SECTION 3

EFFECT OF SOIL AND WATER CONSERVATION PRACTICES ON SEDIMENT DELIVERY

All conservation practices designed to control erosion will potentially reduce sediment. Generally, the reduction in sediment delivery will be proportional to the reduction in erosion. However, the effectiveness of SWCPs for sediment control will depend on field location in relationship to watercourses and to a lesser degree on the sediment producing storm characteristics. Soil that is transported by overland runoff and reaches a surface water becomes a water pollutant.

In North Carolina, SWCPs have traditionally been designed to control soil erosion. Since some form of soil erosion is the first step in the production of sediment, one could logically expect SWCPs to potentially control soil loss to surface water from areas where the practices are used. One could also extend that reasoning to the control of the movement of soil-associated substances to surface water. But to do so requires the assumption that reduction in gross soil erosion leads directly to similar reductions of sediment and sediment-adsorbed substances reaching the surface waters. This line of reasoning has been the starting point for much of the evaluation of the effects of SWCPs on sediment and substances attached to soil in sediment. However, the factors used to evaluate the effectiveness of SWCPs for erosion control are often different than those needed for analysis of effects on sediment and sediment-associated substances. For example, in addition to the average quantity of soil that moves, information is needed on when it moves, how far it moves, from where it originates and what its characters (e.g., adsorptive properties). These and other factors are considered in evaluating the potential effects of SWCP on sediment yield and sediment associated substances.

Cropland Accounts for 50% Sediment

In the U.S., approximately 50% of all sediment originates from cropland (USDA-SCS, 1978) (40). Other major sources of sediment are construction sites, roadbanks, urban areas, and streambanks.

Consideration of soil loss in runoff is important not only because soil itself is a potential water pollutant but also because some pesticides and nutrients are associated with soil losses. Substances attached to soil move with it in the runoff. Therefore, control of soil loss may directly control losses of adsorbed substances. The interrelationship between the character of sediment that is associated with adsorbed substances and that controlled by various SWCPs can provide a means to estimate the effectiveness of a specific SWCP to control adsorbed substances.

Sediment Delivery

Sediment load estimates must be made for each specific watershed to be meaningful in terms of water quality.

Sediment Fills Reservoirs

Many reservoirs are filling at a rate of 5 percent of their capacity per year. Rservoirs with capacities of 123,000 m^3 or less are filling at a rate of 2.7 percent annually. The median storage depletion for all U.S. reservoirs is 1.5 percent per year, McDowell and Grissinger, 1976 (27) after Dendy et al. 1973 (41).

Characteristic of Sediment

The sediment causing processes include soil detachment and transport. The bulk of on-field soil detachment is a result of rainfall impact. Both primary particles and aggregates can be detached. Sand and silt are more easily detached than clay. Aggregates tend to be broken down by continuous raindrop impact. Soil detachment by rainfall occurs in a very thin layer at the soil surface. Soil detachment by runoff can occur if shear forces of flow are great enough or if flow undercuts the soil. Detachment by flow is localized in areas where runoff concentrates and generally comes from deeper in the soil profile than that detached by rainfall. Aggregates detached by runoff tend to be larger than those detached by rainfall.

Soil is transported by runoff. Clay and organic matter are more easily transported than coarses particles such as sand. The energy of runoff is reflected in its velocity and volume.

Sediment charcteristically has smaller and lighter particles than the original soil. Sediment deposition in streams and lakes is not the only form of water pollution from soil; soil can also be in suspension or move as a bed load. The suspended load which can cause turbidity, reduced photosynthesis, etc., will be made up predominately of clay and organic matter. Suspended load is relatively variable over the year and is typically the result of a single or series of intense storm events. If the suspended load originated as soil detached by rainfall, it is more likely to have adsorbed chemicals than if it is made up of soil detached by runoff, especially if the chemicals were surface applied. Bed load typically consists of coarse material. The bed load does not fluctuate as much as the suspended load and is a minor event in terms of soil adsorbed substances.

Effectiveness of Conservation Practices

Certain practices are more effective during one time of the year than another. This is particularly true of vegetative canopies and residue covers. Seasonal practice effectiveness should be matched with seasonal sediment production potential.

(1) Contour Faring - the main advantage of contour farming is in reducing runoff. Most research shows that runoff is reduced by at least 50% with contouring; therefore, on land where contouring can be used, one could assume that contouring would reduce sediment yields by 50%. This would include the use of diversions or terraces to break slope length.

