop damage

A perception in some sectors of rural America is that untended vegetation and natural areas, such as those proposed for buffers managed for wildlife, are a major source of insects that infest crops. While these areas may harbor some pest insects, they also support many beneficial insects. Many birds and bats that frequent these areas may serve to reduce the number of insect pests. Pest management in these areas should be considered in overall integrated pest management for the property and the local watershed.

Birds and mammals that inhabit these areas can also damage certain crops. However, crop depredation may be minimized by providing preferred natural foods in buffer areas. Where deer or other wildlife populations associated with extensive crop damage are too high, care should be taken to ensure additional problems are not generated by buffer management actions.

Predators and nest parasites

Narrow, linear habitats provided by many buffer practices are prone to locally high levels of nest predation. Large ground-nesting birds, such as ring-necked pheasant and ducks, may be particularly susceptible to predation in buffer areas that are not adjacent to larger blocks of habitat. In addition, many songbirds that nest in trees and shrubs along edge habitats are susceptible to nest parasites. The brown-headed cowbird is an example.

While mortality from nest parasitism and predation may be locally high, most biologists agree that the benefits associated with the availability of the additional habitat in the form of buffers and other linear habitats on the landscape outweigh the losses to these factors.

Public education

To the untrained eye, unmanicured areas managed for wildlife may appear as land mismanagement or laziness on the part of the landowner. Unkempt looking hedgerows, buffers, and larger blocks of habitat may contrast sharply with more intensively used and managed croplands on the farm or in the local area.

Signs should be erected to inform neighbors and the public that the area is being managed for wildlife. This may help make landowners more receptive to managing lands for wildlife and will have public education benefits.

New initiatives

NRCS is involved in several new initiatives to assist in managing buffers for fish and wildlife.

Stream Corridor Restoration Manual**—**The recently published Part 653 to the National Engineering Handbook, *Stream corridor restoration: Principles, processes and practices,* provides background information on the ecology of steams and stream corridors as well as detailed guidance on methods for streambank and instream habitat restoration.

Stream Corridor Inventory Techniques—The Watershed Science Institute and collaborating partners, including the Wildlife Habitat Management Institute, are preparing a technical guide to site project and landscape stream inventory techniques to assist local conservation program implementation.

Stream Visual Assessment Protocol (SVAP)—The NRCS Aquatic Assessment Workgroup recently issued the technical note Stream Visual Assessment Protocol (SVAP). This publication provides the user with a relatively quick method to evaluate stream and riparian condition. In addition, the workgroup developed a course entitled "Introduction to Stream Ecological Assessment," which provides instruction for the SVAP as well as basic ecological principles of stream and riparian ecosystems. These tools would be valuable to conservationists seeking technical assistance in coarse evaluation of riparian conditions that precedes the design of conservation buffer practices for streamside areas.

Wildlife Corridors Manual—The NRCS Watershed Science Institute and Wildlife Habitat Management Institute, in cooperation with Utah State University, sponsored preparation of Conservation Corridor Planning at the Landscape Level: Managing for Wildlife Habitat. This manual can assist conservation planners in developing various types of habitat corridors to maximize benefits to fish and wildlife. It provides additional information on the concepts of linear habitats and includes planning tools to maximize wildlife habitat benefits from a landscape perspective.

Buffers for Wildlife job sheets—This paper has not provided detailed information on plant materials needed for installation of buffer practices. Plant materials selected for installation of buffers for wildlife vary by location, wildlife species targeted, availability of plant materials, and other local factors. The job sheets prepared for buffer practices in the National Conservation Buffer Initiative appropriately do not contain this level of detail.

To provide more site-specific information to conservation planners on plant materials and other aspects of installing buffers to maximize fish and wildlife benefits, the NRCS Wildlife Habitat Management and Watershed Science Institutes have initiated efforts, with the assistance of the Wildlife Management Institute, to develop additional job sheets with a fish and wildlife focus.

