Prediction of Storm-Induced Sediment Yield from Highway Construction

LARRY M. YOUNKIN AND GARY B. CONNELLY

A prediction equation is presented for estimating the storm-induced increase in suspended sediment yield in a stream system due to highway construction. The equation was developed by regression analysis of data collected at nine stream-gage sites in five watersheds in Pennsylvania. Two hundred and seventy eight sets of data were included in the analysis. The equation relates factors that describe soil erodibility, rainfall, construction phases, and proximity of construction to the stream system to the increased quantity of sediment transported. The result indicates that the sediment carried by a stream increases with soil erodibility, storm-erosion index, area cleared and grubbed, cut-and-fill heights, and proximity of construction to the stream. The form of the final equation was found to be rational but the standard error of estimate was large, although not exceptional when compared with the results of other sediment-transport studies. It is concluded that the equation may be a useful tool in highway location studies, evaluation of highway development impact, and design of sediment catchment devices.

Highway construction is often cited as one of the major sources of sediment in streams. For the highway engineer and planner, a general method of predicting the increase in sediment yield in a stream system due to uncontrolled highway construction would be a useful tool for evaluating the impact of highway development. With the effect of construction and watershed parameters defined, minimum sediment yield could be a criterion applied in highway location studies. The design capacity of catchment devices in erosion-control plans could be determined and a base for evaluating the effectiveness of the plans would be available. Thus, the method would provide the capability of developing a comprehensive location and construction plan that would minimize the impact of the construction.

The quantity of soil eroded from a construction area is now usually approximated by the universal soil-loss equation (USLE) (1). This equation was originally developed by Wischmeier and Smith for agricultural lands. The applicability was broadened with the development (2) of a soil-erodibility nomograph that quantified an erodibility factor for subsoils exposed by construction. An excellent example of the employment of the USLE for estimating soil loss from a highway construction area was reported by Swerdon and Kountz (3). However, the amount of soil eroded is usually greater than that transported by the stream. The sediment yield might be related to the quantity eroded by using a delivery ratio (4), which is defined as the ratio of sediment yield to gross soil loss. But little research has been performed to evaluate this factor and it may range from 10 percent to 70 percent depending on hydrologic and watershed characteristics. Vice, Guy, and Ferguson (5) found a delivery ratio equal to 50 percent during a three-year study of sediment yield from highway construction areas in a small watershed in northern Virginia.

Younkin (6,7) attempted to develop a general sediment-yield equation from data collected during the construction of Interstate 80 through a watershed in central Pennsylvania. The equation was tested by Connelly (8) by using data obtained from a watershed in northern Pennsylvania during a period of highway construction. The equation was found to overpredict sediment yields primarily because of differences in soil erodibility and cut-and-fill work between the two studies. It was concluded that data from other projects were needed to increase the range of causative factor values to generalize a prediction equation.

This paper describes the development and application of an equation that may be employed to estimate the suspended sediment load carried by a stream system during periods of rainfall-induced erosion of disturbed soils common to highway construction. It was established by the multiple linear regression analysis of data collected during the construction of highways through five watersheds in central Pennsylvania during the period from 1968 through 1975. The variation of site conditions for the study areas has broadened the range of soil and construction factors values beyond those examined previously.

SEDIMENT-YIELD MODEL

Due to the complex nature of the erosion-transport process, it was anticipated that the relationship would be established by the multiple regression analysis of data collected from field studies. The prediction equation model was assumed to be of the following form:

$$Q_s = b_0 K^{b_1} R^{b_2} (\log A)^{b_3} b_4{}^{D} / P^{b_5} \quad (1)$$

where

- Q_s = suspended sediment yield at a particular location in the stream system,
- K = soil-erodibility factor,
- R = storm-erosion index,
- A = area of surface exposed by construction,
- D = average height of cut or fill work, and
- P = dimensionless proximity factor for relative location of construction to stream system.

The values of the independent factors define conditions in the watershed upstream of the particular location in the stream system. The b-constants are the regression coefficients.