(2) Diversion - are effective in reducing slope length and thus reduce erosion. Sediment reduction should be equal to the sum percentage reduction as for erosion.

(3) Terrace - is not dependent on crop canopy or residue. Terraces are more effective in May, June, and July. Terraces should reduce sediment delivery from a field by 50%.

(4) Conservation Tillage - this practice is very effective in reducing runoff and also in protecting the soil from detachment by raindrops. Sediment yields should be from 70 to 90% less on land with conservation tillage as compared to continuous cropping with no conservation practices.

(5) Cover Crop - benefits vary depending on growth of cover crop. A good cover crop reduces soil detachment and reduces runoff. Sediment reduction will vary from 10 to 25%.

(6) Grasses and Legumes in Rotation - this practice should reduce sediment yields by the same percentage as the reduction in erosion which would normally be 25 to 33% for a rotation with one year of sod. Additional years of sod in a rotation will significantly reduce erosion rates.

(7) Grassed Waterways - will serve as filtering area. The amount of sediment reduction will vary greatly depending on site conditions.

(8) Filter Strips - are placed between ditches, streams and agricultural land for the purpose of removing pollutants from overland flow. The principal control mechanism of grassed filter strips is to reduce runoff velocity so that particles settle out. Infiltration might also be increased so that runoff will be reduced. Factors that influence the effectiveness of filter strips are width of strip relative to runoff volume, density of grass cover, detention time and uniformity of flow over the buffer strip.

There is limited data available on the effectiveness of filter strips for removing sediment but several years of field observation would lead us to believe that strips 15 to 25 feet wide are effective on flatter slopes if water is not allowed to concentrate. Work by Dole et al. showed that forest buffer strip of 7.6 m (24.95 ft) was sufficient to prevent stream pollution from animal waste.

(9) Crop Residue - has more impact on reducing soil detachment than in reducing runoff. In some cases, crop residue is more effective than cover crops in reducing erosion and sediment.

(10) Sediment Basin - not considered as an erosion control practice but when designed properly could reduce sediment yields by 70%. Sediment basins do very little to protect the soil resource base.

SECTION 4

COST-EFFECTIVENESS OF SOIL AND WATER CONSERVATON PRACTICES

Soil erosion is undesirable principally because of long-term adverse effects on soil productivity while sediment delivery to waterways is undesirable because of the effect on water quality.

There are many variables to evaluate when determining the cost-effectiveness of soil and water conservation practices for reducing erosion. This process becomes even more complex when determining the cost-effectiveness of SWCPs for reducing sediment pollution. There are several reasons for this, including (1) there are no standards as to the amount of sediment which can be allowed in a body of water, and (2) there are not widely accepted models for predicting sediment transport.

In areas where sediment contributes to the degradation of water quality, it is generally assumed that practices which reduce soil erosion in a field have the effect of causing less sediment to be available for transport to water. To determine the level of effectiveness for selected SWCPs in any given field, both the level of erosion and the sediment delivery ratio (SDR) for each conservation system must be known. The rate of erosion can be computed by using the Universal Soil Loss Equation (USLE) as discussed in the Introduction. Sediment delivery is equal to a calculated sediment delivery ratio (SDR) times the estimated soil erosion.

As with erosion control systems and not single practices should be evaluated as to their cost-effectiveness for improving water quality. Generally, the cost per ton for controlling erosion in a field increases as the soil loss tolerance is approached. For example, if annual erosion is 20 tons per acre on a crop field, it costs less per ton to reduce the erosion from 20 to 15 tons/acre/year than it would cost to reduce the erosion from 10 to 5 tons/acre/tear. The reason for this is that simple management such as contouring and crop residue management can be used. To reduce the soil loss to an acceptable level may require structural practices such as terraces.

A 1978 ACP evaluation of several conservation practices gives the cost per ton of soil loss for the Southern Coastal Plain.

TABLE 1

COST PER TON SOIL SAVED BY CONSERVATION PRACTICE
SOUTHERN COASTAL PLAINS
8% Interest
ACP Evaluation

Conservation Practice	Soil Loss Before	Soil Loss After	Soil Saved	Cost Per Ton Soil Saved
Terrace Systems	15.63	5.94	9.69	0.56
Diversions	92.65	32.66	59.99	0.03
Cropland Protective Cover	12.53	8.98	3.55	4.21
Conservation Tillage Systems	14.93	2.72	12.21	0.69
Stripcropping Systems	13.88	1.48	12.40	0.22
Vegetative Cover on Critical Areas	47.84	1.12	46.71	0.10

To determine the cost-effectiveness of a practice (system), one must know:

1. Amount of reduction in erosion and/or sediment.
2. Cost of practice.
3. Effect on crop yields.
4. Change in production inputs.