Institute staff are working with NRCS and state fish and wildlife agency personnel in six states, one for each NRCS Region, to develop job sheets for the applicable buffer practices in these states (Illinois, Maryland, North Carolina, Texas, South Dakota, and Utah). Detailed information on fish and wildlife objectives, what plant materials should be used to meet those objectives, where these plant materials can be obtained, and how they can be established and maintained will be included in these job sheets.

States near the six pilot states should also be able to use these products, with appropriate adjustments.

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Best, L.B., R.C. Whitmore, and G.M. Booth. 1990. Use of cornfields by birds during the breeding season: the importance of edge habitat. Am. Midl. Nat.123: 84-99.

These two papers look at bird abundance around field perimeters. Cornfields/woody habitat has twice as many species as cornfield/herbaceous habitat. Birds are also more abundant on the woody edges. Both studies show the importance of not eliminating woody vegetation in fencerows.

Best, L.B., K.E. Freemark, J.J. Dinsmore, and M. Camp. 1995. A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa. Am. Midl. Nat. 134: 1-29.

Excellent compilation of studies on bird use of agricultural practices, such as buffers, tillage, pastures, hayland, and row crops, as well as remnant natural habitats, such as prairies, forests, and wetlands. This paper also gives good quantitative estimates of bird increases with increasing levels of complexity added to the landscape by buffers and other types of habitat.

Castrale, J.S. 1985. Response of wildlife to various tillage conditions. Trans. N.A.Wildl. & Nat. Resour. Conf. 50: 142-156.

Discusses wildlife use of cultivated fields as influenced by tillage practices. Such use is generally attributed to food availability, vegetation structure, and timing and type of disturbance. The paper notes that no-till or conservation tillage is no substitute for undisturbed cover.

Emmerich, J.M., and P.A. Vohs. 1982. Comparative use of four woodland habitats by birds. J. Wildl. Manage. 46:43-49.

Shelterbelts and windbreaks add substantially to avifauna, but they generally support a large number of fewer species. Larger and more diverse riparian woodlands and tree claims cannot be replaced by shelterbelts, and landowners should be encouraged to protect them.

Friesen, Lyle. 1994. A literature review on wildlife habitats in agricultural landscapes. COESA Report No. RES/MAN-009/94.

An excellent review of agricultural practices, from tillage to buffers, and their impacts on wildlife habitat and biodiversity. The report is well organized and looks at crop fields and the noncrop habitats with which they interface (field borders, fencerows, roadsides, field ditches, woodlots).

Morgan, K.A., and J.E. Gates. 1982. Bird population patterns in forest edge and strip vegetation at Remington Farms, Maryland. J. Wildl. Manage. 46: 933-944.

Notes the value of shrub hedgerows near grass and cropland fields for nesting, winter cover, feeding cover, and transient cover. Although the plant materials discussed in this paper are no longer recommended, the vegetation structure and juxtaposition of the buffers can be produced with different plant species.

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Discusses the value of mowing clump grass cover next to shrub fencerows, with openings at ground level to provide rabbit habitat.

Reay, W.G. 1997. Native warm season grass vegetation filter strips: evaluation of nitrogen reduction in high-risk coastal plain groundwater discharge region. Final Report. Va. Dept. of Conserv. and Rec.

Describes the capability of switchgrass filter strips to accumulate nitrogen from shallow ground water, reduce erosion and contaminant transport, and increase infiltration and sediment deposition, as well as its value as a stiff grass hedge to reduce wind erosion. The paper also notes the value of NWSG and legume mixes to gamebirds, songbirds, and small mammals.

Stall, H.R., and L.B. Best. 1996. Small mammal use of an experimental strip intercropping system in northeastern Iowa. Am. Midl. Nat. 135: 266-273.

Looks at the impact of the diversity created by adjacent rows of legumes, rowcrops, and small grains on small mammal populations. The paper also allays fears of pest problems thought to be created by such systems.

Stinner, B.R., and J.M. Blair. 1990. Ecological and agronomic characteristics of innovative cropping systems. *In* C.A. Edwards, R. Lal, P. Madden, R. Miller, and G. House (eds.) Sustainable Agricultural Systems, pp. 123-140, Soil and Water Conserv. Soc.