FACTOR DEFINITIONS

The concept of the soil-erodibility factor K (measured in tons per acre per unit of storm-erosion index R) was taken directly from the work of Wischmeier, Johnson, and Cross (2). The K-term was employed because it is based on a great quantity of field data and is relatively easy to evaluate from information usually available to the engineer. The five soil parameters that must be known for a number of representative samples for the determination are as follows: percentage of silt, percentage of sand, organic-matter content, soil structure, and permeability. Proposed highway construction normally would be preceded by a soils and geological investigation that would yield these data.

Wischmeier and Smith (9) found that the best single rainfall variable related to soil loss is the product of the total storm rainfall energy and its maximum 30-min intensity. They define the erosion index R as follows:

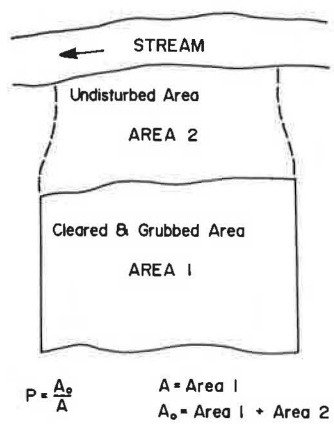
$$R = (E \cdot I)/100 \quad (2)$$

where E is the energy of the storm in foot-tons per acre and I is the maximum 30-min intensity in inches

per hour. The R-value for a specific measured rainstorm may be computed by the procedure described by Wischmeier and Smith. The annual average R-value, the average time distribution of that annual value through the year, and the expected magnitudes of storm R-values for various recurrence intervals may be found in Agricultural Handbook 282 (1) for areas east of the Rocky Mountains.

Sediment yield must be a function of the area of exposed surface available to rainfall-induced erosion. For this study, the area A (in acres) was defined as that exposed by the clearing and grubbing phase of the construction. A preliminary graphical study of the data showed that Q_s best related linearly to log A on a logarithmic plot. The value of this factor may be taken from the highway plans.

Figure 1. Definition of proximity factor P.



Slope length and gradient of exposed surfaces have been shown (10) to be of prime importance in the erosion process. Highway cut-and-fill slope gradients are generally standardized according to their height and it was reasoned that an average height D (in yards) of cut-and-fill work would be a measure of the slope characteristics. The average D-value of earthwork completed upstream of a particular location in a stream system may be obtained from the highway profile. The minimum value of D is zero, which occurs after clearing and grubbing have begun but before the cut-and-fill work has commenced.

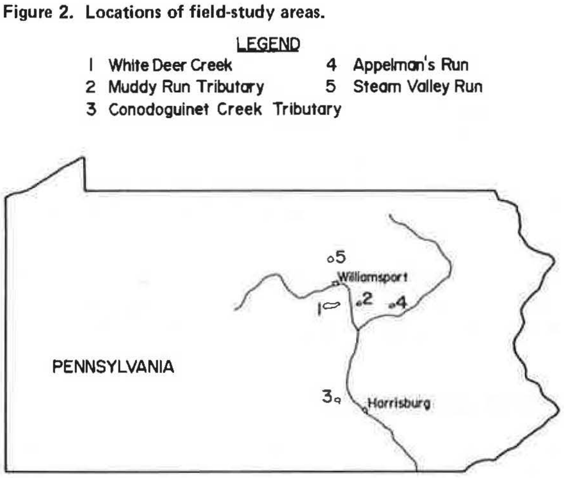
The dimensionless proximity factor P was rationalized as an excellent measure of the location of the construction relative to the stream system. It was defined as follows:

$$P = A_0/A \quad (3)$$

where A_0 is the surface area (in acres) between the upslope side of the construction and the stream system as shown in Figure 1. The value of A_0 may be found by planimetering highway location maps. The minimum value of P is one that occurs when a stream passes through the construction area and sediment discharges directly into it without flowing over undisturbed surfaces.

Finally, Q_s is the highway-construction-related, suspended sediment yield (in tons) caused by rainfall.

Figure 2. Locations of field-study areas.