Reduction in Erosion

This was discussed for each practice in Section 2.

TABLE 2
COST OF INSTALLING CONSERVATION PRACTICES

Practice	Cost Per 1/ Unit	Unit Per Acre	Cost Per Acre	Life Span	% Annual O&M Cost	Total Annual Cost 2/
Conservation Tillage	$ 10/Ac	1	$10.00	1	-	$ 11.00
Contour Farming	0/Ac	1	0	1	-	0
Cover Crop	15/Ac	1	15.00	1	-	16.00
Critical Area Pltg.	900/Ac	-	-	25	3	111.00
Crop Residue	5/Ac	1	5.00	1	-	5.50
Debris Basin (Sediment Pond)	5,000/ea	-	-	25	3	618.00
Diversion	.60/LF	200 Ft.	120.00	10	5	24.00
Filter Strips	.17/LF	175 Ft.	30.00	10	5	6.00
Grassed Waterway	1,200/Ac	.06 Ac.	72.00	10	5	14.00
Grassed & Legumes in Rotation	175 Ac	-	175.00	3	-	68.00
Stripcropping	5/Ac	1	5.00	10	1	1.25
Terraces	.20/LF	400 LF	80.00	10	5	16.00

1/ Price Base 1980, Raleigh, N.C.
2/ Based on 8% Interest Rate

Change in Crop Yields

(1) Conservation Tillage - Most research shows that yields with conservation tillage equal or exceed conventional tillage by 10% on well drained soils and decreased yields by 10% on poorly drained soils (43).

(2) Contour Farming - Since contouring decreases runoff and keeps water on the field, yields would be expected to increase when normal soil moisture is inadequate, but be decreased in areas of excess rainfall or poor drainage. USDA reported in 1945 from various studies an average increase in crop yields of 17% with contouring (13).

(3) Cover Crop - Could have either a positive of negative effect on the yield of the succeeding crop depending mainly on moisture conditions. On the average cover crop probably won't have any effect on yield.

(4) Critical Area Planting - This is not a cropland practice as such. An area treated as a critical area is generally not suited for production.

(5) Crop Residue Use - Increases moisture holding capacity and should have positive effect on yields.

(6) Debris Basin (Sediment Pond) - Does not affect production.

(7) Diversions - When used in combination with contouring, should increased yields by 17%.

(8) Filter Strip - Will not have direct effect on yields. Filter strips can remove land from production around the edges of fields that would sometimes be planted in row crop.

(9) Grasses and Legumes in Rotation - Will have a positive effect on row crop yield (12% increase) (44). However, the amount of land available for row crops would be less.

(10) Grassed Waterway - Does not directly affect crop yields.

(11) Stripcropping - Involves both rotations and contouring so crop yields would be expected to increase.

(12) Terraces - Can have a positive effect on yield by making more efficient use of water. When used in combination with contouring, yields should increase by 20% (13).

For conservation tillage, decreases in machinery and labor expense nearly balance increased pesticide expenditures. Thus the most important factor determining changes in farm income associated with these practices is their effect on yields.

Contouring also shows only a relatively small change in variable costs. However, this practice is not applicable in many fields. Also for this situation, machinery and labor costs for contouring were assumed to increase by 10% above costs for straight-row tillage. Increases of 3 to 4 times this much could occur in many situations.

Changing from continuous corn to a rotation (50% corn) causes a large decrease in variable costs. This is due not only to the lower costs associated with oats and hay, but also to a savings in nitrogen and rootworm insecticide costs amounting to $47.00 for the first year or corn following hay.

Stripcropping costs are simply a combination of rotation costs and costs for contouring. No additional costs would normally occur.

