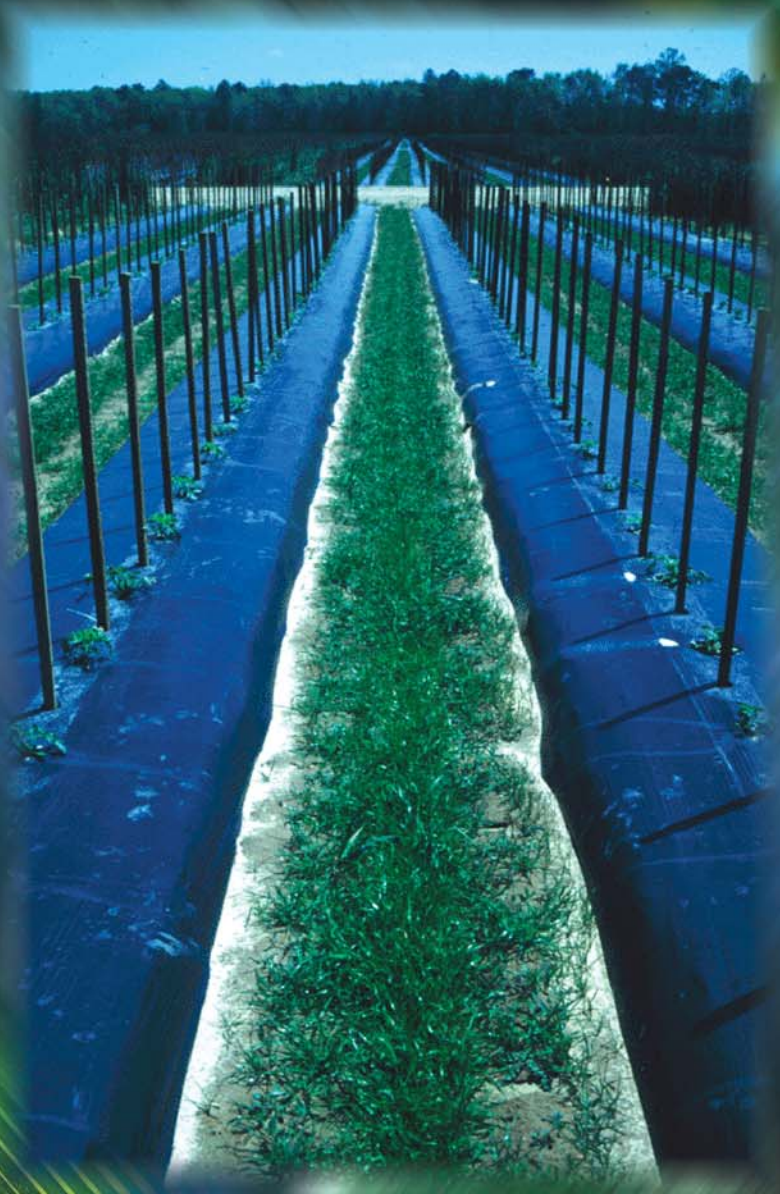
Protecting Water Quality: Best Management Practices for Row Crops Grown on Plastic Mulch in Virginia



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Protecting Water Quality: Best Management Practices for Row Crops Grown on Plastic Mulch in Virginia

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Chapter 1
Introduction

The goal of agricultural crop production is to produce crops in both an economically and environmentally sound manner. Poor crop production practices degrade water quality through nonpoint source (NPS) pollution. Best management practice (BMP) is the term used to describe a practice, or system of practices, designed to control NPS pollution and thus protect water quality. A variety of management practices have been identified as BMPs for different land use activities, including row crop agriculture. Because the effectiveness of BMPs is a function of site-specific conditions, such as topography, soil properties, and vegetative cover characteristics, BMPs that are effective for a given land use activity and a particular site may not be effective in a different situation.

This handbook focuses on BMPs for row crops grown on plastic mulch. Such a production system includes plant rows, often bedded, covered with impervious plastic mulch alternated with uncovered, inter-row spaces. Usually, drip irrigation tubing is placed under the plastic mulch to provide water and nutrients to the crop. In some cases, overhead sprinkler irrigation is used. In a few instances, no irrigation is employed.

Row crop production with plastic mulch has been shown to increase profitability for most fruits and vegetables, such as tomatoes, strawberries, and peppers, compared to conventional row crop production (without plastic mulch). Increased profitability is due to increased yield and improved crop quality. Production is often enhanced by earlier plant growth and maturity compared to production without plastic mulch. Some crops grown with plastic mulch can be harvested one to two weeks earlier, which often enhances marketability. Plastic mulch, by preventing contact with the soil, provides cleaner crops, decreases incidence and severity of disease, and reduces spoilage. Plastic mulch also discourages weed growth and retains soil moisture.

Because of the differences between crop production with plastic mulch and conventional crop production, requirements and conditions for water quality protection differ. For example, applying fertilizers directly under the plastic mulch, a common production practice, reduces the potential for nutrient losses; thus the need for additional nutrient control BMPs should be less for crop production with plastic mulch. Conversely, utilization of plastic mulch can substantially increase the amount of runoff from a field, thereby requiring implementation of additional runoff control BMPs.

Some BMPs that have been determined to be effective for conventional production may not be effective for crop production with plastic mulch, and, conversely, some practices that may not be appropriate for conventional production may be appropriate for crop production with plastic mulch. Because information about BMPs for crop production with plastic mulch is limited, this handbook was developed to assist producers

and water quality specialists in selecting and implementing water quality protection practices for crop fields with plastic mulch.

Chapter 2 of the handbook begins with a description of the impacts of plastic mulch on runoff, as well as leaching. Because the extent of NPS pollution is closely tied to runoff, control approaches must consider the effects of land use activities on runoff. Chapter 2 also describes pollutants that are associated with crop production, including sediment, nutrients, and pesticides. Management practices to control NPS pollution resulting from crop production with plastic mulch are identified. Chapter 3 focuses on the effectiveness of individual practices and describes systems of management practices to protect water quality. Guidelines for developing water quality protection plans are presented in Chapter 4. Chapter 5 includes example water quality protection plans developed using information from the handbook.

Appendix A describes financial assistance programs related to BMP implementation. Appendix B includes a list of websites with information related to crops grown on plastic mulch. Appendix C lists contact information for Federal, state, and local agencies that provide educational information and technical assistance.

This handbook is a state-wide guide to BMPs for protecting water quality with respect to row crops grown on plastic mulch. The handbook does not address other plant production systems that utilize plastic mulch, such as nursery and greenhouse operations. This is not a production handbook; production guidelines and information are available from a number of sources, some of which are cited in the Technical References section following Chapter 5. Major information sources consulted during preparation of this handbook are also listed in the reference section.

Chapter 2
Water Pollutants and Pollution Control Measures

Sources of water pollution from crop production with plastic mulch are diffuse, or nonpoint. This handbook focuses on best management practices (BMPs) used to control nonpoint source (NPS) pollution. Two conditions must be met for pollution to occur. A pollutant must first be available and, second, be transported off the field surface and/or below the root zone. Best management practices reduce or prevent water pollution by reducing or eliminating pollutant sources and/or transport potential.

Best management practice effectiveness depends upon site-specific conditions, such as soil, slope, crop, distance to receiving waters, and the specific pollutant being considered. The mechanisms that BMPs utilize can be grouped into the following general categories: increase infiltration, reduce runoff, reduce percolation, control erosion, enhance sedimentation, reduce chemical (nutrients and/or pesticides) inputs, and provide treatment. The following sections describe the hydrologic principles related to pollutant transport, the potential pollutants from crop production with plastic mulch, and management practices that address each pollutant.

In This Chapter:
Hydrology
Sediment
Nutrients
Pesticides

2.1 Hydrology

Nonpoint source pollutants are transported by runoff to surface water and by percolation through the root zone to ground water. They can be transported by runoff in dissolved, solid, and sediment-adsorbed forms and by percolation in dissolved form. The following sections describe the hydrologic processes of runoff and percolation and identify management practices that can control each process.

Runoff

Runoff occurs when the rainfall rate, or irrigation application rate, exceeds the intake capacity of the soil and after the small surface depressions have been filled. The major factors that impact runoff are crop characteristics, terrain features, soil properties, and the frequency, intensity, and duration of rainfall events.

Fields with close-tilled crops usually have less runoff than those with widely spaced row crops. Steeper slopes result in greater runoff at higher velocity. Fine-textured soils such as clays have lower infiltration rates and, consequently, higher runoff volume than coarse-textured soils such as sands. The USDA-Natural Resources Conservation Service (NRCS) has defined hydrologic soil groups to classify soils in terms of runoff potential:

Group A: lowest runoff potential; deep sands with little silt and clay

Group B: moderately low runoff potential; sandy soils not as deep as group A

Group C: moderately high runoff potential; shallow soils with considerable clay and colloids, though less than group D

Group D: highest runoff potential; mostly clays of high swelling percent, and some shallow clays that are impermeable.

Table 2.1 lists some major Virginia soils that fall into each of the hydrologic soil groups.

Crop fields with plastic mulch in Virginia can have more than 50% of the cultivated portion (row and inter-row areas) of the field covered by impervious plastic film; percent coverage varies widely depending on the crop and cultural practices. As a result, these cropping systems can significantly increase runoff volume compared to conventional row crop production systems. The impact of plastic mulch on runoff amount is greater for soils with lower runoff potential. For example, for a given field and rainfall event, the relative increase in runoff (plastic mulch vs. conventional) will be greater for a group B soil than for a group D soil.

Figure 2.1 provides estimates of rainfall excess, or potential runoff, for both conventional and plastic mulch scenarios for two rainfall intensities. These maximum runoff amounts are based on soil properties (group C assumed) and cover characteristics (row crop with 0% and 30% coverage by plastic mulch assumed). As water flows over a given field, less infiltration will

occur if part of the field is covered with plastic mulch. The portion of this potential runoff that leaves a field also depends on topography, including slope and flow patterns. Considering topographic effects, the actual runoff leaving a given field represents a greater proportion of the potential runoff when there is coverage by plastic mulch as opposed to zero coverage.

The impact of plastic mulch on runoff is particularly significant during smaller storms, i.e., storms that usually produce little or no runoff without plastic mulch (Figure 2.1). As storm intensity and duration increase, the percent difference between the amount of runoff from plastic mulch and conventional fields decreases due to saturation of the soil and reduced infiltration capacity.

In-field practices to reduce runoff from crop fields with plastic mulch are described in Table 2.2. Standards and guidelines for many practices are provided by a variety of sources, such as the Natural Resources Conservation Service. Applicable standards and/or guidelines that were in place at the time this handbook was printed are cited in Table 2.2 and subsequent tables that describe additional BMPs. Standards and guidelines are updated regularly; the most current information should always be used. The Virginia Conservation Practice Standards developed by NRCS in Virginia should be used when available.

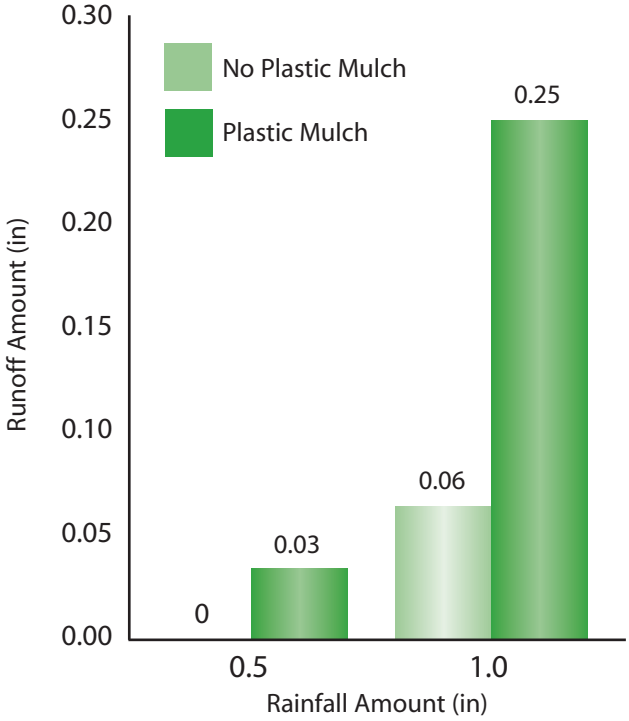


Figure 2.1 Estimated runoff from half-inch and one-inch rainfall events occurring over a 24-hour period for a hydrologic soil group C soil from a field with (30% coverage) and without plastic mulch. Runoff was estimated by the SCS/NRCS curve number method.

Table 2.1 Selected Virginia soils characterized by hydrologic soil group (from county soil survey reports)

Physiographic Region	Soil Name	Hydrologic Soil Group
Coastal Plain	Bojac	B
	Chickahominy	D
	Dragston	C
	Emporia	C
	Kenansville	A
	Munden	B
	Pamunkey	B
	Suffolk	B
	Tetotum	C
Piedmont	Appling	B
	Bolling	C
	Bucks	B
	Cecil	B
	Chester	B
	Leaksville	D
	Tatum	B
Blue Ridge	Hayesville	C
	Myersville	B
	Porters	B
Ridge and Valley	Dekalb	C
	Frederick	B
	Groseclose	C
	Pagebrook	D
Cumberland Plateau	Berks	C
	Shelocta	B
	Grigsby	B

Percolation

Percolation is the process by which water (rainfall/irrigation that infiltrates the soil) moves downward through and below the root zone. Water that percolates through the root zone may transport dissolved chemicals, such as nutrients and pesticides. Depending on the depth to the water table, chemicals may reach ground water. In some Virginia cropland, ground water may be only a few feet below the soil surface, while in other areas, ground water may lie several hundred feet below the surface of the soil.

The rate at which drainage water percolates downward through the soil depends primarily on soil properties and may also be influenced by tillage and compaction. Preferential flow paths, such as cracks, old root channels, animal burrows, and sinkholes and large channels in the limestone of karst areas, may promote relatively rapid downward movement. The time in transit from the soil surface to ground water may range from only a few minutes to years.

Most crop production with plastic mulch in Virginia utilizes an irrigation system to provide water to the crop. Irrigation applications should be managed to reduce runoff and minimize percolation in order to protect ground water quality. In contrast to overhead sprinkler irrigation, drip irrigation under plastic mulch can result in less percolation and runoff because water is not applied to the inter-row areas. If irrigation is a necessary component of the crop production system, irrigation water management practices described in Table 2.3 will help minimize percolation and reduce runoff in crop fields with plastic mulch.

Table 2.2 In-field practices to reduce runoff from crop fields with plastic mulch

Practice	Features	Also Listed in Table(s):	Applicable Standards[1] or Guidelines
Contour Farming	• Tillage, planting, and other farming operations performed on or near the contour of the field slope • Reduces runoff, erosion, and transport of sediment and other pollutants	2.5, 2.7, 2.8	NRCS-VA 330 NRCS 331
Deep Tillage	• Tillage operations commonly referred to as deep plowing, subsoiling, or ripping • Fractures restrictive soil layers thereby increasing infiltration in the inter-row area • Most effective when repeated periodically	2.5, 2.8	NRCS 324
Inter-row Cover Crop	• Established grasses, legumes, forbs, or other herbaceous plants in inter-row areas during the growing season • Reduces runoff and erosion	2.5, 2.7	NRCS 340
Row Direction	• Straight rows laid out across the dominant field slope • Use when contour farming is not feasible • Reduces runoff, erosion, and transport of sediment and other pollutants	2.5	—
Winter Cover Crop	• Established grasses, legumes, forbs, or other herbaceous plants throughout the field for winter cover • Reduces runoff and erosion, manages excess nutrients in the soil profile, and aids weed suppression	2.5, 2.7	NRCS 340

[1]NRCS refers to USDA-Natural Resources Conservation Service Conservation Practice Standard; and NRCS-VA refers to Virginia Conservation Practice Standards developed by NRCS in Virginia.

Table 2.3 Irrigation water management practices to minimize percolation and reduce runoff in crop fields with plastic mulch when irrigation is a component of the production system

Practice	Features	Also Listed in Table(s):	Applicable Standards[1] or Guidelines
Drip Irrigation	• Irrigation system for distribution of water under plastic mulch directly to the root zone • Efficiently and uniformly applies irrigation water and chemicals, reduces leaching	2.5, 2.7	NRCS 441 ASAE EP405.1
Irrigation Scheduling	• Water management strategies intended to apply the optimal amount of irrigation water only when needed by the crop • Reduces leaching potential by maintaining optimal soil moisture levels • Requires monitoring of soil moisture status, crop growth stage, and weather conditions	2.5, 2.7	CVPR

[1]NRCS refers to USDA-Natural Resources Conservation Service Conservation Practice Standard;
ASAE refers to American Society of Agricultural Engineers Standards; and CVPR refers to Virginia Cooperative Extension *Commercial Vegetable Production Recommendations.*

2.2 Sediment

Sediment, or displaced and deposited soil resulting from runoff and erosion, can have adverse water quality effects. In addition to the detrimental effects of sediment alone, nutrients and pesticides adsorbed to the soil particles can cause additional water quality problems.

Four storm-dependent processes determine the amount and rate of erosion and sediment transport. These processes include (1) soil particle detachment by raindrop splash, (2) transport by raindrop splash, (3) detachment by runoff, and (4) transport by runoff. Raindrop splash is a major force in the detachment of soil particles from soil aggregates. The rate of detachment by raindrop splash is dependent upon raindrop size, distribution, and velocity. Soil detachment due to runoff is influenced primarily by the velocity of runoff over the land surface. While some soil particles are transported by raindrop splash, the major transport mechanism is runoff. Transport rate depends largely on runoff velocity and depth and soil particle size.

Some soils have great resistance to erosion while others are highly erodible. The soil erodibility factor indicates the susceptibility of a given soil to erosion by water. Values range from 0.05 to 0.69; higher values indicate greater susceptibility to erosion. Soil erodibility factors for some major Virginia soils are included in Table 2.4.