Describes strip intercropping and the value of the juxtaposition of several vegetation types. The system could provide a range of choices for feeding, escape, or nesting cover.

Warner, R.E., and L.M. David. 1982. Woody habitat and severe winter mortality of ring-necked pheasants in central Illinois. J. Wildl. Manage. 46: 923-932.

Notes that strip woody cover functions as daytime loafing and escape cover with roosting taking place in nearby fields with adequate vegetation. The strips are not the saviors in severe winter storms, and they must be positioned near feeding and roosting cover.

Welsch, D.J. 1991. Riparian forest buffers: Function and design for protection and enhancement of water resources. USDA For. Serv. Publ. NA-PR-07-91, 20 pp.

A concise treatment of riparian buffer functions and design specifications.

Whitworth, M.R. and D.C. Martin. 1990. Instream benefits of CRP filter strips. Trans. N.A. Wildl. & Nat. Resour. Conf. 55: 40-45.

Indicates that vegetative filter strips provided significant benefits to both benthic macroinvertebrates and fish communities. Community quality is a reflection of long-term effects, such as substrate alteration and nutrient loading, as well as short-term effects, such as pesticide applications or peak storm flows.

Yahner, R.H. 1982. Avian use of vertical strata and plantings in farmstead shelterbelts. J. Wildl. Manage. 46: 50-60.

Suggests that avian species use shelterbelts by both vertical strata and genera of plantings (Lornicera, Picea, Populus, Ulmus, and Acer). The use of these genera adds vegetation diversity and increases the differential use of space within a shelterbelt.

Yahner, R.H. 1983(a). Small mammals in farmstead shelterbelts: habitat correlates of seasonal abundance and community structure. J. Wildl. Manage. 47: 74-84.

This paper recommends: (1) ensure vertical stratification by minimizing disturbance (mowing, disking) between rows after shelterbelts are established (≥ 5 yr) and managing grazing; (2) leave or create woody debris (stumps, logs) or constructed debris; (3) shelterbelts should be less than or equal to 1.5 acres.

Yahner, R.H. 1983(b). Seasonal dynamics, habitat relationships, and management of avifauna in farmstead shelterbelts. J. Wildl. Manage. 47: 85-104.

This paper recommends: (1) use 8 rows with a minimum of 35-meter width, (2) use a combination of fast growing, long lived, and conifer trees, (3) use spacing that will allow herbaceous and shrub growth after tree establishment, (4) leave dead snags at a height of 4 to 5 meters and replant next to them, (5) use small grain between the rows and leave for wildlife, and (6) position the food plots to leeward.

CORE 4 Integration Exercise
Buck –Duck Watershed

Watershed/areawide plan summary

Vision/Mission: Sustainability/Quality of life

Desired conditions

Cleaner water:
- Reduce sediment into Peru Lake
- Reduce phosphorous load into Peru Lake
- Reduce atrazine and nitrogen in drinking water (groundwater)

Stable and productive soils:
- Reduce sheet and rill erosion (uplands)
- Reduce wind erosion (bottoms) (filling drainage ditches)
- Improve soil health (quality)

Enhance wildlife habitat:
- Protect and create habitat for migratory birds who use this international flyway
- Restore native plant species and diverse habitats

Improve aesthetics and recreation opportunities:
- Protect and improve scenic quality (fall color tourism)
- Develop and promote Lewis and Clark trail

Improve air quality for traffic safety:
- Reduce blowing soil particles in the river flood plain
- Reduce snow deposition on roadways

Develop income opportunities:
- Develop agroforestry markets
- Develop alternative crop markets

CORE4 Integration Exercise
Scenario 1

Setting

500 acre cash grain farm with no livestock. Principle crops grown are corn soybeans and grain sorghum. Landowner is interested in maximizing net income while protecting the environment. Also enjoys hunting. Field is eroding, grassed waterways have gullies on each side and channels are full of silt. Some trees and shrubs are encroaching into parts of the waterways. Farmer had heard about the continuous CRP sign up and Conservation Buffers and wants assistance in exploring his options

Existing practices

Old grassed waterways, contouring.