FIELD STUDIES

The five watersheds that provided the data for the development of the highway sediment yield equation were located in central Pennsylvania as shown in Figure 2. White Deer Creek is located approximately 20 miles south of Williamsport and 70 miles north of Harrisburg. It is a tributary that flows from west to east to the west branch of the Susquehanna River. Muddy Run is in the same vicinity but flows into the west branch from the east. Conodoguinet Creek flows into the Susquehanna River near Harrisburg; its watershed is located approximately 10 miles west of the city. Appelman's Run is a tributary to Fishing Creek, which flows into the north branch of the Susquehanna at Bloomsburg. Steam Valley Run flows into Blockhouse Creek, which is a tributary of Pine Creek and the west branch of the Susquehanna. It is located about 20 miles north of Williamsport. The

Table 1. Watershed characteristics.

Watershed	Area (miles^2)	Stream Slope (%)	Avg Land Slope (%)	Land Use	Mean Annual Temperature (F°)	Mean Annual Precipitation (in)	Soil: Overburden	Soil: Bedrock
White Deer Creek			25	Forest	50	41.7	Coarse-graded alluvium	Clinton shale
S2	29.6	1.0						
S4	4.9	2.8						
S5	3.3	3.1						
S9	1.6	6.7						
S10	2.1	6.1						
Muddy Run tributary	1.6	1.8	7	Grass and cropland	50	41.7	Fine-graded alluvium	Bloomsburg shale
Conodoguinet Creek tributary	0.8	2.0	30	Forest and grassland	53	43.4	Stony to gravelly silt loam	Clinton and Martinsburg shales
Appelman's Run	7.2	1.0	10	Grass and cropland	50	38.5	Silty clay loam	Keyser, Tonoloway, and Wills Creek shales
Steam Valley Run	5.3	5.2	20	Forest	46	35.0	Glacial till	Catskill sandstone

watersheds have similar climatic conditions but other characteristics such as areas, slopes, soils, and land uses varied as listed in Table 1. Data were collected at five locations--S2, S4, S5, S9, and S10--in the White Deer Creek stream system to provide a greater variation in construction-factor values.

The highway construction in every case was for completely new roadway locations. It was for four-lane limited-access highways in the White Deer Creek watershed for I-80, in the Conodoguinet Creek tributary watershed for I-81, and part of the work in the Muddy Run tributary watershed for state route 147. The other construction projects were for two-lane roadways. The highway or route, length, and erosion-control practice for the project in each watershed are shown in Table 2. As seen, erosion-control practices varied for the projects, and the timing of the application of the particular practice with the construction also was different. Most of the cut-and-fill work was completed at White Deer by August 1969 but the permanent seeding and mulching were not completed until the summer of 1970. At Muddy Run, earthwork was completed in the spring and the seeding and mulching were completed in the summer. The Conodoguinet Creek tributary watershed was part of a research project and the seeding and mulching were purposely not applied until the paving had been finished. In the other two watersheds, additional structural devices were employed. Reed (11) found that check dams, straw bales, and small sediment ponds may only have trap efficiencies of 5 percent, and their effect on the data for this study was ignored. The seeding and mulching kept pace with the earthwork for those two projects.

Table 2. Highway or route, highway length, and erosion-control practice.

Watershed	Highway or Route	Highway Length (miles) Two-Lane	Highway Length (miles) Four-Lane	Erosion-Control Practice
White Deer Creek	I-80			Seeding and mulching
S2		-	5.4	
S4		-	3.4	
S5		-	1.8	
S9		-	0.7	
S10		-	0.6	
Muddy Run tributary	PA-147 PA-405	- 1.4	0.6 -	Seeding and mulching
Conodoguinet Creek tributary	I-81	-	0.6	Seeding and mulching
Appelman's Run	PA-487	0.6	-	Check dams, seeding and mulching
Steam Valley Run	US-15	2.7	-	Check dams, straw bales, sediment ponds, seeding and mulching

Sediment yield was measured in the White Deer Creek and the Muddy Run tributary by manual sampling supplemented by using results from several automatic samplers. It was primarily measured at the stream stations in the other stream systems by using automatic samplers supplemented by using a manual sampling. Natural sediment transport was measured upstream of construction in the White Deer Creek, Muddy Run tributary, and Appelman's Run. It was established in the Conodoguinet Creek tributary from the results of sampling for three years before construction began. Total sediment yields at stations downstream of construction were adjusted for natural transport. Vice, Guy, and Ferguson (5) adjusted their sediment-yield data for seeding and mulching. They assumed that sediment yield was reduced 50 percent on application and further reduced to 80 percent as a fairly well-established sod cover developed. It was assumed that this reduction occurred over a period of 60 days. Sterniak (12) developed a method for computing a planting factor that may be divided into measured sediment yield to adjust to unplanted conditions. The value of the planting factor varied from 1.00 before seeding and mulching to 0.20 60 days after completion of this work. The sediment data for this study were adjusted with the planting factor.