In addition to soil properties, soil erosion is ultimately the combined result of several other factors including rainfall amount and intensity, soil cover, and slope steepness and length. Of these factors, rainfall characteristics, some soil properties, and slope steepness are essentially uncontrollable. For example, soil properties such as the proportions of sand, silt, and clay cannot be altered economically. While it is not often feasible to change overall slope steepness, in some cases, it is possible to reduce slope slightly by land grading. Orienting rows/beds across the slope can reduce the slope in the direction of runoff.

Cover is the most significant factor in controlling runoff and soil erosion. A dense vegetative cover absorbs the energy of rainfall, decreases the amount and velocity of runoff, increases infiltration, and reduces sediment detachment and transport. Plastic mulch protects the soil surface from raindrop impact and erosion, and eliminates erosion in the area under the plastic mulch.

The remaining exposed soil, however, can have higher erosion losses due to increased runoff rates between the rows. If rows are relatively short, sediment loss from a field with plastic mulch may be less than from a similar field without plastic mulch. As slope length increases, however, runoff rates increase between the rows, providing more energy for erosion. Thus, for longer rows, sediment loss from fields with plastic mulch and bare inter-row areas will be higher than from conventionally cropped fields.

In general, for conventional crop fields, a relatively small number of large storm events over the course of a year account for the majority of annual soil erosion losses. For crop fields with plastic mulch, however, many more storms are involved in erosion losses annually because of the increased runoff potential.

Best management practices for soil erosion control include both cultural and structural measures. Cultural practices generally have relatively low initial cost

Table 2.4 Soil erodibility factors for selected Virginia soils (K-factors from county soil survey reports)

Physiographic Region	Soil Name	Soil Erodibility (May vary based on texture)
Coastal Plain	Bojac	0.17
	Chickahominy	0.37
	Dragston	0.17
	Emporia	0.28
	Kenansville	0.15
	Munden	0.20
	Pamunkey	0.28
	Suffolk	0.28
	Tetotum	0.28
Piedmont	Appling	0.24
	Bolling	0.28
	Bucks	0.37
	Cecil	0.28
	Chester	0.32
	Leaksville	0.43
	Tatum	0.24
Blue Ridge	Hayesville	0.22
	Myersville	0.32
	Porters	0.17
Ridge and Valley	Dekalb	0.17
	Frederick	0.30
	Groseclose	0.43
	Pagebrook	0.37
Cumberland Plateau	Berks	0.17
	Shelocta	0.32
	Grigsby	0.28

unless new machinery is required. Such practices are effective in controlling erosion through protection of the soil surface from raindrop impact, by improving soil structure and infiltration rate, and by reducing runoff velocity. Cultural practices that can reduce soil erosion potential in crop fields with plastic mulch are listed in Table 2.5. Because techniques that reduce the quantity and velocity of runoff generally reduce erosion, practices listed in Table 2.2 for runoff control are also listed in Table 2.5.

In contrast to cultural practices, structural measures usually have higher initial costs, but lower annual costs. They require proper design and construction and have a degree of permanency. Structural measures can be very effective in improving the quality of runoff and may allow more intensive crop production than would otherwise be possible. They are effective in controlling impacts of erosion primarily by reducing the amount of runoff and sediment delivered to receiving waters. Structural measures to control impacts of erosion are listed in Table 2.6.

Table 2.5 Cultural practices to minimize soil erosion in crop fields with plastic mulch

Practice	Features	Also Listed in Table(s):	Applicable Standards[1] or Guidelines
Contour Farming	• Described in Table 2.2	2.2, 2.5, 2.7 2.8	NRCS-VA 330 NRCS 331
Deep Tillage	• Described in Table 2.2	2.2	NRCS 324
Drip Irrigation	• Described in Table 2.3	2.3, 2.7	NRCS 441 ASAE EP405.1
Inter-row Cover Crop	• Described in Table 2.2	2.2, 2.7, 2.8	NRCS 340
Inter-row Mulching	• Applying plant residues or other suitable materials not produced on the site to the soil surface • Prevents crusting, reduces erosion, and controls weeds	2.7, 2.8	NRCS 484
Irrigation Scheduling	• Described in Table 2.3	2.3, 2.7	CVPR
Row Direction	• Described in Table 2.2	2.2, 2.7	—
Winter Cover Crop	• Described in Table 2.2	2.2, 2.7, 2.8	NRCS 340

[1]NRCS refers to USDA-Natural Resources Conservation Service Conservation Practice Standard; NRCS-VA refers to Virginia Conservation Practice Standards developed by NRCS in Virginia; ASAE refers to American Society of Agricultural Engineers Standards; and CVPR refers to Virginia Cooperative Extension *Commercial Vegetable Production Recommendations*.

Table 2.6 Structural practices to control impacts of erosion from crop fields with plastic mulch

Practice	Features	Also Listed in Table(s):	Applicable Standards[1] or Guidelines
Buffer Strips	• Narrow strips of permanent, herbaceous cover established across the slope and alternated down the slope with wide cropped areas • Reduces erosion and transport of sediment and other pollutants downslope	—	NRCS-VA 332
Constructed Wetland	• Wetland that is constructed for the primary purpose of water quality improvement • Treats surface runoff through biological, chemical, and physical processes • Located between field and receiving waters • Often prohibitive due to operational and space requirements	2.7, 2.8	NRCS 656 NEFH 650

Table 2.6 (Continued)

Practice	Features	Also Listed in Table(s):	Applicable Standards[1] or Guidelines
Diversion	• Channel constructed across the slope to intercept and divert runoff • Use upslope of crop field to prevent runoff onto the field from upslope areas • Use downslope of crop field to direct runoff to desired areas	2.7	NRCS-VA 362 (draft) VESCH 3.12
Field Border	• Strip of permanent grasses established at the edges of a field (minimum 30 ft wide/60 ft wide at the downslope end of rows) • Reduces erosion from border areas by protecting soil from machinery operations • Traps sediment in runoff leaving crop fields at downslope end of rows • Manages harmful insect populations by interrupting migration paths	2.7, 2.8	NRCS 386
Filter Strip	• Strip or area of herbaceous vegetation situated between crop field (beyond field border described above) and receiving waterway • Reduces sediment and adsorbed and dissolved pollutants in runoff • Most effective when runoff is uniformly dispersed and not concentrated before entering the filter strip • To prevent concentrated flow from entering the strip, use in conjunction with level spreader or other dispersion method	2.7, 2.8	NRCS-VA 393
Grassed Waterway	• Natural drainageway within a field shaped and vegetated to convey concentrated runoff at a nonerosive velocity and prevent gully formation and erosion	—	NRCS 412
Level Spreader	• Converts concentrated runoff to diffuse flow and releases it uniformly onto areas stabilized by vegetation • Enhances effectiveness of filter strips and riparian buffers • In applying the cited standard to fields with plastic mulch, the design event should be modified. The design should be for the 2-year, 24-hour duration event rather than the 10-year, 24-hour event.	—	VESCH 3.21
Precision Land Forming	• Reshaping the land surface to improve drainage • Reduces concentrated flow and erosion • Soils must be of sufficient depth and suitable texture	—	NRCS 462
Riparian Herbaceous or Forest Buffer	• Area of grasses, grasslike plants, and forbs (herbaceous) or trees and shrubs (forest) adjacent to and upslope from water bodies receiving runoff from fields • Reduces sediment, nutrients, and pesticides in surface runoff and nutrients in shallow ground water flow • Applied in areas adjacent to permanent or intermittent streams, lakes, ponds, wetlands and areas with ground water recharge that are capable of supporting woody vegetation (forest) or where the natural plant community is dominated by herbaceous vegetation	2.8	NRCS-VA 390 NRCS 391
Sediment Basin	• Constructed to collect and store sediment and to detain runoff • Prevents sedimentation in reservoirs, ditches, canals, waterways, and streams; prevents deposition on bottom lands and developed areas; and traps sediment	2.7, 2.8	NRCS-VA 350 NRCS 378

Table 2.6 (Continued)

Practice	Features	Also Listed in Table(s):	Applicable Standards[1] or Guidelines
Sediment Basin (continued)	• Applies where physical conditions or land ownership preclude treatment of a sediment source by the installation of erosion-control measures to keep soil in place • In applying the cited standards and guidelines to fields with plastic mulch, the modified design criteria provided below should be followed. a. Design capacity = normal permanent pool storage (if any) + runoff volume from 2-year, 24-hour design storm from the contributing area. The 2-year, 24-hour runoff amount should be estimated using the SCS/NRCS curve number runoff method. A weighted curve number should be calculated for the field, using a value of 98 for the portion covered by plastic mulch. b. Outlets for the detention structure may consist of a combination of principal and emergency spillways. The outlets must pass the peak runoff expected from the contributing drainage area for the design storm specified for the structure in the applicable standards or regulations. c. The principal spillway should provide at least a 60-hour drawdown time for the 2-year, 24-hour duration storm. Research has indicated that most of the pollutant reduction in detention facilities occurs within the first 60 hours of detention. Suggested procedures for determining the required maximum orifice diameter for the principal spillway riser are provided below. Use the modified version of the discharge equation for a vertical circular orifice. $Q = \frac{S}{216{,}000}$ $A = \frac{Q}{0.6\left(\frac{64.32h}{2}\right)^{1/2}}$ $d = 2\left(\frac{A}{\pi}\right)^{1/2}$ Q = volumetric flowrate through the orifice required to dewater the stormwater volume in 60 hours, ft^3/s (Note: 216,000 = number of seconds in 60 hours) S = total stormwater volume for 2-year, 24-hour or larger storm determined using SCS/NRCS curve number method, ft^3 A = orifice area, ft^2 h = maximum head on the orifice, ft (distance from the horizontal centerline of the orifice to the crest of the principal spillway) d = orifice diameter, ft (should never be less than 3 inches to minimize clogging)		

[1]NRCS refers to USDA-Natural Resources Conservation Service Conservation Practice Standard; NRCS-VA refers to Virginia Conservation Practice Standards developed by NRCS in Virginia; NEFH refers to the *National Engineering Field Handbook* (USDA-NRCS); and VESCH refers to *Virginia Erosion and Sediment Control Handbook*.

2.3 Nutrients

Nutrients are essential for plant growth and can readily be lost from the crop field when applied in excess of crop utilization. Nutrients can be transported to receiving waters by runoff and percolation in dissolved form or adsorbed to sediment. Nitrogen (N) and phosphorus (P) are of particular concern because of the detrimental effects of excessive N and P in surface and ground water. In addition, loss of nutrients from crop fields represents a cost to producers.

Minimizing nutrient losses involves (1) limiting the availability of nutrients to be transported and (2) limiting the transport of available nutrients. Practices to limit the availability of nutrients focus on fertilizer application considerations, specifically amount, form, method, and timing. Practices to limit nutrient availability for transport from crop fields with plastic mulch are described in Table 2.7 and include most of the practices listed in Tables 2.2 and 2.3 for runoff control and irrigation water management, respectively, and in Tables 2.5 and 2.6 for erosion and sediment control.

The goal of nutrient management practices is to match nutrient applications to crop needs. Guidelines and specifications for soil testing and other aspects of nutrient management can be obtained from Virginia Cooperative Extension and the Virginia Department of Conservation and Recreation *Nutrient Management Handbook*. Fertilizer application rate recommendations for specific fruits and vegetables are available in the handbook, *Virginia Commercial Vegetable Production Recommendations*, which is updated annually.

For most crop fields with plastic mulch in Virginia, the pattern of fertilizer applications during the growing season is generally dependent upon the type of irrigation system in use. Applying fertilizers via irrigation provides nutrients as they are needed by the crop. Furthermore, drip irrigation applies both water and nutrients directly under the plastic mulch, which is particularly beneficial in limiting losses by percolation. When fertilizers are applied through an irrigation system, standards and guidelines for chemigation should be followed to avoid detrimental water quality impacts.

2.4 Pesticides

Pesticides, or crop protectant chemicals, are applied to soil and plant foliage to manage crop pests, such as insects, weeds, and fungi. Each pesticide (herbicide, insecticide, fungicide, nematicide) has unique physical and chemical properties that influence its fate, which is further impacted by crop characteristics, soil properties, management practices, site geology and topography, climatic factors, and chemical application method. These factors vary from field to field and pesticide fate is, therefore, highly site-specific.

Pesticides can be lost in dissolved and adsorbed phases. The ratio of the amount of pesticide in the adsorbed and dissolved phases is termed the partition coefficient, which gives a good measure of pesticide leaching potential. If a pesticide is highly soluble, it will be primarily dissolved in water and very little will adsorb to soil particles. In general, herbicides are more soluble than fungicides and insecticides and, consequently, have a greater potential for leaching. More leaching occurs in coarse-textured soils with low adsorptive capacity and large soil pores that promote rapid water movement through the soil profile. Less leaching occurs in fine-textured soils with high adsorptive capacity and smaller pores for water movement.

Most pesticides rapidly degrade after application. Degradation is generally enhanced through interaction with soil. Some pesticides are persistent and do not degrade or have very slow degradation rates (long half-lives) and can build up in the soil over time with repeated applications. For example, in Virginia soils, there are low concentrations of legacy (banned) chemicals found even though they have not been available for decades. In addition, some currently used pesticides, such as copper compounds, do not decay and will accumulate in soils with repeated use.

Most pesticides are degradable and break down into daughter products and eventually inert compounds. The intermediate daughter products, however, can be more or less toxic than the original chemical. These transformations are dependent upon chemical properties, soil properties, and environmental conditions. The toxicity, half-life, and leaching potential of a pesticide must be considered in conjunction with its intended use and the field's physical properties. The likelihood of a rainfall event shortly after a planned pesticide application should also be taken into account.

In crop fields with plastic mulch, pesticide residue due to overspray and wash-off is more likely to accumulate on the plastic mulch as opposed to the soil surface. Runoff carries the residue to the inter-row area and readily transports it from the field unless infiltration occurs. In most cases, infiltration-based practices should be more effective than erosion control practices in reducing pesticide losses.

Table 2.7 Practices to limit nutrient losses from crop fields with plastic mulch

Practice	Features	Also Listed in Table(s):	Applicable Standards[1] or Guidelines
Chemigation	• Application of chemicals through an irrigation system by mixing the chemicals with the irrigation water • Proper chemigation safety measures are required to prevent backflow to the water source and chemical storage tank, undesirably high application rates, and spills	2.8	ASAE EP409.1 ASAE EP405.1 CVPR
Constructed Wetland	• Described in Table 2.6	2.6, 2.8	NRCS 656 NEFH 650
Contour Farming	• Described in Table 2.2	2.2, 2.5, 2.8	NRCS-VA 330 NRCS 331
Diversion	• Described in Table 2.6	2.6, 2.8	NRCS-VA 362 (draft) VESCH 3.12
Drip Irrigation	• Described in Table 2.3	2.3	ASAE EP405.1 NRCS 441
Field Border	• Described in Table 2.6	2.6, 2.8	NRCS 386
Filter Strip	• Described in Table 2.6	2.6, 2.8	NRCS-VA 393
Inter-row Cover Crop	• Described in Table 2.2	2.2, 2.5, 2.8	NRCS 340
Inter-row Mulching	• Described in Table 2.5	2.5, 2.8	NRCS 484
Irrigation Scheduling	• Described in Table 2.3	2.3	CVPR
Level Spreader	• Described in Table 2.6	2.6, 2.8	VESCH 3.21
Nutrient Management	• Managing the form, source, amount, timing and method of application of nutrients to achieve realistic yield goals, while minimizing nutrient movement to surface and ground waters • Base application rate upon soil and plant tissue tests and realistic yield goals • Apply commercial fertilizers in efficient split applications • Time nitrogen application to coincide with the period of maximum crop uptake	—	NRCS-VA 590 NMH CVPR
Riparian Herbaceous or Forest Buffer	• Described in Table 2.6	2.6, 2.8	NRCS-VA 390 NRCS 391
Row Direction	• Described in Table 2.2	2.2, 2.5	—
Sediment Basin	• Described in Table 2.6	2.6, 2.8	NRCS-VA 350 NRCS 378
Winter Cover Crop	• Described in Table 2.2	2.2, 2.5, 2.8	NRCS 340

[1]NRCS refers to USDA-Natural Resources Conservation Service Conservation Practice Standard; NRCS-VA refers to Virginia Conservation Practice Standards developed by NRCS in Virginia; ASAE refers to American Society of Agricultural Engineers Standards; NMH refers to Department of Conservation and Recreation *Nutrient Management Handbook*; CVPR refers to Virginia Cooperative Extension *Commercial Vegetable Production Recommendations*; and VESCH refers to *Virginia Erosion and Sediment Control Handbook*.

Practices to control pesticide losses from crop fields with plastic mulch are identified in Table 2.8. Because techniques that reduce the quantity and velocity of runoff will reduce pesticide losses, practices listed in Table 2.2 for runoff control are also listed in Table 2.8. Although applying pesticides through drip irrigation allows better control than broadcasting or spraying, drip irrigation is not listed because few products are labeled for chemigation. In addition, drip irrigation cannot be used for foliar applications.

Integrated pest management (IPM) is the most cost-effective means of reducing pesticide losses in fields with plastic mulch. It is generally defined as a system of cultural, biological, and chemical pest management strategies that keep pest populations below levels that cause net economic loss while minimizing off-site environmental impacts. IPM programs can include strategies that range from conventional prophylactic use of pesticides to biologically-intensive methods that rely upon little or no chemical use. Successful IPM programs reduce off-site pesticide losses and impacts by reducing the quantities of pesticides used and by avoiding use of those with greater potential for off-site environmental impacts.

Four aspects of an IPM program are prevention, avoidance, monitoring, and suppression of pest populations. Prevention is the practice of keeping a pest population from infesting a crop or field. When a pest population exists, avoidance is practiced if the impact of the pest can be minimized through cultural practices. Monitoring and proper identification of pests through surveys or scouting programs should be performed as the basis for any suppression activities. Suppression of pest populations may become necessary to avoid economic loss if prevention and avoidance tactics are not successful. Tactics that address each aspect are presented in Table 2.9. The most appropriate tactics will vary from site to site, by pest and by crop.