Suggest alternatives for integrating practices from the Core4 groupings

Nutrient management

Pest management

Conservation Tillage

Conservation Buffers

Other practices and management measures needed to complete the Resource Management System

CORE 4 Integration Exercise
Scenario 2

Setting
Adjacent landowner with a 500-acre farm and a confinement hog operation has recently purchased this 160 acres to provide additional land area to apply animal waste. Principle crops grown in the operation are corn, soybeans, and grain sorghum. This field is eroding, the old gradient terraces need renovation, grassed waterways have gullies on each side, and channels are silted in. Some trees and shrubs are encroaching into the waterways. Farmer requests NRCS help in replacing the terrace system with a parallel tile outlet system to eliminate the waterways and "brushy draws." Farmer participated in the watershed meetings to discuss sediment and chemical runoff problems in the Peru Lake and is concerned since his farm is served by a rural water system that uses Peru Lake as its source.

Existing practices
Gradient terraces, old grassed waterways, contouring.

Suggest alternatives for integrating practices from the Core4 groupings
Nutrient management

Pest management

Conservation Tillage

Conservation Buffers

Other practices and management measures needed to complete the Resource Management System

CORE4 Integration Exercise
Scenario 3

Setting

This 160-acre farm is absentee owned and unlike most neighboring farms was never terraced or contoured. The tenant grows corn, soybeans, and grain sorghum. Field is badly eroded with ephemeral gullies on all slopes. Some trees and shrubs are encroaching into the draws. The owner wants to continue cropping for a while, but also wants to improve wildlife-carrying capacity for a hunting group from Kansas City.

Existing practices

Old grassed waterways.

Suggest alternatives for integrating practices from the Core4 groupings

Nutrient management

Pest management

Conservation Tillage

Conservation Buffers

Other practices and management measures needed to complete the Resource Management System

Soils: silty clay loams, 8% slopes 200 feet long. T=5
2 years of high residue row crops and 1 year of low residue row crops

Sheet and Rill Erosion Control Alternatives
(soil loss in tons per acre per year)

	Conventional tillage	Mulch tillage	No-tillage
Contouring	16	9	5
Terraces and contouring	12	5	2
Contouring and contour buffer strips	14	6	3
Vegetative barriers and contouring	16	7	4
Up and down hill farming	30	20	8

CORE4 Integration Exercise
Scenario 4

Setting

This 160 acre field is located on the flood plain The soils are loamy fine sands that are excessively drained, rapidly permeable, and low in organic matter. The soil is also wind erosive (WEG=2 or I=134) and deficient in nitrogen and phosphorous. The area is occasionally flooded. Over the years wind eroded soil has nearly buried the fence along the interstate and has been dredged from adjacent township road ditches. The farm is in cash grain production and has a well and center pivot irrigation system on it. The landowner is interested in reducing the wind erosion and wind impacts on his crop production and the adjoining road ditches.

Existing practices

None

Suggest alternatives for integrating practices from the Core4 groupings

Nutrient management

Pest management

Conservation Tillage

Conservation Buffers

Other practices and management measures needed to complete the Resource Management System

Integration of CORE4 Practices

Evaluating conservation improvements one practice at a time may not enable the producer to see the combined effects and the estimated change to the bottom line if all of the Core 4 practices are used together as a system. The combination of practices is an essential part of the planning and evaluation process. This section provides an analysis of the economic considerations of the full set of CORE4 practices together.

The actual combination of practices depends on the site conditions, type of farm operation, and a host of other factors similar to those outlined for the individual practices. Often, however, the combination of practices can be formulated to work in many site-specific situations.

Example case scenario

The example unit is the 500-acre crop and livestock operation that recently purchased a 160-acre unit. The livestock portion is comprised of a confined hog operation that raises 2,100 hogs at 130 pounds annually. The crop rotation is corn, soybeans, and wheat.