TABLE 3

TYPICAL CHANGE IN VARIABLE COSTS ASSOCIATED WITH IMPLEMENTATION OF SWCPs AS COMPARED TO CONTINUOUS CORN GRAIN

Values represent expected change in input cost from continuous, straight-row, conventinally tilled corn grain

Dollars

SWCP	Nitrogen Fertilizer Ha	Nitrogen Fertilizer Ac	Pesticides Ha	Pesticides Ac	Equipment Ha	Equipment Ac	Labor Ha	Labor Ac	Const., Maint. & Other Ha	Const., Maint. & Other Ac	Total Ha	Total Ac
Conservation tillage	0	0	+24	+9.60	-10	-4.00	-9	-3.60	0		+5	+2.00
Rotation 1/	-26	-10.40	-30	-12.00	-15	-6.00	-1	-.40	-2	-.80	-74	-29.60
Contouring	0	0	0	0	+6	+2.40	+3	+1.20	0	0	+9	+3.60
Diversion 2/	-2	-.80	-3	-1.20	+3	+1.20	+2	+.80	+15	+6.00	+15	+6.00
Strip-cropping	-26	-10.40	-30	-12.00	-11	-4.40	+2	+.80	-2	-.80	-67	-26.80
Terrace A 3/	0	0	0	0	+6	+2.40	+3	+1.20	+101	+40.40	+110	+44.00

1/ Six year rotation with three years corn, one year oats, two years hay. Values are average for the six years.

2/ One diversion ditch across center of 120 m slope, with contouring. Construction costs are amortized over 45 years.

3/ Terrace A had a terrace at 30 m, 60 m, and 90 m, respectively, above lower edge of field with 120 m slope, with contouring. Construction costs amortized over 45 years.

Source: Effectiveness of Soil and Water Conservation Practices for Pollution Control, EPA Report, October 1979.

Effectiveness of SWCPs

The effectiveness of SWCPs for reducing sediment delviery to waterways depends on both the initial level of soil erosion and the initial sediment delivery ratio (SDR). To illustrate the relative effectiveness of different practices and how effectiveness changes for different field situations, levels of soil erosion and sediment deliery have been calculated for a hypothetical field situation. Initally, levels of soil erosion were calculated on a field with 250 ft. slope and a 4% gradient; K = .32; R = 250; C = .492; (continuous soybeans). Table 4 illustrates several conservation systems.

TABLE 4

COST-EFFECTIVENESS VALUE FOR SELECTED SWCPs FOR AN EXAMPLE SOYBEAN FIELD

Practice	Assumed % Change In Yield	1/ Change In Net Income $/Ac.	Erosion 2/ Reduction Tons/Ac.	Erosion 3/ Cost-Eff. $/Ton	Sediment 2/ Reduction Tons/Ac.	Sediment 3/ Cost-Ef $/Ton
Contouring with terraces	15%	+$7.00 4/	12	-	3.3	-
Contouring + terraces + grassed waterways	15%	-$7.00	12	+.58	3.3	+$2.12
Conservation tillage	10%	+$5.25 5/	20	-	6.0	-

1/ Net cost is defined as the loss in income with the SWCP as compared to continuous soybeans with no SWCP. Includes change in yield less increased variable bost. Yields were based on 25 bushels per acre before treatment @ $6.50 per bushel. Interest rate 8%.

2/ Reduction is defined as the drop in rate of erosion or sediment delivery compared to rates with continuous soybeans with no SWCPs. Initial erosion rate is 23 tons per acre per year and sediment delivery ratio is 0.3.

3/ Cost-Effectiveness is the cost per ton for reducing erosion or sediment yield. No cost effectiveness is not shown when there is an increase in net return.

4/ Net cost is the increase of 5 bushels per acre less 10% for additional machinery, fuel and labor costs due to contouring (see Exhibit 1).

5/ Net cost of the increase in production less $11.00 per acre annual cost for increased pesticide cost.

Summary

The cost-effectiveness of practices on a field can vary considerably depending on effectiveness and costs which will vary according to physical properties of the field, rainfall and crops grown.

Conservation tillage appears to have the most widespread adoption and potential in North Carolina for reducing erosion and sediment pollution. This practice is relatively inexpensive and is very effective in reducing sediment pollution and saves time and fuel.

Section V of the Soil Conservation Service Technical Guide available in all counties in North Carolina should be a helpful reference in determining the cost-effectiveness of conservation systems.

EXHIBIT 1

PARTIAL BUDGETING WORKSHEET

Date 6-80

By Waller

Name Timothy Wolfpack

Present RMS Soybeans, conventional tilled, soil loss of 23 tons/ac./yr.

Alternative RMS Soybeans, terraces, Contour farming, soil loss of 11 T/Ac./yr.