An IPM program should be developed with a government or private consultant who has training and experience in developing and implementing such programs. Development and implementation of a program should include the following steps:

- identify the pest or pests and determine if control is warranted for each;
- determine pest control goal(s);
- know what control tactics are available;
- evaluate the benefits and risks of each tactic or combination of tactics;
- choose a strategy that will be most effective and will cause the least harm to the environment; and
- use each tactic in the strategy correctly.

When pesticides are used, it is essential that the most current information be obtained, in order to prevent environmental and health hazards. The *Pest Management Guide for Horticultural and Forest Crops* provides information for selecting pesticide application schemes for a particular crop. There are also special use labels for some pesticides on various commodities. Check with university or Extension sources for the latest labels. The handbook, *Virginia Commercial Vegetable Production Recommendations*, also provides information on the proper use of crop protectant chemicals. The Extoxnet database, available online at *www.ace.orst.edu/info/extoxnet/ghindex.html*, provides information regarding environmental hazards and other concerns related to chemical usage. Local Extension agents can provide assistance and answer questions related to these information sources.

Table 2.8 Practices to limit pesticide losses from crop fields with plastic mulch

Practice	Features	Also Listed in Table(s):	Applicable Standards[1] or Guidelines
Chemigation	• Described in Table 2.7	2.7	ASAE EP409.1 ASAE EP405.1 CVPR
Contour Farming	• Described in Table 2.2	2.2, 2.5, 2.7	NRCS-VA 330 NRCS 331
Deep Tillage	• Described in Table 2.2	2.2, 2.5	NRCS 324
Diversion	• Described in Table 2.6	2.6, 2.7	NRCS 362 VESCH 3.12
Drip Irrigation	• Described in Table 2.3	2.3, 2.5, 2.7	NRCS 441 ASAE EP405.1
Field Border	• Described in Table 2.6	2.6, 2.7	NRCS 386
Filter Strip	• Described in Table 2.6	2.6, 2.7	NRCS-VA 393
Integrated Pest Management	• Managing agricultural pest infestations (including weeds, insects, and diseases) with a combination of cultural, biological, and chemical controls to reduce adverse effects on plant growth, crop production, and water quality • Decreases use of pesticides, thus reduces pesticide losses from fields • Four aspects are prevention, avoidance, monitoring, and suppression. Specific practices for each aspect are given in Table 2.9.	2.9	NRCS 595 CVPR PMG
Inter-row Cover Crop	• Described in Table 2.2	2.2, 2.5, 2.7	NRCS 340
Inter-row Mulching	• Described in Table 2.5	2.5, 2.7	NRCS 484
Irrigation Scheduling	• Described in Table 2.3	2.3, 2.5, 2.7	CVPR
Level Spreader	• Described in Table 2.6	2.6, 2.7	VESCH 3.21
Riparian Herbaceous or Forest Buffer	• Described in Table 2.6	2.6, 2.7	NRCS-VA 390 NRCS 391
Row Direction	• Described in Table 2.2	2.2, 2.5, 2.7	—
Sediment Basin	• Described in Table 2.6	2.6, 2.7	NRCS-VA 350 NRCS 378
Spray Application Management	• Managing the application of pesticides to achieve pest control, while minimizing pesticide movement to surface and ground waters • Calibrate application equipment periodically • Select correct sprayer tips • Spray only during appropriate weather conditions	—	CVPR
Winter Cover Crop	• Described in Table 2.2	2.2, 2.5, 2.7	NRCS 340

[1]NRCS refers to USDA-Natural Resources Conservation Service Conservation Practice Standard; NRCS-VA refers to Virginia Conservation Practice Standards developed by NRCS in Virginia; VESCH refers to *Virginia Erosion and Sediment Control Handbook*; NEFH refers to *National Engineering Field Handbook* (USDA-NRCS); CVPR refers to Virginia Cooperative Extension *Commercial Vegetable Production Recommendations*; ASAE refers to American Society of Agricultural Engineers Standards; and PMG refers to *Pest Management Guide – Virginia*.

Table 2.9 Tactics to address aspects of integrated pest management (IPM) programs to control pesticide loss from crop fields with plastic mulch (based on Coble, 2001)

IPM Aspect	Features
Prevention	• Pest-free seeds and transplants • Irrigation timing that avoids situations conducive to disease development • Tillage and harvesting equipment cleaned between uses • Field sanitation procedures • Elimination of alternate hosts or sites for insect pests and disease organisms
Avoidance	• Crop rotation such that the crop of choice is not a host for the pest • Cultivars with genetic resistance to pests • Trap crops • Pheromone traps • Cultivars with maturation dates that may allow harvest before pest populations develop • Fertilization to promote rapid crop development • No planting in areas of fields where pest populations are likely to cause crop failure
Monitoring	• Insect traps • Weather • Soil • Pest incidence and distribution for each field
Suppression	**Cultural Management** • Optimized in-row plant populations • Cover crops or mulches • Crops with genetic resistance to pests in the rotation **Physical Tactics** • Cultivation or mowing for weed control • Temperature management or exclusion devices for insect and disease management **Biological Control** • Mating disruption for pests • Avoidance of pesticides or other practices that may reduce effectiveness of naturally occurring biological controls • Baited or pheremone traps for certain insects **Chemical Controls** • Cost:benefit ratio determination prior to use • Pesticide selection based on least negative effects on environment and human health • Site-specific suitability of pesticide based on environmental warnings on label • Pesticide use limited to areas where pests actually exist or are anticipated • Pesticide application device calibration prior to use and occasionally during the season • Avoiding continuous use of chemicals with the same mode of action to prevent resistance development

Chapter 3
Practice Effectiveness and Implementation

The initial consideration in the selection of a BMP should be its effectiveness in affording water quality protection. BMP effectiveness depends on site-specific conditions and the pollutant(s) being targeted. In addition, a system of practices is usually required rather than a single BMP. For example, to be effective, BMPs such as filter strips require the entering runoff to be dispersed, shallow flow as opposed to more concentrated, channelized flow. Level spreaders, or similar practices, are often necessary to disperse the concentrated flow before entering filter strips.

In This Chapter:
Practice Effectiveness
Management Practice Systems

3.1 Practice Effectiveness

Effectiveness of practices is summarized in Figure 3.1 based on the targeted pollutant. Effectiveness is expressed on a qualitative, rather than quantitative, scale due to the influence of site-specific characteristics, such as soils, slope, crop, and distance to water. The practices are ranked according to their expected effectiveness for irrigated crop fields with plastic mulch. All listed practices have some degree of effectiveness. Since most of the BMPs are based on increasing infiltration, reducing runoff, or capturing and treating runoff, the hydrologic response of crop fields with plastic mulch requires some modifications to be made to the cited standards, such as the required runoff storage capacity of sediment basins. Features listed in Chapter 2 tables describe application of the practices specifically to crop fields with plastic mulch as opposed to conventional production.

Practices in Figure 3.1 are grouped as “in-field” and “off-site” practices. The purpose of in-field practices is to reduce runoff, sediment, and associated pollutants below the levels that would leave a crop field without the practices. Off-site practices are intended to manage and/or treat runoff, sediment, and associated pollutants that leave a crop field. Successful implementation of in-field practices may reduce the size and extent of needed off-site practices.

Quantitative information on the effectiveness of practices in reducing pollution from fields with plastic mulch is not included in this handbook because limited studies have been conducted. In Virginia, one objective of a study conducted by Arnold et al. (2001) was to evaluate the movement of crop protectants from fields through various runoff control features. The specific features investigated included sediment basins, irrigation ponds, and forest buffers. The limited results of the study indicated that the sediment basins evaluated had the potential to improve the quality of runoff leaving fields with plastic mulch. The study indicated that irrigation ponds were not effective in removing pollutants from runoff. Forest buffers were effective in improving runoff quality. It was beyond the scope of the study to evaluate design criteria for sediment basins or to provide quantitative pollutant removal information for a variety of basins or forest buffers.

3.2 Management Practice Systems

Achieving effective water quality protection at a given site usually requires a combination of management practices. The most effective management practice systems simultaneously reduce pollutant availability and transport from one or more sources and treat the runoff. For example, to reduce the delivery of pesticides from crop fields to water bodies, such a system could include IPM to reduce pesticide usage and inter-row cover crops to reduce erosion and runoff. The remaining runoff leaving the field could be treated by being directed into field borders and riparian buffer areas before discharging into receiving waters.

Management practice systems should be designed with technical assistance from qualified water quality professionals. Each practice must be selected, designed, implemented, and maintained in accordance with site-specific considerations to ensure that the practices function together to achieve overall water quality goals. If, for example, IPM, cover crops, field borders, grass filters, and riparian buffers are used to address a pesticide problem in a field with plastic mulch, then pesticide applications need to be conducted in a manner consistent with grass filter and riparian requirements (e.g., sprayers must be turned off before entering field borders unless pests in the field border

are targeted). In addition, runoff from the fields must be conveyed evenly to the field borders, which, in turn, must be capable of delivering the runoff to the filter strips and riparian buffers in accordance with design standards and specifications (shallow uniform flow).

Emergency measures used to quickly drain low areas in fields, such as shovel ditches, tend to concentrate field runoff and prevent the required even distribution of flow for buffer areas. If shovel ditches are used, they should be used in combination with other practices, such as level spreaders, that can redistribute the flow prior to discharge into filter strips or buffer areas. Alternatively, they can be used in combination with detention structures that can capture and treat concentrated flow. Under no circumstances should shovel ditches discharge readily to receiving waters.

Figure 3.1 Relative effectiveness[1] of practices in minimizing sediment, nutrient, and pesticide losses from crop fields with plastic mulch

Sediment

In-Field Practices	Off-Site Practices
Contour Farming	Sediment Basin
Row Direction	Riparian Buffer with Level Spreader if needed
Inter-row Cover Crop	Constructed Wetland
Inter-row Mulching	Filter Strip with Level Spreader if needed
Winter Cover Crop	Diversion (Downslope) with one or more of the above BMPs
Diversion (Upslope)	Field Border
Buffer Strips	
Irrigation Scheduling	
Drip Irrigation	
Precision Land Forming	
Grassed Waterway	
Deep Tillage	

Nutrients

In-Field Practices	Off-Site Practices
Nutrient Management	Sediment Basin
Chemigation	Riparian Buffer with Level Spreader if needed
Irrigation Scheduling	Constructed Wetland
Drip Irrigation	Filter Strip with Level Spreader if needed
Winter Cover Crop	Diversion (Downslope) with one or more of the above BMPs
Inter-row Mulching	Field Border
Inter-row Cover Crop	
Contour Farming	
Row Direction	

Pesticides

In-Field Practices	Off-Site Practices
Integrated Pest Management	Riparian Buffer with Level Spreader if needed
Spray Application Management	Filter Strip with Level Spreader if needed
Inter-row Cover Crop	Sediment Basin
Contour Farming	Diversion (Downslope) with one or more of the above BMPs
Row Direction	Field Border
Irrigation Scheduling	
Drip Irrigation	
Deep Tillage	
Winter Cover Crop	
Inter-row Mulching	
Chemigation	

[1]Arrow indicates increasing BMP effectiveness for the specified pollutant

Chapter 4
Guidelines for Developing Water Quality Protection Plans for Crops Grown on Plastic Mulch in Virginia

The goal in developing a water quality protection plan is to identify a system of practices that will prevent adverse water quality impacts from crop production. The system of practices must be feasible for a grower to implement and maintain, thus, the water quality protection plan is an essential component of the overall production plan for the site. This chapter describes the steps that should be followed to develop a water quality protection plan.

In This Chapter:

Steps in Developing a Water Quality Protection Plan

1. **Collect data**
2. **Develop master site map**
3. **Select in-field BMPs to reduce runoff and erosion from fields**
4. **Select and design off-site BMPs**
5. **Develop integrated pest management (IPM) program**
6. **Develop nutrient management plan**
7. **Develop irrigation/chemigation management plan**
8. **Develop implementation schedule and maintenance plan**
9. **Determine cost of plan implementation and operation**
10. **Finalize water quality protection plan**

Step 1. Collect data

Collect the following data for use in selecting appropriate water quality protection practices. Federal, state, and local agencies can assist in obtaining this information as well as provide technical assistance.

a. Aerial photographs of the production fields and surrounding area

b. Locations of irrigation pipelines and hydrants, subsurface drainage networks, fencing, and other permanent infrastructure that may limit management options

c. Topographic map of the production fields and surrounding area

U.S. Geological Survey topographic maps are available for all areas of the state. Maps can be purchased through the Charlottesville sales office of the Division of Mineral Resources of the Department of Mines, Minerals, and Energy (P.O. Box 3667, Charlottesville, VA 22903, 804-951-6340 (phone), 804-951-6365 (fax)) or from private companies, with some available through the internet. A more precise topographic survey of the production fields may be required if drainage patterns are not well defined in the production field area and for the design of detention facilities if they are needed. Such a detailed survey is often developed prior to designing the irrigation system as well.

d. Soil properties as found in county/city soil survey publications and/or available from NRCS

e. Locations of areas with vulnerable ground water (from soil or geologic maps)

f. Locations of any nearby waterbodies and environmentally sensitive areas, such as water supply sources, natural wetlands, and critical habitats

The presence of environmentally sensitive areas in close proximity to a crop field may require more intensive measures to prevent pollutant discharge into the sensitive areas. There may

also be buffer requirements or setbacks for certain activities near environmentally sensitive areas. Information on legal requirements, including water quality standards, can be obtained from local and state agencies, such as the Virginia Department of Environmental Quality (contact information is included in Appendix C). The Chesapeake Bay Local Assistance Department can provide information on the buffer policy in the locally designated Chesapeake Bay Preservation Area.

g. Locations and dimensions of any existing buffers

h. Information related to permit requirements

Step 2. Develop master site map

From the data gathered in step 1, develop a master site map that includes the following features:

a. Location and boundaries of crop fields

b. Drainage patterns in the production fields for crops grown on plastic mulch

c. Downslope waterbodies and other environmentally sensitive areas that will receive runoff from the production fields

d. Drainage patterns (perennial and ephemeral drainageways) between the production fields and downslope waterbodies and other environmentally sensitive areas

e. Artificial drainage features such as ditches, surface water inlets, and subsurface drainage outlets

f. Areas with high runoff and erosion potential

g. Existing buffers

Complete steps 3 through 7 for each field, considering the potential interaction between fields.

Step 3. Select in-field BMPs to reduce runoff and erosion from fields

Because in-field practices that reduce runoff will decrease the extent of required off-site practices, in-field BMPs should be considered first. In-field practices also enhance both short- and long-term productivity. Appropriate practices are described in Tables 2.2, 2.3, and 2.5. Practices should be designed as specified in applicable standards and guidelines.

Step 4. Select and design off-site BMPs

In most cases, in-field BMPs will not reduce runoff and erosion enough to eliminate the need for off-site BMPs. Vegetative measures, such as filter strips and riparian buffers, should be considered next. If all field runoff cannot be dispersed into buffer areas as shallow uniform flow, detention facilities should be designed to treat the runoff. Appropriate practices are described in Table 2.6. Practices should be designed as specified in applicable standards and guidelines, with the modifications noted in Table 2.6.

Step 5. Develop integrated pest management (IPM) program

Because of the potential for off-site transport of pesticides from crop fields with plastic mulch, an integrated pest management program is essential. If pesticide use is part of the IPM program, special attention should be paid to environmental hazards identified on the pesticide labels. The *Pest Management Guide for Horticultural and Forest Crops* provides information for selecting pesticide application schemes for a particular crop. The handbook, *Virginia Commercial Vegetable Production Recommendations*, provides information on the use of pesticides, as well as crop-specific information. An individual with training and experience in IPM program development should be consulted for assistance.

Step 6. Develop nutrient management plan

A nutrient management plan should also be developed. Assistance in the development of nutrient management plans is available from Virginia Cooperative Extension (VCE) personnel, Department of Conservation and Recreation (DCR) nutrient management specialists, and private certified nutrient management specialists. Locations and phone numbers for local VCE and regional DCR offices are included in Appendix C.

Step 7. Develop irrigation/chemigation management plan

The purpose of the irrigation and chemigation plan is to ensure that irrigation and chemical applications are based on crop needs and do not contribute to leaching or runoff of nutrients and pesticides. The nutrient management plan identifies fertilizer needs; the IPM program identifies pesticide needs. The chemigation plan describes how to inject and apply the chemicals in a manner that minimizes potential water quality

impacts. Recommended irrigation and chemigation practices are described in Tables 2.3 and 2.7, respectively. Additional information is available from Virginia Cooperative Extension and irrigation equipment and chemical companies.

Step 8. Develop implementation schedule and maintenance plan

To be effective, BMPs must be implemented and maintained as specified by standards and guidelines. Depending on the practice(s), implementation may require a longer period of time to complete. The implementation schedule and maintenance plan will help to evaluate the practicality of the water quality protection plan.

Step 9. Determine cost of practice implementation and operation

The costs associated with each component of the water quality protection plan should be estimated and summed to obtain the overall cost of implementation and operation. Costs include, but are not limited to, materials and labor for implementation of BMPs, maintenance of BMPs and equipment, and operating expenses, such as chemicals. Assistance in determining the total cost of the plan is available from sources such as the Natural Resources Conservation Service and Virginia Cooperative Extension (contact information for local offices is included in Appendix C). Financial assistance may be available from BMP or conservation incentive programs administered by various government agencies. Information on such programs that were current at the time this handbook was printed is included in Appendix A.

Step 10. Finalize plan

The cost analysis should be reviewed to determine if the plan is economically feasible. If the plan is not economically feasible, components of the plan must be revised. An alternative crop production plan and/or implementation of different BMPs or combinations of BMPs can be evaluated with the objective of lowering the overall cost of the water quality protection plan. Alternatives should be considered until an economically feasible plan is developed. In some cases, it will not be possible to develop an economically feasible water quality protection plan; therefore, crops should not be grown on plastic mulch at such sites.

Chapter 5
Example Water Quality Protection Plans

The purpose of this chapter is to illustrate the development of water quality protection plans for crop fields with plastic mulch. The water quality protection plans in this chapter are based on actual farms; however, some details described may vary from those of the actual site. The sites represent a range of characteristics, including topography, soils, irrigation systems, crops, and type and size of operation. As stated throughout this handbook, effectiveness of BMPs is site-specific; therefore, appropriate water quality protection plans will vary from site to site. The intent is to demonstrate how a plan can be developed and to discuss the site features that should be considered in developing a plan. There are numerous possible plans for each site; one suggested plan for each site is presented in this chapter.