For this operation, it is assumed that:

- The producer will use all the nutrients in the manure generated by the hog operation. The 636 acres of cropland are calculated to absorb all the nutrients produced by the hogs.
- 24 acres are set aside for a conservation buffer, reducing total cropland to 636 acres from the total 660 acres available for the farm. The buffer area is comprised of acres slightly less productive than the rest of the cropland.
- The cropping is comprised of the following:

Corn	280 acres
Soybeans	280 acres
Wheat	76 acres

- The same yields that were used in the individual cases presented earlier are assumed to apply to the integration of practices. These are: corn 140 bushels per acre, soybeans 37 bushels per acre, and wheat 58 bushels per acre.
- The yield change associated with the nutrient management will be 10, 5, and 4 bushels per acre respectively for corn, soybeans, and wheat. The yield change with integrated pest management will be 5 bushels per acre for corn and 2 bushels per acre for soybeans. Wheat will not have a yield change from integrated pest management.
- Costs are assumed to change as indicated in the earlier examples.

With the combination of no-till, nutrient management, integrated pest management, and conservation buffers, all resource problems are adequately treated. Further, a number of changes to the economic situation for the operation is as follows:

Added returns

Yield improvements from the nutrient management and integrated pest management are the major additions to returns on the cropland. In addition, the producer receives $85 per acre for the next 10 years under a CRP continuous signup contract for the 24 acres devoted to the conservation buffer.

Reduced costs

A reduction in purchased fertilizer for the corn, soybeans, and wheat help to reduce costs. Similarly, a reduction in the production cost associated with the no-till corn is included here. The 24 acres in the conservation buffer also reduce production cost.

Reduced returns

The only reduction in returns for this case situation is the loss of production on the 24 acres devoted to the conservation buffer.

Added costs

By adopting the set of core 4 practices, the producer will have added costs for the nutrient and IPM consultant, although at the combined $7.50 per acre rate rather than the sum of the two separate rates used in the other examples. Some added production costs occur for the soybeans and wheat. Finally, the costs of installing and maintaining the conservation buffer, less the cost share and the maintenance allowance from CRP, are included.

Conclusion

The analysis indicates that the added revenue and reduced cost for the system is greater than the reduced revenue and added cost. The combination of all CORE4 practices improves the producer's bottom line by $22,918 for the whole operation under the indicated conditions.

Partial budget of all CORE4 practices compared to current conditions without conservation system

Added returns					
IPM increases corn yield 5 bushels	5 bu x 280 ac. x $2.08	=	$2,912		
IPM increases soybean yield 2 bushels	2 bu x 280 ac x $5.45	=	3,052		
Nutrient mgmt increases corn yield 10 bushels	10 x 280 x $2.08	=	5,824		
Nutrient mgmt increases soybean yield 5 bushels	5 x 280 x $5.45	=	7,630		
Nutrient mgmt increases wheat yield 4 bushels	4 x 76 x $3.31	=	1,006		
CRP payment for buffer 24 acres at $85 per acre	24 x $85	=	2,040		
Total				**$22,464**	
Reduced costs					
Decrease of purchase fertilizer for corn			$7,168		
Decrease of purchase fertilizer for wheat			460		
Decrease of purchase fertilizer for soybeans			2,395		
Reduced production cost for no-till corn					
	$17 per acre 280 acres		4,760		
Elimination of production cost on buffer acres (composite)					
	$96.30 x 24 acres		2, 311		
Total				**$17,094**	
Total of added returns and reduced costs					**$39,558**
Reduced returns					
Absence of production on 24 acres of buffer	$200 per acre			**$4,800**	
Added costs					
Crop consultant (IPM and nutrient) for corn	280 acres at $7.50 per acre		$2,100		
Crop consultant (IPM and nutrient) for soybeans	280 acres at $7.50 per acre		2,100		
Nutrient mgmt. consultant for wheat	76 acres at $5.00 per acre		380		
Added production cost for no-till soybeans	280 acres at $21.00 per acre		5,880		
Added production cost for no-till wheat	76 acres at $5.00 per acre		380		
Producers share of buffer installation cost s	24 acres		928		
Remaining maintenance cost for buffer acres net of CRM maintenance payment			72		
Total of added costs			**$11,840**		
Total of the reduced returns and added costs					**$16,640**
Net change for operation					**$22,918**

CORE4 Key Conservation Practices

References