	Units	Without Conditions	With Conditions
Gross Receipts (a) Soybeans (b) (c) (d)	bu.	25 @ 6.50 = $162.50	28.75 @ 6.50 = $187.50
Variable Cost (a) (b) (c) 10% increase in machinery, (d) labor, and fuel due to (e) Contouring rows. (f) (g)		65.50	65.50 1.50
Ownership Cost (a) (b)		17.00	17.00
Land Charge (a) (b)		0	0

Average Annual Cost of Conservation Practices (BMPs)

Practices	Cost	A.F. *	A.C. **	O & M	
(a) Terraces 400 ft.	80.00	0.14902	12.00	4.00	
(b) Contour farming	0.00	0.0	0	0	
(c)					
(d)					
(e)					
(f)					
(g)					
(h)					
(i)					
(j)					
Total Practice Cost			12.00	4.00	16.00

	Without Conditions	With Conditions
Net Returns to Land & Management	80.00	87.00
Net Difference in Alternatives		7.00

*A.F. - Amortization Factor
**A.C. - Amortized Cost

PARTIAL BUDGETING WORKSHEET EXHIBIT 2

Date ____________________

By ____________________

Name ____

Present RMS ____

Alternative RMS ____

	Units	Without Conditions	With Conditions
Gross Receipts (a) (b) (c) (d)			
Variable Cost (a) (b) (c) (d) (e) (f) (g)			
Ownership Cost (a) (b)			
Land Charge (a) (b)			

Average Annual Cost of Conservation Practices (BMPs)

Practices	Cost	A.F. *	A.C. **	O & M
(a)				
(b)				
(c)				
(d)				
(e)				
(f)				
(g)				
(h)				
(i)				
(j)				
Total Practice Cost				

	Without Conditions	With Conditions
Net Returns to Land & Management		
Net Difference in Alternatives		

*A.F. - Amortization Factor
**A.C. - Amortized Cost

INSTRUCTIONS FOR USE OF WORKSHEET

1. This worksheet is designed for use in conjunction with prepared cost-return budgets to evaluate and compare alternative resource management systems. The information developed is not exact net returns for the present or future treatments and should be used as estimates. The amounts and estimates may be made for one acre, several acres, or the entire operation unit.

2. Gross receipts should include all products to be marketed as well as values for those products to be used in another enterprise before marketing. The amounts or values shown in the cost-return budgets may need adjusting to reflect the best estimates of the without and with conditions. If more than one product (several crops or more than one product such as wheat grain and wheat straw) is included, list various crops or various products and total the amount in the complete resource management system.

3. Variable cost, ownership cost, land charge contained in the cost-return budget should be adjusted to reflect changes different to this enterprise. List the amount(s) contained in the cost-return budget and reduce or increase the applicable individual inputs. Be sure to show a (+) or (-) to insure credit in the final total for the two condition totals.

4. Average annual cost of conservation practices (BMPs) - List each conservation practice that will be installed in the alternative resource management system and determine installation cost. Multiply this amount by the amortization factor which best reflects the landuser's desire for period of repayment and interest rate. This may be done for each practice or for the total of all practices. This amount is the annual equivalent cost. To this cost, add the expected cost of operation and maintenance and insert total in the Total Practice Cost under "with condition."

5. Net returns to land management - Total the amounts contained in the without and with columns. Subtract the smaller total from the larger total to determine net differences in the alternative.

GLOSSARY

Erosion	Detachment and movement of soil or rock fragments by water, wind, ice or gravity (for purposes of this study, erosion refers only to that caused by water and gravity).
Gully Erosion	Advanced stage of erosion which produces large channels which cannot be smoothed over by normal tillage operations.
Geologic Erosion	The normal or natural erosion caused by geological processes acting over long geologic periods and resulting in the wearing away of mountains, the building up of floodplains, coastal plains, etc. Syn. natural erosion.
Rill Erosion	An erosion process in which numerous small but well defined channels only several inches deep are formed. The rills can easily be removed by normal tillage operations.
Sheet Erosion	The removal of a thin, relatively uniform layer of soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.
Sediment	Any solid material, either mineral or organic, that has been eroded, transported and deposited on and or in water.
Sediment Yield	Any solid material which moves off a unit area (e.g., edge of field losses).
Sediment Delivery	Sediment that is transported to a specific point, generally a stream.
Sediment Delivery Ration (SDR)	The ratio between sediment delivery and soil erosion.
Gross Soil Erosion	Soil erosion as defined by the Universal Soil Loss Equation.

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