In This Chapter:
Example Water Quality Protection Plan:
- **Eastern Shore**
- **Northern Neck**
- **Southwest**

5.1 Example Water Quality Protection Plan – Eastern Shore

This water quality protection plan describes activities planned by Succulent Vegetables, Inc. to minimize off-site losses of sediment and agricultural chemicals from fields with plastic mulch on its recently acquired Chesapeake Farm.

Step 1. Collect Data

The Cheaspeake Farm is located on the Eastern Shore of Virginia. The farm has a tillable area of approximately 150 acres. Figure 5.1 shows the United States Geological Survey topographic map of the area, including the farm and surounding drainage area, with the production fields identified by a checkerboard pattern and the existing riparian buffers shaded. The farm is located on the Atlantic Ocean side of the Eastern Shore between North and South Creeks. The farm is bounded on the west by a county road and on the east by estuaries of the Atlantic Ocean.

Elevation of the farm ranges from approximately 15 to 35 ft. Slopes of the production fields are slight, ranging from about 1% to 3%. The production fields are located on Bojac sandy loam and loamy sand soils, while the riparian areas are located on Nimmo sandy loam. The following detailed descriptions of the principal soils at the site were obtained from the county soil survey.

- BOJAC LOAMY SAND, 2 TO 6 PERCENT SLOPES - Bojac loamy sand is gently sloping, very deep, and well drained. Erosion hazard is moderate for water and severe for wind. Cultivated crops and nursery stock are moderately well suited to this soil. This soil will contribute to the leaching of fertilizer below the root zone unless intensive nutrient management is applied. Hydrologic soil group B. Soil erodibility factor = 0.17. Depth to water table is approximately 4 to 6 ft.

- BOJAC SANDY LOAM, 0 TO 2 PERCENT SLOPES - Bojac sandy loam is nearly level, very deep, and well drained. Erosion hazard is slight for water and moderate for wind. This soil is prime farmland. It has few limitations for commercial use. Cultivated crops, nursery stock, pasture grasses, and legumes are well suited to this soil. This soil will contribute to leaching fertilizers below the root zone unless intensive nutrient management is applied. Hydrologic soil group B. Soil erodibility factor = 0.24. Depth to water table is approximately 4 to 6 ft.

- NIMMO SANDY LOAM, 0 TO 2 PERCENT SLOPES - Nimmo sandy loam is a nearly level, very deep, and poorly drained soil that is located on flats and in depressions of Carolina Bays. Erosion hazard is slight for water and moderate for wind. This soil has severe limitations for agricultural and commercial use. Cultivated crops and nursery stock are moderately suited to drained areas. Pasture grasses, legumes, and timber are more suited to this soil. This soil may contribute to fertilizer leaching below the root zone. Hydrologic soil group D. Soil erodibility factor = 0.20. Depth to water table is approximately 0 to 1 ft.

Environmentally sensitive areas adjacent to the production fields include North and South Creeks and the marshes and estuary to the east. There is also a drainage ditch parallel to the county road to the west

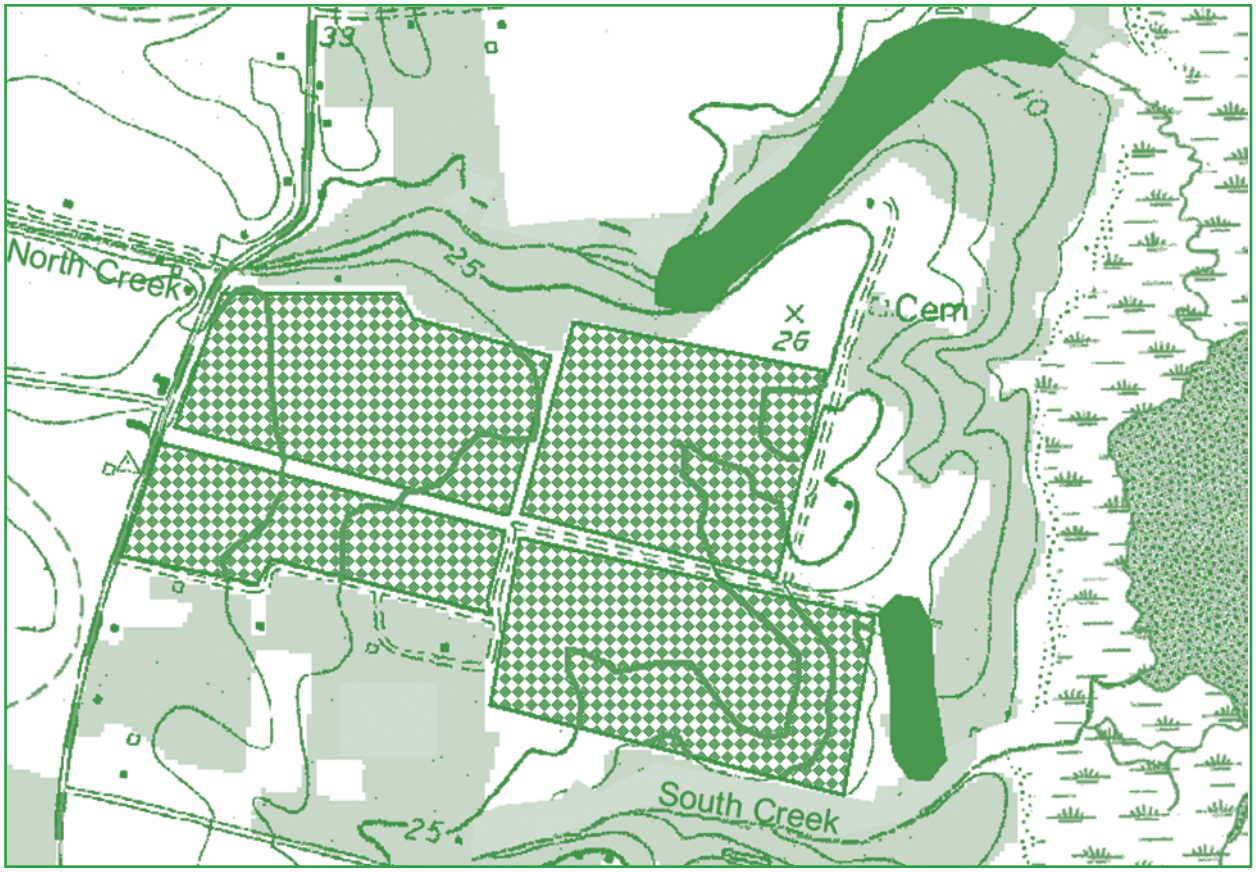


Figure 5.1 Topographic map of the Chesapeake Farm and surrounding drainage area. Existing forest buffers are shaded, and the production fields are shown in a checkerboard pattern. Existing ponds are shaded in black.

that will transport any entering runoff directly to North and South Creeks. The two large constructed ponds, one on North Creek and the other at the southeast corner of the farm, drain a portion of the production fields and are used for irrigation water supply

Buffer areas exist around much of the site. This is a beneficial feature that has the potential to help protect receiving waters from runoff leaving the farm. This feature should be taken into account in selecting and designing water quality protection practices for the site.

Step 2. Develop master site map

The master site map (Figure 5.2) was developed from the data collected in step 1. The natural drainage patterns for fields 1 through 4 can be seen in the map. Flow concentrates in the southeast portion of field 1. The natural drainage pattern in field 2 discharges runoff into the south pond, with some flow going into the buffer area at the south edge of the field. Field 3 discharges into the ditch at the eastern edge of the field. The natural drainage pattern in field 4 results in some runoff flowing into the buffer area at the north edge of the field and some flowing into field 1.

Step 3. Select in-field BMPs

The purpose of in-field BMPs is to reduce runoff and erosion within the field so that less runoff must be treated after leaving the field. The first in-field BMPs that should be considered are contour farming and row direction. Contour farming should be selected, if appropriate. Contour farming is not warranted at this site due to the mild slopes. Orienting rows across the slope, designated “row direction” BMP in this handbook, is the next choice to be considered. An equal water quality benefit, with less intensive management, can be realized by orienting rows across the slope.

Site-specific characteristics and features, such as the natural drainage pattern in the field, the locations of permanent irrigation pipelines and hydrants, and alternative runoff receiving areas, should be considered in determining row orientation. Because this is a newly acquired farm without an existing irrigation system, row orientation is not constrained. The irrigation system can be designed concurrently with the water quality protection plan. The natural drainage pattern in field 1 indicates that concentrated flow occurs in that field. An effective option is the establishment of a

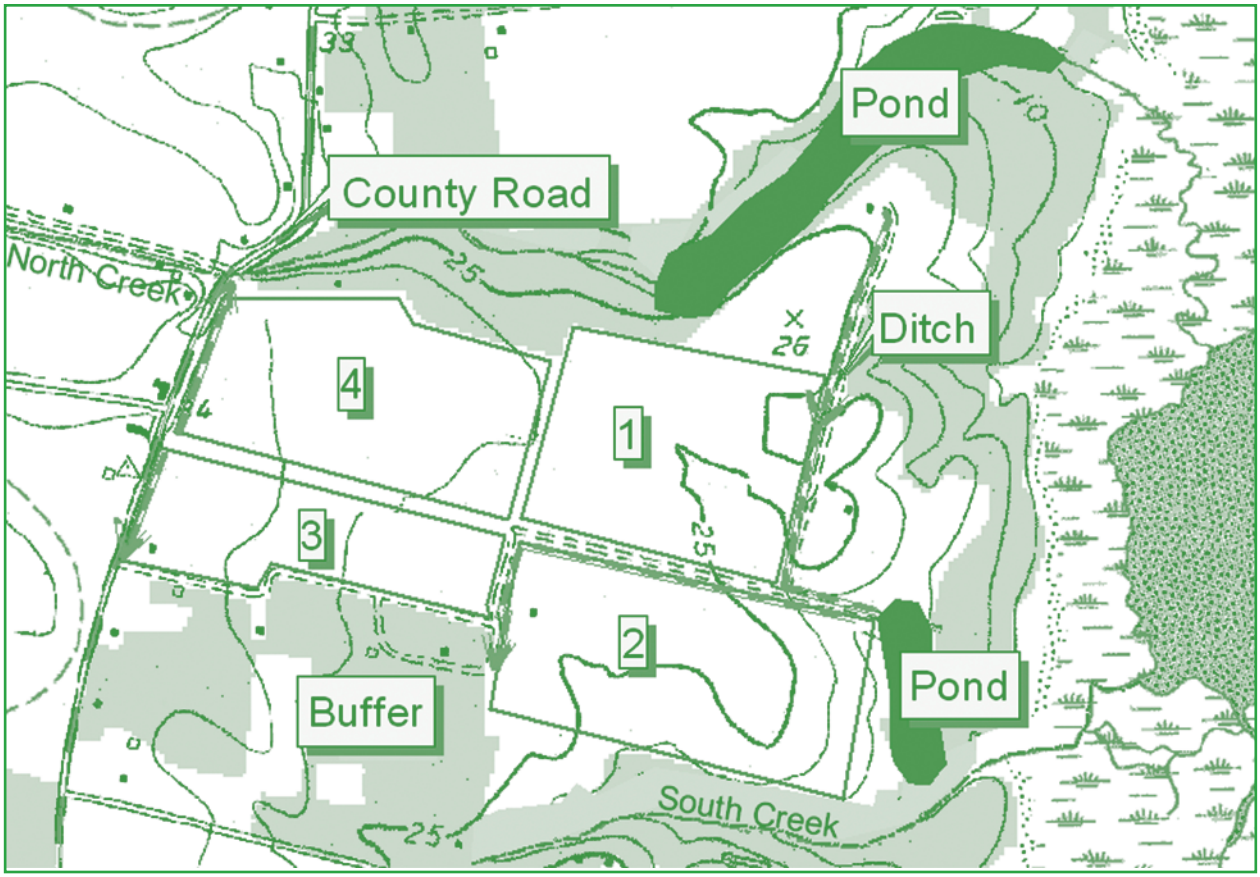


Figure 5.2 Master site map for the Chesapeake Farm

grassed waterway, as shown in Figure 5.3, and orientation of the rows so that they drain toward the waterway. The waterway can then transport the runoff from the field to the southeast pond. The grassed waterway will be designed, established, and maintained as recommended in practice standard NRCS 412.

The natural drainage pattern of field 2 discharges runoff to both the eastern and southern edges of the field. Orienting the rows as shown in Figure 5.3 would take advantage of the existing buffers adjacent to the southern edge of the field and would also result in shorter rows, which would reduce sediment loss as compared to longer rows.

For fields 3 and 4, rows can be laid out across the dominant slope, as illustrated in Figure 5.3. In both cases, the runoff will be directed into the existing buffer areas, which are wide enough (at least 100 ft) to treat the runoff before it reaches the creeks. An initial site inspection may show existence of concentrated flow paths, indicating that level spreaders are needed to ensure that the runoff enters the buffer areas as dispersed flow. Inspection during runoff events will indicate if the flow is adequately dispersed when entering the buffer area.

Additional in-field BMPs that will be implemented in all fields include drip irrigation, irrigation scheduling, cover crops, and deep tillage. Off-season cover crops will be planted in the fall throughout the fields to reduce runoff, sediment, and chemical loss during the winter and early spring. Inter-row areas will be seeded with suitable grass cover in the spring, following deep tillage. Precision land forming will be implemented in field 2 to ensure that runoff drains readily from the field.

Step 4. Select and design off-site BMPs

Runoff leaving the field will be treated by off-site BMPs to minimize impacts on receiving water quality. The BMPs that will be implemented are the following:

- Field borders will be installed perpendicular to the rows. All field borders should be at least 30 ft wide except at the downslope end of the rows, where they should be 60 ft wide. Equipment traffic will not be allowed on the lower 30 ft of the 60-ft wide border.

- The riparian buffers that currently exist along North and South Creeks and the marsh vary in width from approximately 100 to 500 ft. If field runoff is distributed as uniformly as possible across these buffers, they will be very effective in trapping

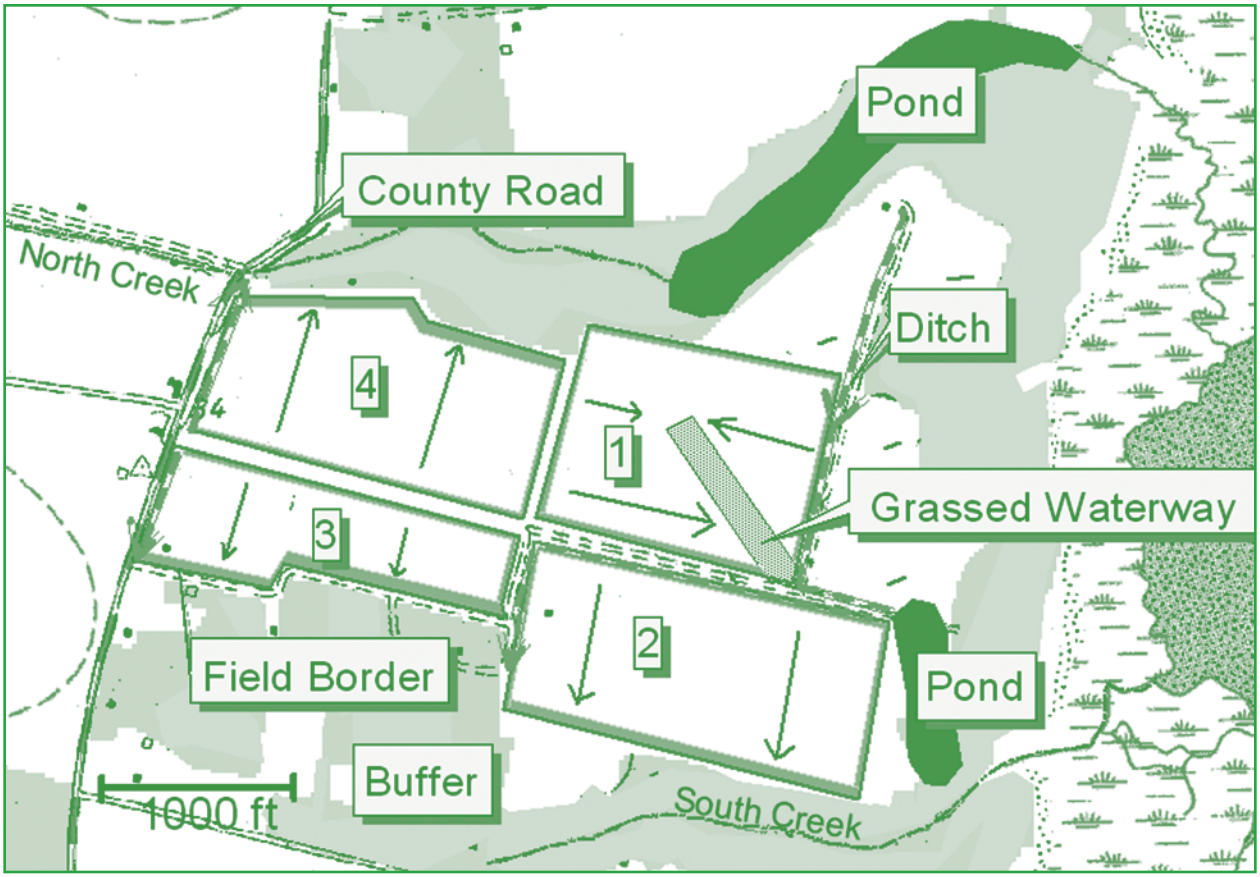


Figure 5.3 Alternative (a) BMPs proposed for Chesapeake Farm water quality protection plan. Arrows indicate crop row direction.

sediment and sediment-bound pollutants and in infiltrating dissolved pollutants.

- Level spreaders will be used as needed in conjunction with the buffer areas for maximum performance. The effectiveness of the level spreaders plus buffers will be enhanced by forcing runoff from the inter-row areas to flow directly into the adjacent field borders and forested buffers without combining with the flow from other inter-row areas.

Step 5. Develop integrated pest management (IPM) program

The IPM program will include a combination of cultural, biological, and chemical controls to reduce adverse effects on plant growth, crop production, and water quality. Appropriate practices, such as those described in Table 2.9, will be selected in consultation with an IPM professional. Some specific components of this IPM program include the following:

- Succulent Vegetables, Inc. has developed economic thresholds for each type of pest that may be encountered.
- A professional IPM scouting service has been contracted to provide scouting services and to make pesticide application recommendations. This is in addition to daily scouting that the grower will conduct. Scouting reduces unnecessary pesticide applications if an infestation has not reached a critical economic threshold.
- A crop rotation system will be developed based upon the crops grown and the ownership status of the land.
- High quality, disease free transplants will be used to reduce disease populations and pesticide use.
- Windbreaks will be planted parallel to the bed direction in locations where wind damage could occur to protect young transplants from wind erosion damage and resulting bacterial and fungal infections.
- Only pesticides labeled for the crop grown will be used. All pesticides used will be applied in conformance with application and environmental risk restrictions on the product's label. Waterbody setbacks and application restrictions related to impervi-

ous surfaces, including the plastic mulch, will be strictly followed.

- Cost-effective pesticides with minimum environmental risks will be selected whenever possible.

- Specialized directed spray-rigs will be used to apply pesticides directly to the plant to minimize drift and overspray.

Step 6. Develop nutrient management plan

A nutrient management plan is a function of the specific crops to be grown, soil properties, and production practices. Plant nutrient recommendations are provided in the handbook, *Virginia Commercial Vegetable Production Recommendations*. Assistance in the development of nutrient management plans is available from Virginia Cooperative Extension personnel, Department of Conservation and Recreation nutrient management specialists, and private certified nutrient management specialists.

Step 7. Develop irrigation/chemigation management plan

The irrigation and chemigation management plan incorporates crop water and nutrient needs, soil properties, weather conditions, irrigation equipment specifications, water availability and quality, and safety considerations. Recommended irrigation and chemigation practices are described in Tables 2.3 and 2.7, respectively. Additional information is available from Virginia Cooperative Extension and irrigation equipment and chemical companies.

Step 8. Develop implementation schedule and maintenance plan

All planned BMPs must be implemented prior to and during the upcoming growing season. None of the recommended BMPs in this example requires a lengthy implementation time period. The maintenance plan for the BMPs must be integrated with the production schedule. Maintenance of each BMP must be included. One important element in the maintenance plan is to maintain vegetated cover in the grassed waterway, field borders, and riparian buffer zones through reseeding and mowing as needed. Irrigation and chemigation equipment must be maintained to ensure safe, precise application of water and chemicals.

Step 9. Determine cost of plan implementation and operation

The costs associated with each component of the water quality protection plan should be estimated and summed to obtain the overall cost of implementation and operation. Costs include, but are not limited to, materials and labor for implementation of BMPs, maintenance of BMPs and equipment, and operating expenses, such as chemicals. Assistance in determining the total cost of the plan is available from sources such as the Natural Resources Conservation Service and Virginia Cooperative Extension. Financial assistance may be available from BMP or conservation incentive programs administered by various government agencies. Information on such programs that were current at the time this handbook was printed is included in Appendix A.

Step 10. Finalize water quality protection plan

In evaluating the costs and practicality of the proposed water quality protection plan, it may be determined that the short rows, particularly in field 3, are not the preferred choice. Longer rows may be more compatible with the most desirable irrigation system installation pattern (longer laterals, fewer connections, shorter headers). Some of the alternatives that could be considered include the following:

Alternative (a):
Orienting the rows across the slope as shown in Figure 5.3 and discussed previously.

Alternative (b):
Alternative (a) except orienting the rows with the slope in field 3, as shown in Figure 5.4. This would require that the runoff be transported by the ditch at the eastern edge of the field to an appropriate structure before dispersal into the buffer area. The structure could be either a level spreader or a detention basin. Both alternatives should be designed and evaluated in terms of cost and practicality.

Alternative (c):
Alternative (b) except orienting the rows in field 2 along the length of the field. Most of the runoff from the field would flow into the southern pond. This pond also drains the interior portion of field 1. The 2-year, 24-hour storm for this alternative results in 7.92 acre-ft of runoff. This requires approximately 1.5 ft of design wet weather storage above the permanent pool level. This is feasible for the southern pond and the principal

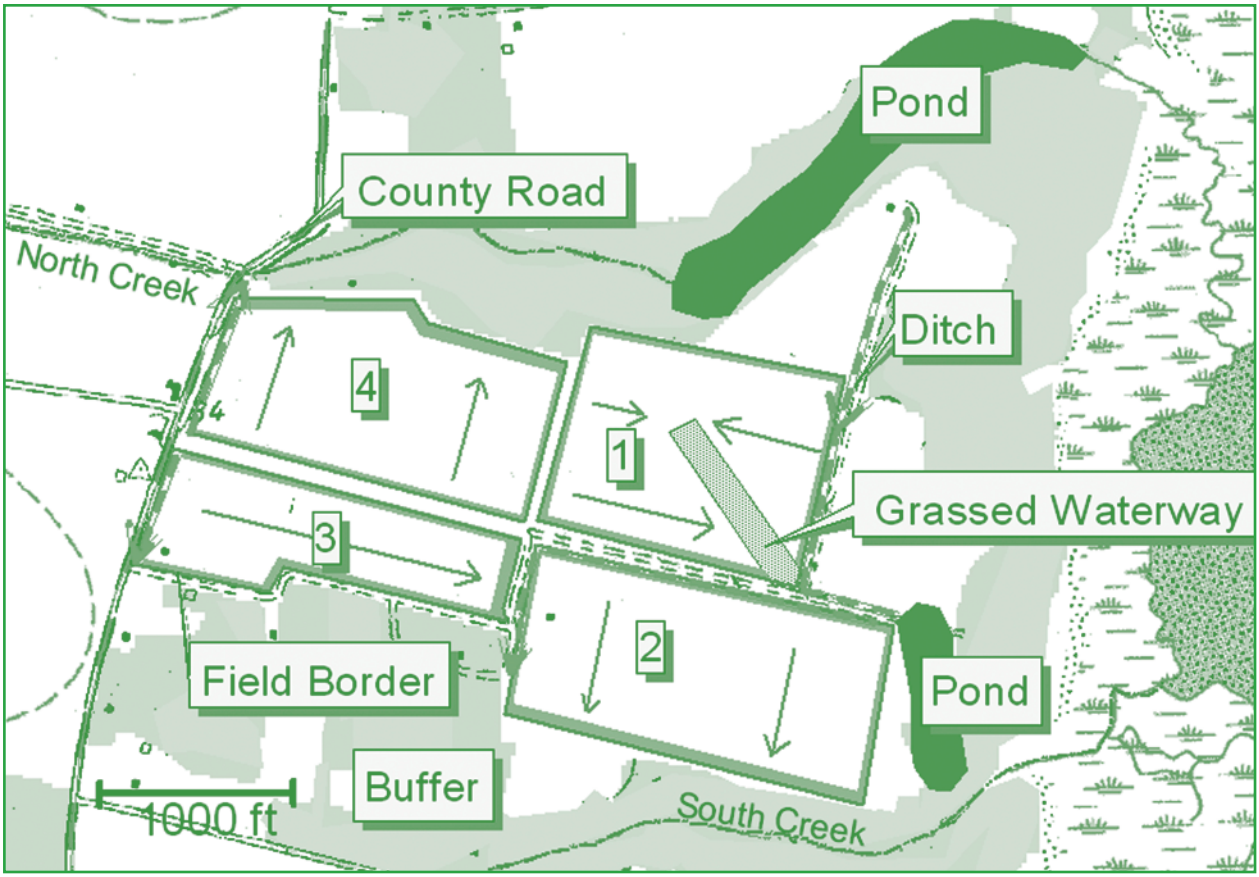


Figure 5.4 Alternative (b) BMPs proposed for Chesapeake Farm water quality protection plan

spillway will be redesigned to dewater this volume of water in 60 hours, as described in Table 2.6. The principal spillway orifice required to dewater 7.92 acre-ft in 60 hours is 8.4 in. (calculated with procedures in Table 2.6). Outflow from the southern pond will be dispersed into adjacent forested buffers using a level spreader in accordance with the *Erosion and Sediment Control Handbook* Standard for Level Spreaders (VESCH 3.21) for the 2-year, 24-hour duration storm rather than the 10-year, 24-hour duration storm.

Alternative (d):
Alternative (c) except orienting the rows in field 4 with the slope. This would result in runoff from field 4 flowing into field 1 and being transported by the grassed waterway into the southern pond. This alternative would require the waterway, as well as the principal spillway and level spreader, to be larger. This alternative would also result in the longest rows on all four fields and potentially produce the most runoff and erosion.

From a water quality perspective, the combination of BMPs described as alternative (a) would be the best choice. With costs taken into account, alternative (b) may be a preferred plan.

5.2 Example Water Quality Protection Plan – Northern Neck

This water quality protection plan describes activities planned by Palatable Produce, Inc. to minimize off-site losses of sediment and agricultural chemicals from fields with plastic mulch on its Rappahannock Farm.

Step 1. Collect Data

The Rappahannock Farm is located on the Northern Neck of Virginia. Approximately 200 acres are suitable for cropping. Figure 5.5 shows the United States Geological Survey topographic map of the area, including the farm and surrounding drainage area, with the production fields identified by a checkerboard pattern and the existing riparian buffer shaded. The farm is located toward the western end of the Northern Neck between the Rappahannock River and a small tidal creek to the north. Drip irrigation under plastic is used on approximately 110 acres, while a center pivot system is used to irrigate 30 acres of vegetables grown on plastic mulch. An additional field seen on the map is about 60 acres, under a part-circle center pivot irrigation system; plastic mulch will not be used on that field.

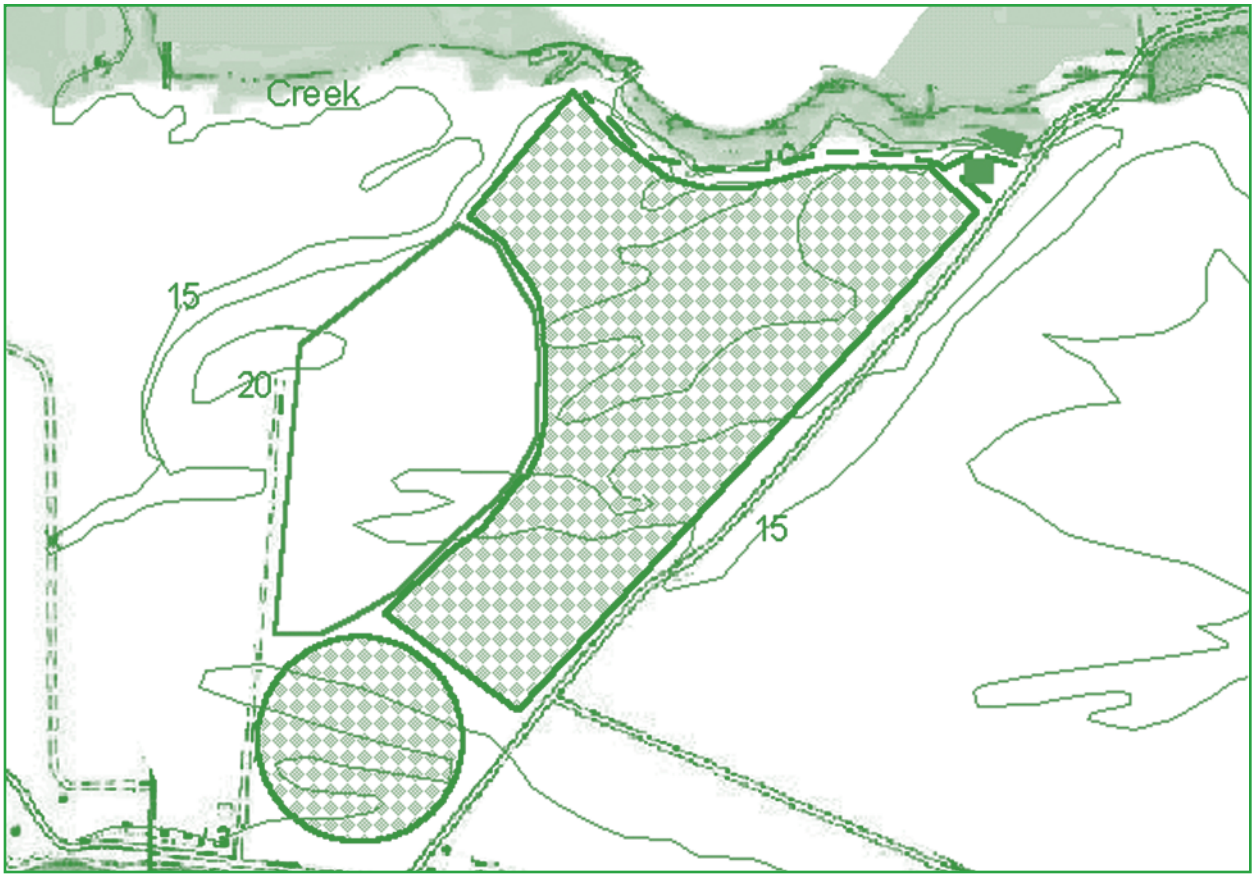


Figure 5.5 Topographic map of the Rappahannock Farm and surrounding drainage area. Existing forest buffers are shaded, and the production fields are shown in a checkerboard pattern.

Slopes in the field are very slight and average approximately 1%. Elevation ranges from 10 to 15 ft. The following detailed descriptions of the production field soils were obtained from the county soil survey.

- PAMUNKEY FINE SANDY LOAM - Pamunkey fine sandy loam is deep, nearly level, and well drained. Erosion hazard is slight for water and moderate for wind. Cultivated crops and nursery stock are moderately well suited to this soil. This soil will contribute to the leaching of fertilizer below the root zone unless intensive nutrient management is applied. Hydrologic soil group B. Soil erodibility factor = 0.28. Depth to water table is approximately 3 to 4 ft.

- BOJAC SANDY LOAM, 0 TO 2 PERCENT SLOPES - Bojac sandy loam is nearly level, very deep, and well drained. Erosion hazard is slight for water and wind. This soil is prime farmland. It has few limitations for commercial use. Cultivated crops, nursery stock, pasture grasses, and legumes are well suited to this soil. This soil will contribute to leaching fertilizers below the root zone unless intensive nutrient management is applied. Hydrologic soil group B. Soil erodibility factor = 0.24. Depth to water table is approximately 4 to 6 ft.

- TETOTUM LOAM, 0 TO 2 PERCENT SLOPES - Tetotum loam is nearly level, deep, and moderately well drained. Erosion hazard is slight for water and moderate for wind. This soil has some limitations for agricultural and commercial use due to a seasonal high water table. Cultivated crops and nursery stock are moderately suited to drained areas. Pasture grasses, legumes, and timber are more suited to this soil. This soil may contribute to leaching of fertilizer below the root zone. Hydrologic soil group C. Soil erodibility factor = 0.32. Depth to water table is approximately 1.5 to 2.5 ft.

- LENOIR SILT LOAM – Lenoir silt loam is deep, somewhat poorly drained, and nearly level. Erosion hazard is slight for water and wind. The soil is moderately well suited to cultivated crops and well suited to pasture. The soil may contribute to leaching fertilizer below the root zone. Hydrologic soil group D. Soil erodibility factor = 0.37. Depth to water table is approximately 1.0 to 2.5 ft.

Environmentally sensitive areas adjacent to the production fields include the tidal creek and the forested riparian zone along its shoreline, and the Rappahannock River with its estuarine marshes. There is also a drainage ditch parallel to the county road that will transport any entering runoff directly to the creek and river, which are water sources for the irrigation systems. A narrow forested buffer exists to the north and northeast of the property along the creek.

Step 2. Develop master site map

The master site map (Figure 5.6) was developed from the data collected in step 1. A natural ridge runs across field 1 in an east-west direction and divides the field drainage, directing runoff from the northern part of the field toward the creek and runoff from the southern part to a farm drainage ditch. Runoff from the lower part of field 3 drains to the same ditch that then directs the flow toward the county road ditch. A ditch at the northeast corner of field 1 is currently an eroded gully leading directly into the creek. The field is steepest at its northern end leading into the ditch. As this ditch approaches the stream, the runoff flows across the farm road along the bank of the stream where no buffer exists. This results in a series of small, eroded rills/gullies through the road requiring regrading from time to time. Toward the southern end of the farm, runoff collected in both the county road and farm ditches is conveyed directly to the Rappahannock River via a culvert under the county road and a large open ditch. Runoff from field 2 combines in the southeast corner of the field with county road ditch drainage at the entrance to the culvert. Runoff from field 3 (crops grown without plastic mulch) runs onto fields 1 and 2, with the majority flowing onto field 1.

Step 3. Select in-field BMPs

The purpose of in-field BMPs is to reduce runoff and erosion within the field so that less runoff must be treated after leaving the field. The first in-field BMPs that should be considered are contour farming and row direction. Contour farming should be selected, if appropriate. Contour farming is not an option at this site due to the minimal slopes. Orienting rows across the slope, designated "row direction" BMP in this handbook, is the next choice to be considered. Two constraints at this site preclude orienting the rows across the slope, so the "row direction" BMP will not be implemented in this case.

The two constraints are the almost negligible slope in the fields and the locations of the existing permanent

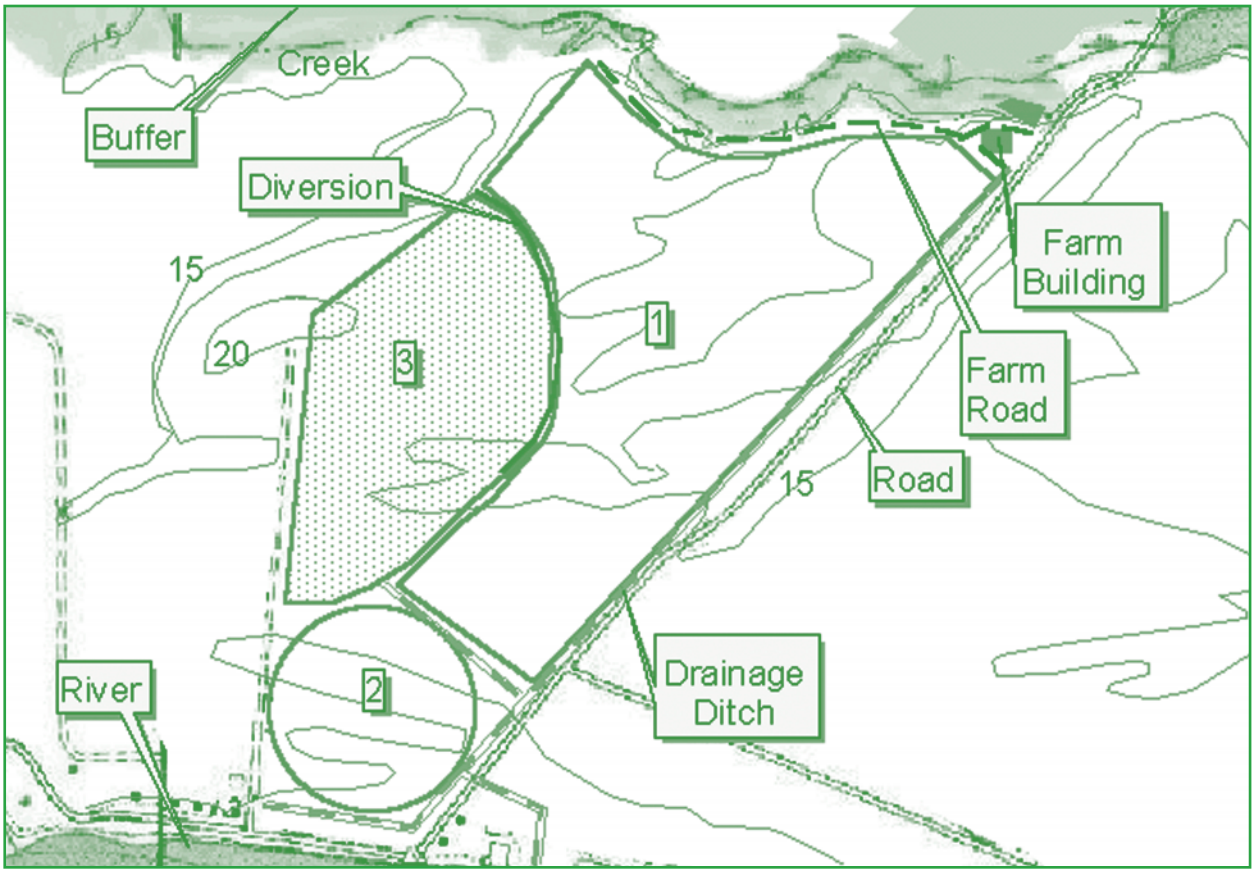


Figure 5.6 Master site map for the Rappahannock Farm

irrigation water supply lines. In field 1, underground submains and hydrants dictate that headers be installed perpendicular to the county road. Additionally, the almost negligible slope in these fields requires that rows be oriented up and down the slope to facilitate drainage from the fields (Figure 5.7). In field 1, orienting rows in this manner parallel to the county road will further insure that little field runoff will be directly contributed to the ditch. For field 2, orienting the rows with the slope results in discharge directly to the county road ditch and in the direction of the road culvert.

Additional in-field BMPs that will be implemented in all fields include cover crops and deep tillage. Off-season cover crops will be planted in the fall throughout the fields to reduce runoff, sediment, and chemical loss during the winter and early spring. Inter-row areas will be seeded with suitable grass cover in the spring, following deep tillage.

Irrigation scheduling will be implemented in both fields, and is especially critical in field 2. The overhead irrigation system will likely result in more runoff compared to a drip irrigation system. In addition, nutrients should only be applied through the irrigation system when the crop needs water. The chemigation plan must consider these limitations.

Step 4. Select and design off-site BMPs

Runoff from the southern part of field 1 and from field 2 flows across the property boundary upon entering the county road culvert, limiting the options for treating runoff from these fields. It is essential to keep runoff leaving the fields to a minimum since the runoff flows directly to the river. Implementing the in-field BMPs described in step 3, as well as field borders as described below, should reduce the runoff leaving the farm.

The off-site BMPs that will be implemented are the following:

- Field borders are a key BMP at this site. At the northern edge of field 1, a 60-ft wide border will be installed perpendicular to the rows. This will help stabilize the road ditch and disperse runoff before it flows across the road into the buffer area. Permanent vegetation will be established in the far northeast corner of field 1 to reduce the possibility of runoff flowing directly to the creek without any treatment. All other field borders should be at least 30 ft wide; borders at the downslope end of the rows should be at least 60 ft wide. Equipment traffic will not be allowed on the lower 30 ft of the 60-ft wide border.

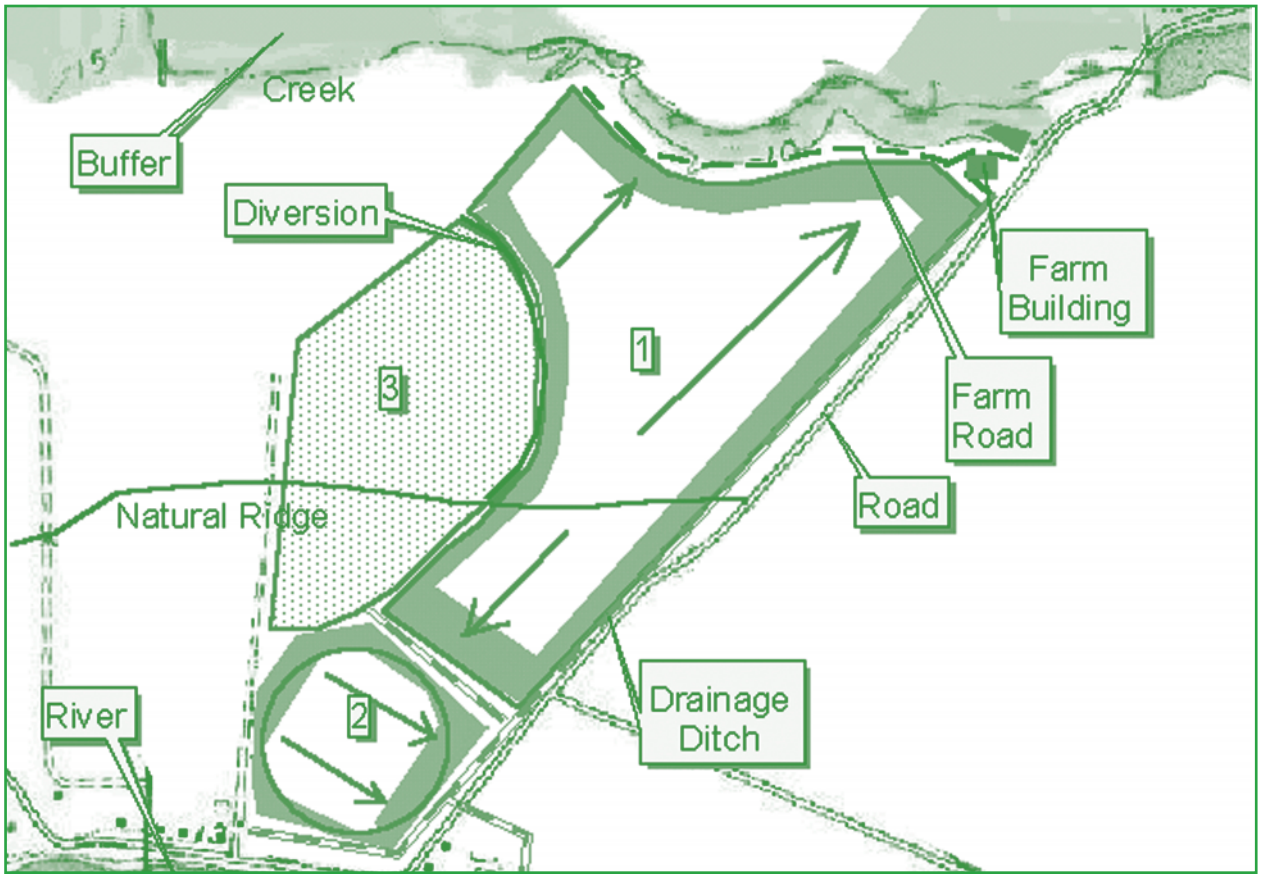


Figure 5.7 Proposed BMPs for the Rappahannock Farm water quality protection plan

- The eroded gully just beyond the northeast corner of field 1 will be graded, vegetated, and maintained as a grassed waterway. A culvert will be installed to pass water from the waterway to the creek without flowing over the road. The runoff entering the creek via the waterway should be of acceptable quality because of the in-field practices and field borders. The road cannot be relocated due to existing facilities and property boundaries.

- The riparian buffers that currently exist along the tidal creek north of field 1 vary in width from approximately 50 to 75 ft. The 60-ft wide field border that will be established along the northern end of field 1 will enhance the effectiveness of the riparian buffer. In addition, measures, such as additional plantings, should be applied within the riparian buffer itself to encourage denser vegetative cover.

- Level spreaders will be used as needed in conjunction with the buffer areas for maximum performance. The effectiveness of the level spreaders plus buffers will be enhanced by forcing runoff from the inter-row areas to flow directly into the adjacent field borders and forested buffers without combining with the flow from other inter-row areas.

- A diversion will be installed to prevent runoff from field 3 from entering field 1. The diverted runoff from field 3 should be properly treated and dispersed before discharging to the buffer area along the creek.

Step 5. Develop Integrated Pest Management (IPM) Program

The IPM program will include a combination of cultural, biological, and chemical controls to reduce adverse effects on plant growth, crop production, and water quality. Appropriate practices, such as those described in Table 2.9, will be selected in consultation with an IPM professional. Some specific components of this IPM program include the following:

- Palatable Produce, Inc. has developed economic thresholds for each type of pest that may be encountered.

- A professional IPM scouting service has been contracted to provide scouting services and to make pesticide application recommendations. This is in addition to daily scouting that the grower will conduct. Scouting reduces unnecessary pesticide applications if an infestation has not reached a critical economic threshold.

- A crop rotation system will be developed based upon the crops grown and the ownership status of the land.

- High quality, disease free transplants will be used to reduce disease populations and pesticide use.

- Windbreaks will be planted parallel to the bed direction in locations where wind damage could occur to protect young transplants from wind erosion damage and resulting bacterial and fungal infections.

- Only pesticides labeled for the crop grown will be used. All pesticides used will be applied in conformance with application and environmental risk restrictions on the product's label. Waterbody setbacks and application restrictions related to impervious surfaces, including the plastic mulch, will be strictly followed.

- Cost-effective pesticides with minimum environmental risks will be selected whenever possible.

- Specialized directed spray-rigs will be used to apply pesticides directly to the plant to minimize drift and overspray.

Step 6. Develop nutrient management plan

A nutrient management plan is a function of the specific crops to be grown, soil properties, and production practices. Plant nutrient recommendations are provided in the handbook, *Virginia Commercial Vegetable Production Recommendations*. Assistance in the development of nutrient management plans is available from Virginia Cooperative Extension personnel, Department of Conservation and Recreation nutrient management specialists, and private certified nutrient management specialists.

Step 7. Develop irrigation/chemigation management plan

The irrigation and chemigation management plan incorporates crop water and nutrient needs, soil properties, weather conditions, irrigation equipment specifications, water availability and quality, and safety considerations. Recommended irrigation and chemigation practices are described in Tables 2.3 and 2.7, respectively. Additional information is available from Virginia Cooperative Extension and irrigation equipment and chemical companies.

Step 8. Develop implementation schedule and maintenance plan

All planned BMPs must be implemented prior to and during the upcoming growing season. None of the recommended BMPs in this example requires a lengthy implementation time period. The maintenance plan for the BMPs must be integrated with the production schedule. Maintenance of each BMP must be included. One important element in the maintenance plan is to maintain vegetated cover in the grassed waterway, field borders, and riparian buffer zones through reseeding and mowing as needed. Irrigation and chemigation equipment must be maintained to ensure safe, precise application of water and chemicals.

Step 9. Determine cost of plan implementation and operation

The costs associated with each component of the water quality protection plan should be estimated and summed to obtain the overall cost of implementation and operation. Costs include, but are not limited to, materials and labor for implementation of BMPs, maintenance of BMPs and equipment, and operating expenses, such as chemicals. Assistance in determining the total cost of the plan is available from sources such as the Natural Resources Conservation Service and Virginia Cooperative Extension. Financial assistance may be available from BMP or conservation incentive programs administered by various government agencies. Information on such programs that were current at the time this handbook was printed is included in Appendix A.

Step 10. Finalize water quality protection plan

As discussed earlier, the water quality protection plan presented in Figure 5.7 may not meet water quality goals for the runoff leaving field 2. The location of field 2 relative to the property boundary severely limits the options for capturing and/or treating runoff from the field. If implemented as presented, runoff leaving the farm can be sampled at the culvert to determine if the quality is acceptable. If the runoff is not of suitable quality, alternative measures would need to be implemented. Due to the proximity of the fields to the property line, additional measures would need to focus on in-field practices. The irrigation system could be converted to drip to reduce the potential for runoff. This alternative may not be feasible due to the cost. Another alternative may be to not grow crops on plastic mulch in field 2.

This example illustrates that a water quality protection plan needs to be monitored after implementation to determine if it is working as planned. Modifications may be required over time.

5.3 Example Water Quality Protection Plan - Southwest

This water quality protection plan describes activities planned by Pick-Your-Own Operations, Inc. to minimize off-site losses of sediment and agricultural chemicals from fields with plastic mulch on its Blue Ridge Farm.

Step 1. Collect Data

The Blue Ridge Farm is located in Southwest Virginia in the foothills of the Blue Ridge Mountains. The entire farm has approximately 10 acres available for production. Figure 5.8 shows the United States Geological Survey topographic map of the area, including the farm and surrounding drainage area, with the production fields using plastic mulch identified by a checkerboard pattern and the existing riparian buffers shaded.

Crop production on the farm is very diverse with both perennial small fruits and annual vegetable crops raised on the farm. Drip irrigation is used on all crops, including a small fruits orchard in which plastic mulch is not used, located in the smallest field shown on the map. Plastic mulch is used for some annual vegetable crops and one row-cropped, perennial small fruit crop. Additionally, for the latter, an overhead irrigation system is used solely for frost protection. All water for drip irrigation and frost protection is supplied by a groundwater well located on the farm.

Slopes in the field are moderate to steep and range from 5% to 20%. Elevation averages approximately 2000 ft. The following detailed descriptions of the production field soils were obtained from the county soil survey.

- GROSECLOSE SILT LOAM, 2 TO 7 PERCENT SLOPES - These soils are well drained and gently sloping on ridgetops. Erosion hazard is moderate. Cultivated crops, pasture grasses, and legumes are well suited to these soils. Hydrologic soil group C. Soil erodibility factor = 0.43. Depth to water table is greater than 6 ft.

- GROSECLOSE SILT LOAM, 15 TO 25 PERCENT SLOPES - These soils are well drained and moderately steep. Erosion hazard is severe. These soils

Figure 5.8 Topographic map of the Blue Ridge Farm and surrounding drainage area. Existing buffers are shaded and the production fields are shown in a checkerboard pattern.

are used mainly for pasture and woodland. Soil conservation measures are necessary for cultivated crops, which are poorly suited to these soils. Hydrologic soil group C. Soil erodibility factor = 0.43. Depth to water table is greater than 6 ft.

- FREDERICK SILT LOAM, 7 TO 15 PERCENT SLOPES - These are well drained, strongly sloping soils on ridgetops and side slopes. Erosion hazard is moderate. Cultivated crops are well suited to these soils. Hydrologic soil group B. Soil erodibility factor = 0.32. Depth to water table is greater than 6 ft.

There are no perennial streams, either through or adjacent to the property. An intermittent stream, framed by an herbaceous buffer of varying width and vegetative quality, is located to the east of the production fields. No surface drainage ditches or other artificial drainage measures are necessary because of the pronounced field slopes. No environmentally sensitive areas are identified in the immediate vicinity of the production fields. The private homes, and associated domestic water supplies, to the northwest of the farm should not be impacted, from a water quality standpoint, by the downgradient crop production activities.

Step 2. Develop master site map

The master site map (Figure 5.9) was developed from the data collected in step 1. Runoff from all fields eventually drains into the intermittent stream that forms the eastern border of the farm. All of the fields have high runoff potential and moderate to severe erosion potential, therefore, there should be a low risk of leaching to groundwater due to rainfall alone. With plastic mulch, runoff potential will be increased. The potential for increased runoff, as well as increased leaching in the inter-row areas, however, will be enhanced under the overhead frost protection system in conjunction with plastic mulch.

The production diversity of the farm allows some flexibility in relegating crop production posing greater runoff and erosion hazards to those fields (and soils) with less runoff and erosion potential. For example, perennial small fruit orchards, grown without plastic mulch and involving minimal soil disturbance, should be located where runoff and erosion potential is greatest (assuming that recommended measures, such as vegetated alleyways, are implemented). Conversely, fields/soils having less runoff and erosion potential should be reserved for

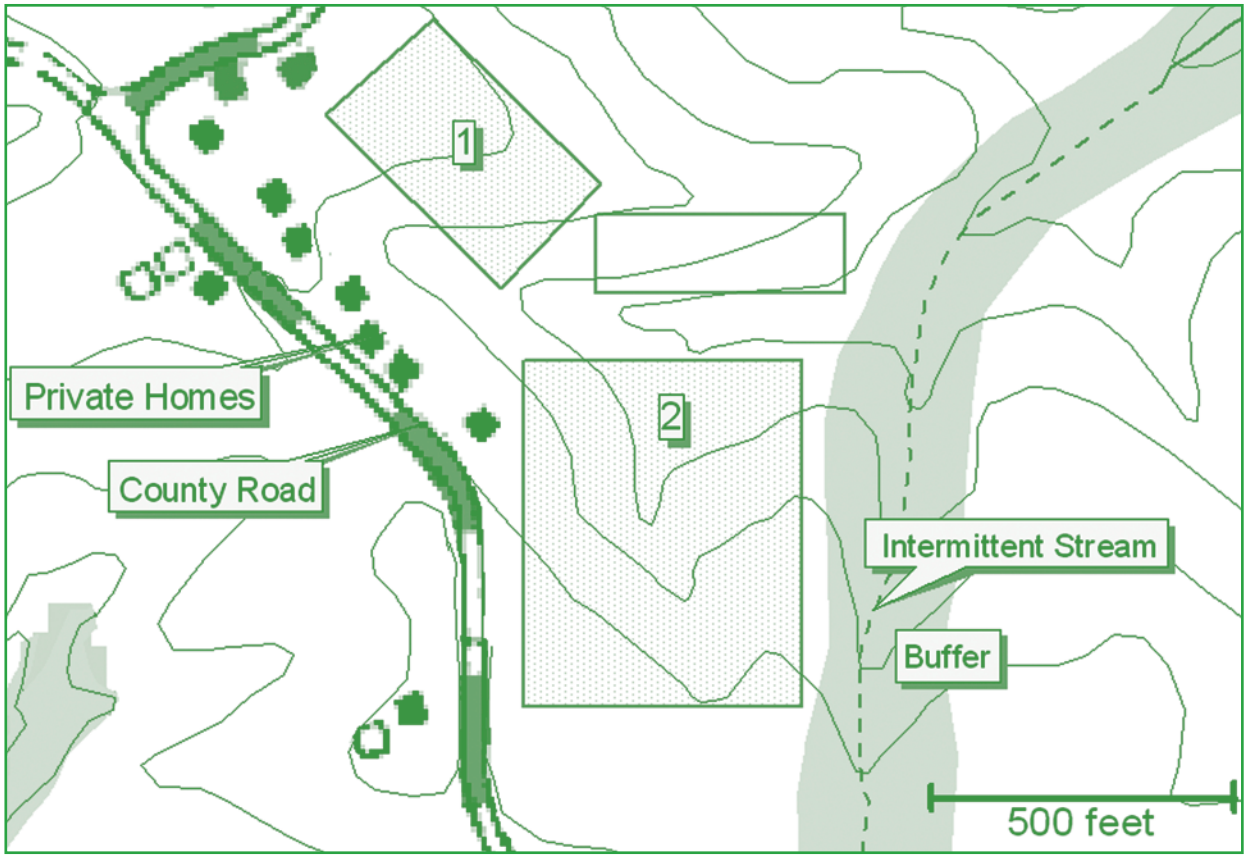


Figure 5.9 Master site map for the Blue Ridge Farm

crops with plastic mulch, and, in particular, where frost protection by overhead sprinklers is used. While this represents a water quality protection viewpoint only, other factors, such as air drainage and field aspect considerations, public access and harvesting schedules, and crop rotation patterns, will need to be taken into account.

For the purposes of this proposed plan, the small fruit row crop with plastic mulch and overhead sprinkler frost protection will be produced in field 1 (predominately Groseclose silt loam, 2 to 7% slopes), and various row-cropped vegetables, both with and without plastic mulch, will be grown in field 2 (predominately Frederick silt loam). The field that has the greatest runoff and erosion potential (predominately Groseclose silt loam, 15 to 25% slopes) currently contains the small fruits orchard in which plastic mulch is not used.

Step 3. Select in-field BMPs

The purpose of in-field BMPs is to reduce runoff and erosion within the field so that less runoff must be treated after leaving the field. These practices are most critical in this application because of the lack of existing buffers and limited space for off-site BMPs to be implemented. Additionally, because of the erosion potential, soil conservation measures are necessary to maintain long-term productivity of the farm.

The first in-field BMPs that should be considered are contour farming and row direction. Contour farming should be selected, if feasible, and will be implemented in field 2. For field 1, orienting rows across the slope, designated "row direction" BMP in this handbook, is proposed.

Site-specific characteristics and features, such as the natural drainage pattern in the fields, the locations of permanent irrigation pipelines and hydrants, and possible runoff receiving areas, should be considered in determining row orientation. In this case, all irrigation supply lines are portable and aboveground, so they do not constrain the desired row orientation.

The magnitude of the field slopes dictates that rows be run across the slope with sufficient cross slope incorporated to allow drainage of the inter-row areas. In some situations, it may be possible to orient the rows so that field drainage can exit either side of the field to take advantage of natural drainage patterns which will not only treat runoff but direct it around, and not through, downslope production areas. Proposed row directions for fields 1 and 2 are indicated in Fig. 5.10.

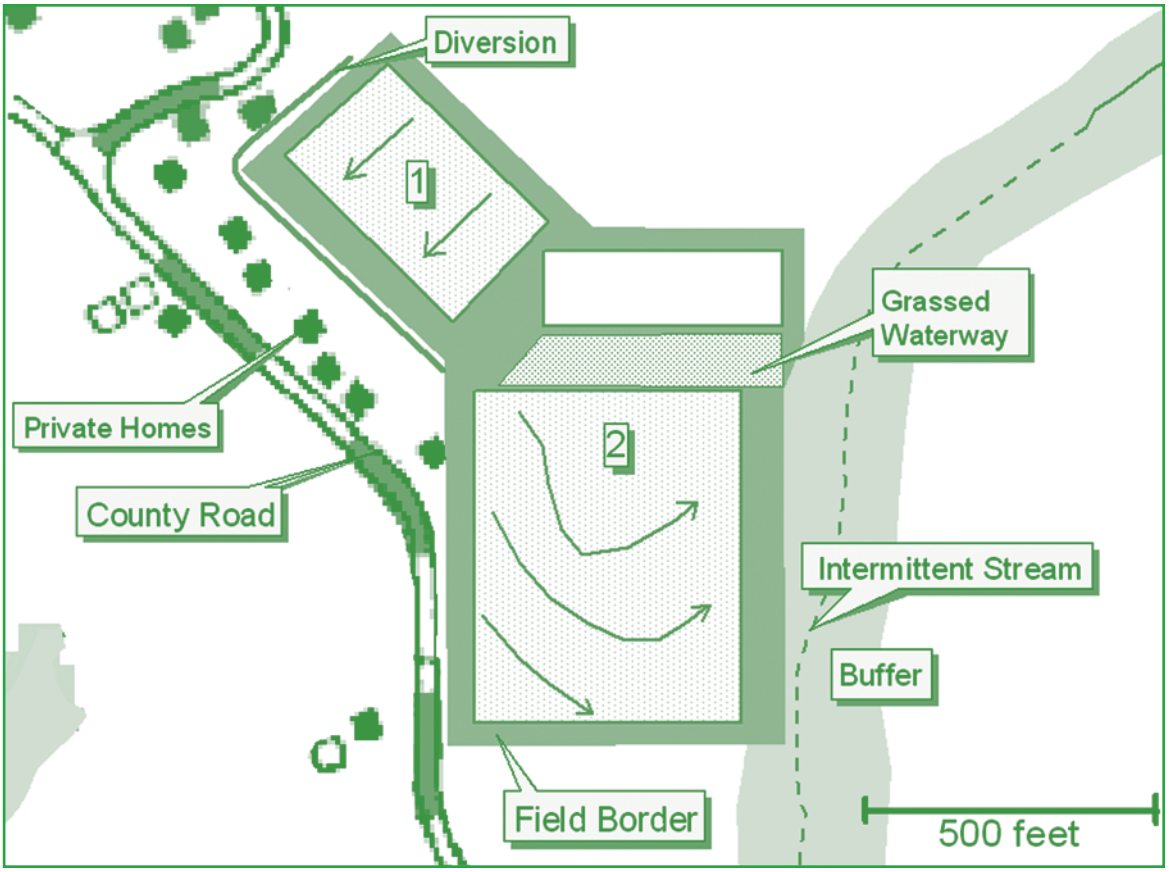


Figure 5.10 Proposed BMPs for the Blue Ridge Farm water quality protection plan

Additional in-field BMPs that will be implemented in fields 1 and 2 include cover crops and deep tillage. Off-season cover crops will be planted in the fall (where applicable) throughout the fields to reduce runoff, sediment, and chemical loss during the winter and early spring. Inter-row areas for annual crops will be seeded with suitable grass cover in the spring, following deep tillage.

Irrigation scheduling for frost protection is critical in field 1 because use of an overhead irrigation system leads to the potential for increased runoff and leaching. The irrigation/frost protection system should be specifically designed not to apply water at a rate greater than that required and run only when, and to the extent, necessary to counter freezing temperatures and conditions that may incur frost/freeze damage.

Step 4. Select and design off-site BMPs

Runoff leaving the field will be treated by off-site BMPs to minimize impacts on receiving water quality. The BMPs that will be implemented are the following:

- The current layout of the farm fields provides adequate room for field borders to be established and maintained without taking any existing cultivated land out of production. Therefore, permanent vegetation will be established and maintained in all inter-field areas. In the outer field perimeter areas, all field borders should be at least 30 ft wide; borders at the downslope end of the rows should be at least 60 ft wide. Equipment traffic will be allowed only within the first 30 ft of the field borders from the edge of the field and remain out of the drainageways. Access roads will not be routed along drainageways and cross them only where necessary.

- The primary drainageway, between field 2 and the small fruits orchard, will be established and maintained as a grassed waterway. Access roads will not cross the grassed waterway. The grassed waterway will be designed, established, and maintained as recommended in practice standard NRCS 412.

- The riparian buffer that currently exists along the intermittent stream east of field 2 varies in width from approximately 50 to 75 ft. The 60-ft wide field border that will be established along the eastern end of field 2 will enhance the effectiveness of the riparian buffer. The riparian buffer should be enhanced through vegetation management.

- Runoff from the private homes and lawns runs onto field 1. A diversion will be utilized to intercept and direct this runoff around the field and into the primary drainageway above the grassed waterway.

Step 5. Develop Integrated Pest Management (IPM) Program

The IPM program will include a combination of cultural, biological, and chemical controls to reduce adverse effects on plant growth, crop production, and water quality. This plan will also help to mitigate concerns by the public about exposure to chemical pesticides. Appropriate practices, such as those described in Table 2.9, will be selected in consultation with an IPM professional. Some specific components of this IPM program include the following:

- Pick-Your-Own Operations, Inc. has developed economic thresholds for each type of pest that may be encountered.
- The farm manager will conduct daily scouting for the purposes of recommending pesticide applications. Scouting reduces unnecessary pesticide applications if an infestation has not reached a critical economic threshold.
- A crop rotation system will be developed based upon the crops to be grown.
- High quality, disease free transplants will be used to reduce disease populations and pesticide use.
- Only pesticides labeled for the crop grown will be used. All pesticides used will be applied in conformance with application and environmental risk restrictions on the product's label. Waterbody setbacks and application restrictions related to impervious surfaces, including the plastic mulch, will be strictly followed.
- Cost-effective pesticides with minimum environmental risks will be selected whenever possible.
- Specialized directed spray-rigs will be used to apply pesticides directly to the plant to minimize drift and overspray.

Step 6. Develop nutrient management plan

A nutrient management plan is a function of the specific crops to be grown and production practices. Plant nutrient recommendations are provided in the handbook, *Virginia Commercial Vegetable Production Recommendations*. Assistance in the development of nutrient management plans is available from Virginia Cooperative Extension, Department of Conservation and Recreation nutrient management specialists, and private certified nutrient management specialists.

Step 7. Develop irrigation/chemigation management plan

The irrigation and chemigation management plan incorporates crop water and nutrient needs, weather conditions, irrigation equipment specifications, water availability and quality, and safety considerations. Recommended irrigation and chemigation practices are described in Tables 2.3 and 2.7, respectively. Additional information, including frost protection design specifications and guidelines, is available from Virginia Cooperative Extension, irrigation companies, and fertilizer dealers.

Step 8. Develop implementation schedule and maintenance plan

All planned BMPs should be implemented prior to the next growing season if practical. The perennial nature of some crops may delay full implementation for several years, however, none of the recommended BMPs in this example requires a lengthy implementation time period. The maintenance plan for the BMPs must be integrated with the production schedule. Maintenance of each BMP must be included. One important element in the maintenance plan is to maintain vegetated cover in the grassed waterway and field borders through reseeding and mowing as needed. Irrigation, chemigation, and frost protection equipment must be maintained to ensure safe, precise application of water and chemicals.

Step 9. Determine cost of plan implementation and operation

The costs associated with each component of the water quality protection plan should be estimated and summed to obtain the overall cost of implementation and operation. Costs include, but are not limited to, materials and labor for implementation of BMPs, maintenance of BMPs and equipment, and operating expenses, such as chemicals. Assistance in determining the total cost of the plan is available from sources such as the Natural Resources Conservation Service and Virginia Cooperative Extension. Financial assistance may be available from BMP or conservation

incentive programs administered by various government agencies. Information on such programs that were current at the time this handbook was written is included in Appendix A.

Step 10. Finalize water quality protection plan

If runoff is excessive and water quality unsuitable, alternative measures will need to be implemented. To counter problems in field 1, the rows could possibly be drained in the opposite direction or contour farming could be considered. If severe problems are encountered with frost protection by sprinklers, row covers could provide an alternative means of preventing freeze/frost damage, eliminating the need for overhead sprinkler applications altogether.

In field 2, a grassed waterway in the main drainageway of the field may provide additional water quality protection, if warranted. Field 2 also contains a mix of vegetable crops, some of which are produced with plastic mulch and some without. Initially, it appears that plastic mulch use limited to the upper field areas, where the slopes are somewhat milder and the travel distance of runoff is greatest, would perhaps lead to a reduction in the amount of runoff and soil leaving the farm. Given crop rotation constraints, experience over time, however, will help determine exactly where in the field plastic mulch use will result in the least environmental impact.

Technical References

1. Arnold, G., M. Luckenbach, M. Roberts, Jr., M. Newman, E. Shumann, M. Unger, and G. Vadas. 2001. Fate and effects of crop protectants from tomoato cultivation on living resources in tidal creeks. Draft Final Report submitted to Virginia Department of Agriculture and Consumer Services, August 2001.

2. ASAE Standards 2001. 48th Edition. ASAE, St. Joseph, MI.

3. Coble, H. Determining the Practice of Integrated Pest Management (IPM): A Working Definition for the Year 2000 Goal. Accessed at: www.ipm-education.org/papers/coble012099.html, June 26, 2001.

4. Commercial Vegetable Production Recommendations – Virginia, 2001. Virginia Cooperative Extension. Publication No. 456-420.

5. NRCS Conservation Practice Standards. Available online at www.ftw.nrcs.usda.gov/practice_stds.html

6. Pest Management Guide: Horticultural & Forest Crops – Virginia, 2001. Virginia Cooperative Extension. Publication No. 456-017.

7. Virginia Conservation Practice Standards. Available online at www.va.nrcs.usda.gov/DataTechRefs/std_specs.htm

8. Virginia Erosion and Sediment Control Handbook. Third Edition, 1992. Virginia Department of Conservation and Recreation. Division of Soil and Water Conservation, Richmond, Virginia.

Appendix A
Financial Programs

Conservation incentive programs are available for Virginia landowners and producers. Programs range from cost sharing for conservation practices to tax credits, land rentals, and easements for preserving resources. These programs are available through the United States Department of Agriculture and the Commonwealth of Virginia.

Additional programs target erosion and water quality, enhance habitat for wildlife, and encourage good forest stewardship. Each conservation program has specific requirements and some have limited sign-up dates. Conservation incentive programs are constantly changing so it is advisable to contact the Natural Resources Conservation Service (NRCS), the Farm Service Agency (FSA), Virginia Cooperative Extension (VCE), Virginia Department of Conservation and Recreation (DCR), and/or the local Soil and Water Conservation District (SWCD) office to receive the latest information on these and other programs. Contact information for these agencies is included in Appendix C. The programs described briefly below were some of the programs available at the time this handbook was printed.

Programs administered by NRCS

Environmental Quality Incentives Program (EQIP). The Environmental Quality Incentives Program provides technical, educational, and financial assistance to eligible farmers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner. Cost-share payments may be made to implement one or more eligible structural or vegetative practices, such as terraces, filter strips, tree planting, and permanent wildlife habitat. Incentive payments can be made to implement one or more land management practices, such as pest management and nutrient management.

Wildlife Habitat Incentives Program (WHIP). This is a voluntary program for people who want to develop or improve wildlife habitat on private lands. Cost-share assistance up to 75% is available for establishing

habitat. WHIP agreements between NRCS and the participant generally last from 5 to 10 years from the date the agreement is signed.

Wetland Reserve Program (WRP). This program is available to qualified landowners statewide to restore wetlands. Sign-up is on a continuous basis. Landowners who choose to participate in WRP may receive payments for a conservation easement or cost-share assistance for a wetland restoration agreement. The landowner retains ownership but voluntarily limits future use of the land.

Emergency Conservation Program (ECP). In the event of a natural disaster, ECP may be implemented to rehabilitate farmlands and conservation facilities. ECP provides cost-share assistance to eligible producers. The Farm Service Agency and the Natural Resources Conservation Service administer this program.

Programs administered by FSA

Conservation Reserve Program (CRP). The primary goals of the CRP program are to establish long-term, resource-conserving covers on eligible land to reduce erosion. The program provides wildlife habitat benefits and provides for water quality benefits from reduced erosion, runoff, and leaching. Offers are accepted and processed during fixed signup periods announced by FSA. All eligible cropland offers are ranked using a national ranking process. If accepted, contracts are developed for a minimum of ten and not more than 15 years. Payments are based on a per-acre soil rental rate. Eligible practices include planting of these areas in trees and/or herbaceous vegetation.

Conservation Reserve Enhancement Program (CREP). This voluntary program uses financial incentives to encourage farmers and ranchers to enroll in the Conservation Reserve Program (CRP) with contracts to remove lands from agricultural production. The Virginia enhancement program consists of two components: the Chesapeake Bay CREP and the Southern Rivers CREP. When fully implemented, these projects will collectively restore up to 30,500 acres of riparian habitat and 4,500 acres of wetlands. One project will target 25,000 acres within the Bay watershed, while a second project will target 10,000 acres in non-Bay drainage basins.

Programs administered by SWCDs

Virginia Agricultural Best Management Practices Cost-Share Program (BMP). The program's primary goals are to encourage voluntary installation of agricultural BMPs; to address Virginia's nonpoint source pollution water quality objective; to improve water quality in the state's streams, rivers, and the Chesapeake Bay; and to prevent additional nonpoint source pollution and meet the criteria for Virginia's compliance with Section 319 of the Clean Water Act. There are many individual practices under this program. Local SWCDs can provide information about current eligible practices and cost-share limits.

Virginia Agricultural Best Management Practices Tax Credit Program. This program provides an incentive to voluntarily install agricultural best management practices (BMPs) in accordance with an approved conservation plan. The local SWCD Board must approve the tax credit before the BMP is installed. Another goal is to reduce the amount of nonpoint source pollution entering the state's streams, rivers, and estuaries. This program is applicable to all land within the Commonwealth. Agricultural producers with an approved conservation plan can take a credit against their state income tax in the amount of 25% of eligible BMP expenses, not to exceed $17,500. If the credit is in excess of the total state income tax obligation for the given tax year, producers may carry over the credit for up to five years.

Virginia Conservation Equipment Tax Credit. The Department of Conservation and Recreation (DCR), in conjunction with the local SWCD, administers this program. It applies statewide and may be claimed for the year of purchase for equipment meeting state-approved specifications. To be eligible for the equipment tax credit, the applicant must have a nutrient management plan approved by the SWCD. Categories of equipment potentially eligible for the credit are sprayers for pesticide and liquid fertilizers, pneumatic fertilizer applicators, manure applicators, tramline adaptors, and starter fertilizer banding attachments for planters. The above listed items qualify for a tax credit equaling 25% of the equipment purchase price or $3750, whichever amount is less. Conservation tillage equipment is eligible for a 25% tax credit, not to exceed $2500. The equipment must meet state established criteria, and the producer must have a nutrient management plan approved by the local SWCD.

Program administered by the Virginia Department of Environmental Quality

Virginia Agricultural Best Management Practices Loan Program. This program provides a source of low interest financing which will encourage the use of specific best management practices which reduce or eliminate the impact of agricultural nonpoint source pollution to Virginia's waters. The goal of this program is to help reduce or eliminate pollution of state waters from the Commonwealth's agricultural operations. This program is available to agricultural producers statewide.

Program administered by the Virginia Department of Business Assistance

Small Business Environmental Compliance Revolving Loan Program. In February 2000, the Governor's Office announced the implementation of the Virginia Small Business Environmental Compliance Assistance Fund. This is a direct loan program designed to help businesses purchase and install equipment to comply with the federal Clean Air Act, and to purchase and install equipment or structures to implement agricultural best management practices (BMP). Under the program, borrowers may apply for up to $50,000. The interest rate will be fixed at 3% with favorable repayment terms based on the borrower's ability to repay and the useful life of the equipment being purchased or the BMP being implemented.

Appendix B
Websites

The following is a list of websites that may be of interest to producers growing crops on plastic mulch. Growers should carefully evaluate the source and accuracy of the information. These addresses are included for information purposes only and were current at the time of printing.

Technical References

www.va.nrcs.usda.gov/DataTechRefs/std_specs.htm	Virginia NRCS Standards and Specifications
www.ftw.nrcs.usda.gov/nhcp_2.html	National Handbook of Conservation Practices (NHCP)
www.ext.vt.edu/pubs/pmg/index.html#hort	Virginia Pest Management Guides (PMGs)

Virginia Agencies

www.va.nrcs.usda.gov	Virginia Office - Natural Resources Conservation Service
www.ext.vt.edu	Virginia Cooperative Extension
www.dcr.state.va.us/index.htm	Virginia Department of Conservation and Recreation
www.deq.state.va.us	Virginia Department of Environmental Quality

Federal Agencies

www.ocrm.nos.noaa.gov	Office of Ocean and Coastal Resource Management
www.nrcs.usda.gov	USDA-Natural Resources Conservation Service
www.epa.gov	United States Environmental Protection Agency
www.usgs.gov	United States Geological Survey

Crop Production on Plastic Mulch

www.plasticulture.org/	American Society for Plasticulture
hortweb.cas.psu.edu/plastic	Center for Plasticulture
www.plastitech.com/	PlastiTech, Inc. (supplier)
www.climagro.com/	Climagro (supplier)
members.aol.com/kenncomfg/	Kennco Mfg (supplier)
www.pikrite.com/	Pik Rite Inc (supplier)
www.spc-volta.com/yoram/spc_divisions/agriculture/Tillage.htm	BHC Agricultural Implements
www.bsi.vt.edu/welbaum/hort4764/lessons/mulch/lesson.html	Use of Plastic Mulch in Vegetable Production
www.repelgro.com/	ReflecTek Foils, Inc.

Dedicated Agricultural Search

hammock.ifas.ufl.edu	Florida Agr. Information Retrieval System
www.agnic.org	Nat'l Agr. Library/Univ. Search Engine
www.agrisurfer.com	Guide to Agricultural Websites

Pest Management

www.reeusda.gov/nipmn	National IPM Network
www.nysaes.cornell.edu/ent/biocontrol	Biocontrol NY

IPM Information for Specific States

www.ipm.ucdavis.edu	California
www.udel.edu/IPM	Delaware
pest.umd.edu/ipm/ipm.html	Maryland
www.umass.edu/umext/programs/agro/ipm	Massachusetts
www.ipmworld.umn.edu	Minnesota
www.nysaes.cornell.edu/ipmnet/ny/vegetables	New York
www.ippc.orst.edu/cicp/vegetable/vegindex.htm	Oregon

Pesticide News and Information

www.ace.orst.edu/info/nptn	National Pesticides Communications Network
www.bluebooktor.com/free_b.asp	Pesticide Labels and Material Safety Data Sheets
www.oznet.ksu.edu/__library/entml2/samplers/mf958.htm	Factors Affecting Pesticide Behavior and Breakdown
www.epa.gov/reg3wcmd/pesticides.htm	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
www.greenbook.net	C&P Press, Inc. (pesticide labels)

Marketing

www.ams.usda.gov/marketnews.htm	USDA Agr. Market Service Market Reports
govinfo.kerr.orst.edu/ag-stateis.html	Census of Agriculture: 1987, 1992, 1997
www.sfproduce.org/home.html	San Francisco Wholesale Market Listings
www.usda.gov/nass/pubs/agr98/acro98.htm	USDA National Agriculture Statistics Service
www.ams.usda.gov/directmarketing	USDA's Direct Marketing Information
www.agr.ca/newintre.html	Agri-Food Canada Market

Appendix C
Contact Information

USDA Natural Resources Conservation Service - Virginia State Office

1606 Santa Rosa Road, Suite 209
Richmond, VA 23229-5014
804-287-1691
804-287-1737 (fax)

USDA Farm Service Agency - Virginia State Office

1606 Santa Rosa Road, Suite 150
Richmond, VA 23229
804-287-1500
804-287-1723 (fax)

USDA Service Centers (local offices of NRCS, FSA, and other agencies)

Most of the Soil and Water Conservation Districts (SWCDS) listed in the next section are located at USDA Service Centers. The following are additional Service Center locations. Service boundaries vary among the agencies. Contact your local SWCD or USDA Service Center for additional information.

Amelia Service Center

16352 Church St.
Amelia Court House, VA 23002-4817
804-561-2147
804-561-6401 (fax)

Bonsack Service Center

36 Executive Circle
Roanoke, VA 24012
540-977-2698
540-977-2754 (fax)

Charlottesville Service Center

695 Berkmar Ct.
Charlottesville, VA 22901-1401
804-975-0047
804-975-029 (fax)

Chesapeake Service Center

310 Shea Drive
Chesapeake, VA 23322-5571
757-547-7172
757-436-0285 (fax)

Courtland Service Center

22313 Main Street
Courtland, VA 23837-1026
757-653-2532
757-653-2201 (fax)

Gate City Service Center

372 W. Jackson St.
Gate City, VA 24251-4134
540-386-3951
540-386-9051 (fax)

Jonesville Service Center

Ag Service Center, Highway 58W
Jonesville, VA 24263
540-346-1531
540-346-1262 (fax)

Kenbridge Service Center

119 West Seventh Avenue
Kenbridge, VA 23941
804-676-1078
804-676-3017 (fax)

Lawrenceville Service Center

1727 Lawrenceville Plank Road
Lawrenceville, VA 23868
804-848-2145
804-848-0976 (fax)

Louisa Service Center

39 Industrial Drive, Suite 1
Louisa, VA 23093-9747
540-967-0233
540-967-2557 (fax)

Orange Service Center

325-B Madison Road
Orange, VA 22960-1015
540-672-1523
540-672-2455 (fax)

Rustburg Service Center

163 Kabler Lane
Rustburg, VA 24588
804-332-6640
804-332-4892 (fax)

Suffolk Service Center

1548 Holland Road
Suffolk, VA 23434-6528
757-539-9270
757-539-9292
757-539-0975 (fax)

Sussex Service Center

20125 Sussex Dr.
Sussex, VA 23884
804-246-8541
804-246-6507 (fax)

Woodstock Service Center

505 North Main Street, Rm 102
Woodstock, VA 22664-1803
540-459-5735
540-459-2643 (fax)

Virginia Soil and Water Conservation Districts (SWCDs)

The following information was obtained from the 2001 Directory of Districts, accessed at www.dcr.state.va.us/sw/docs/swcddir.pdf.

1. Tidewater SWCD
P.O. Box 677
Gloucester, VA 23081
804-693-3562 ext. 5
804-694-5921 (fax)

2. Thomas Jefferson SWCD
2134 Berkmar Court
Charlottesville, VA 22901
804-975-0224
804-975-1367 (fax)

3. Southside SWCD
250 LeGrande Avenue, Suite B
Charlotte Courthouse, VA 23923
804-542-5342
804-542-5823 (fax)

4. Natural Bridge SWCD
30 East Preston Street
Woody Bldg
Lexington, VA 24450-2325
540-463-7124, ext. 101
540-463-1061 (fax)

5. Piedmont SWCD
100B Dominion Drive
Farmville, VA 23901
804-392-3782, ext. 5
804-392-4577 (fax)

6. Blue Ridge SWCD
1297 State Street
Rocky Mount, VA 24151-2284
540-483-5269
540-483-0006 (fax)

7. Culpepper SWCD
351 Lakeside Drive
Culpeper, VA 22701-1945
540-825-8591
540-825-8637 (fax)

8. Northern Neck SWCD
P.O. Box 220
Warsaw, VA 22572
804-333-3525
804-333-5223 (fax)

9. Shenandoah Valley SWCD
1934 Deyerle Avenue,
Suite B
Harrisonburg, VA 22801
540-433-2853, ext. 3
540-433-9998 (fax)

10. Robert E. Lee SWCD
Route 4, Box 99-K
Appomattox, VA 24522
804-352-2819
804-352-9405 (fax)

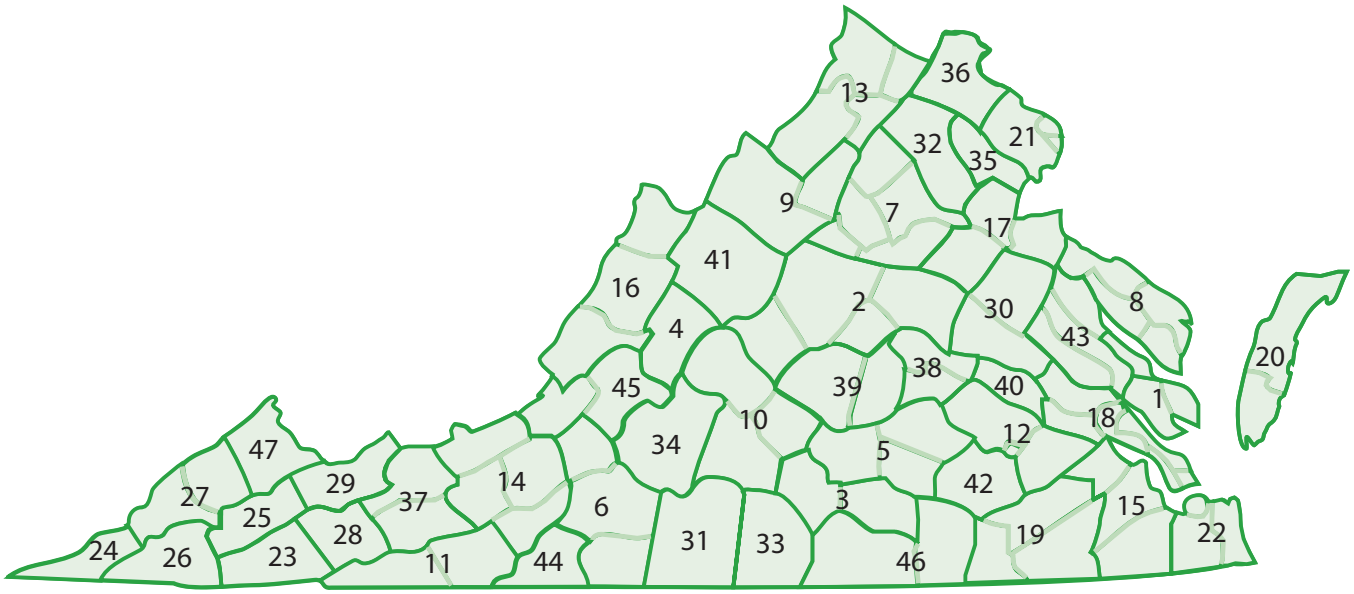
11. New River SWCD
968 East Stuart Drive
Galax, VA 24333
540-236-7191
540-238-9959 (fax)

12. James River SWCD
6450 Courthouse Road
Prince George, VA 23875-2527
804-957-6156 / 6148
804-733-9476 (fax)

13. Lord Fairfax SWCD
130 Carriebrooke Drive
Stephens City, VA 22655-6000
540-868-1130, ext. 3
540-868-1135 (fax)

14. Skyline SWCD
75 Hampton Boulevard
Christiansburg, VA 24073
540-382-3262
540-381-5604 (fax)

15. Peanut SWCD
USDA Service Center
203 Wimbledon Lane
Smithfield, VA 23430
757-357-7004
757-357-7798 (fax)



16. Mountain SWCD
P.O. Box 310
Warm Springs, VA 24484
540-839-4616
800-254-3854
540-839-7232 (fax)

17. Tri-County/City SWCD
4805 Carr Drive, Jackson
Square Office Park
Fredericksburg, VA 22408
540-899-9492
40-899-2014 (fax)

18. Colonial SWCD
2502 New Kent Highway
P.O. Box 190
Quinton, VA 23141
804-932-4376
804-932-3438 (fax)

19. J.R. Horsley SWCD
706 South Main Street
Emporia, VA 23847
804-634-2115
804-634-6725 (fax)

20. Eastern Shore SWCD
22545 Center Parkway
Accomac, VA 23301-1328
757-787-0918
757-787-8142 / 7739 (fax)

21. Northern VA SWCD
12055 Government Center
Parkway, Suite 905
Fairfax, VA 22035-5512
703-324-1460
703-324-1421 (fax)

22. Virginia Dare SWCD
P.O. Box 6097
Virginia Beach, VA 23456-
0097
757-427-4775
757-426-5684 (fax)

23. Holston River SWCD
448 Commerce Drive
Abingdon, VA 24211-3829
540-628-8187
540-628-8889 (fax)

24. Daniel Boone SWCD
Route 2, Box 2010
Jonesville, VA 244263
540-346-1658, ext. 3
540-346-1262 (fax)

25. Clinch Valley SWCD
383 Highlands Drive
Suite 4
Lebanon, VA 24266
540-889-0968
540-889-2105 (fax)

26. Natural Tunnel
95 US Highway 23 South
Suite 1
Gate City, VA 24251
540-386-2323
540-386-9051 (fax)

27. Lonesome Pine SWCD
Main St., Route 2, Box B
Clintwood, VA 24228
540-926-6621 / 8527
540-926-4640 (fax)

28. Evergreen SWCD
1112 North Main Street
Marion, VA 24354-4122
540-783-7280
540-783-7426 (fax)

29. Tazewell SWCD
727R West Riverside Drive
North Tazewell, VA 24630-
9431
540-988-9588
540-988-9014 (fax)

30. Hanover-Caroline SWCD
P.O. Box 446
Hanover, VA 23069-0446
804-537-5225
804-537-5536 (fax)

31. Pittsylvania SWCD
P.O. Box 9
Chatham, VA 24531
804-432-8146
804-432-2068 (fax)

32. John Marshall SWCD
98 Alexandria Pike
Suite 31
Warrenton, VA 20186-2849
540-347-3120
540-347-6423 (fax)

33. Halifax SWCD
P.O. Box 247
Halifax, VA 24558
804-476-7923
804-476-4217 (fax)

34. Peaks of Otter SWCD
1031 Turnpike Road
Bedford, VA 24523
540-586-9195
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540-228-3513, ext. 110
540-228-2049 (fax)

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804-501-5919 (fax)

41. Headwaters SWCD
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42. Appomattox River SWCD
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804-469-7297
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43. Three Rivers SWCD
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804-443-2327
804-443-1707 (fax)

44. Patrick SWCD
USDA Agricultural Service Center
135 Stonewall Court
P.O. Box 457
Stuart, VA 24171
540-694-3121, ext. 101
540-697-3725 (fax)

45. Mountain Castles SWCD
36 Executive Circle, Suite 1
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540-977-2754 (fax)

46. Lake Country SWCD
P.O. Box 428
Boydton, VA 23917-0428
804-738-0150
804-738-0168 (fax)
888-301-0150

47. Big Sandy SWCD
Rt. 1 Box 14
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276-566-4858
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Charlottesville, VA 22911
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703-684-5285 (fax)

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Covington, VA 24426-1294
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540-245-5752 (fax)

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804-848-2151
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Sussex, VA 23884-1308
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