The range of factor values that occurred upstream of each of the locations in the stream systems is shown in Table 3. An average soil-erodibility factor value was established for each construction area. It was assumed that these values remained constant for the entire construction period. The storms that were included consisted exclusively of rainfall and generally occurred between March and November. Storms separated by less than 24 h were considered one event, whereas those separated by between 24 and 48 h were excluded. The minimum values for exposed area were larger than desirable to fully describe the possible range of values of that variable. But they measured the conditions when a first significant storm occurred on each watershed following the initiation of construction. The minimum value of the average height of cut-and-fill work for most of the study areas (D = 0.00) shows that measured storms had occurred before earthwork began in those areas. A proximity-factor

Table 3. Hydrologic, soil-erodibility, construction, and location-factor data.

Watershed	Number of Storms	Range of Storm R (foot-tons per acre x inches per hour) Maximum	Range of Storm R Minimum	Avg K	Range of Area Exposed A (acres) Maximum	Range of Area Exposed Minimum	Range of Height of Cuts and Fills D (yd) Maximum	Range of Height of Cuts and Fills Minimum	Range of Proximity Factor P Maximum	Range of Proximity Factor P Minimum	Construction Period
White Deer Creek											1968-1970
S2	28	24.0	0.3	0.15	168.8	89.9	2.55	0.00	4.27	2.15	
S4	28	26.0	0.3	0.13	110.9	47.0	2.22	0.00	5.10	2.16	
S5	28	29.2	0.3	0.15	59.6	20.3	2.14	0.00	3.22	1.09	
S9	28	27.1	0.3	0.20	14.5	9.7	2.70	0.00	1.00	1.00	
S10	28	27.1	0.3	0.14	6.0	4.1	1.90	0.00	1.00	1.00	
Muddy Run tributary	14	21.4	0.4	0.25	66.5	29.0	2.17	0.00	1.92	1.75	1969-1971
Conodoguinet Creek tributary	53	75.8	0.6	0.18	25.0	25.0	2.63	0.20	1.00	1.00	1972-1974
Appelman's Run	42	12.4	0.5	0.48	10.9	9.5	7.21	1.18	1.00	1.00	1971-1974
Steam Valley Run	29	50.3	0.5	0.21	72.4	8.8	9.04	0.00	1.32	1.00	1972-1975

value of 1.00 indicates that four of the nine locations received sediment by surface runoff over disturbed surfaces that flowed directly into the stream rather than having an undisturbed surface between construction and stream system.

REGRESSION ANALYSIS

Multiple linear regression is commonly employed to obtain a relationship between a dependent variable and an independent variable from sets of observations. The particular method employed for this study was a computerized analysis developed by Ryan, Joiner, and Ryan (13) called Minitab. The procedure was to compute a sequence of multiple linear regression equations in a stepwise manner. In the initial step, the regression equation that relates the dependent variable to one independent variable was computed. For each succeeding step, one new variable was added to the equation and the result computed; the process continued until all independent variables had been considered. The resulting equation from each step was the least-squares best-fit solution of the relationship between the dependent and the included independent variables.

Graphical studies of the data revealed that better linear relationships occurred with logarithmic plots as compared with arithmetic plots. The regression analysis was therefore performed by using the transformation of the model equation, which is given below:

$$\log Q_s = \log b_0 + b_1 \log K + b_2 \log R + b_3 \log(\log A) + D \log b_4 + b_5 \log P \quad (4)$$

The first step of the analysis entered R as the best-related independent variable and resulted in an equation that had a standard error of 0.57 and a correlation coefficient of 0.67. The second step added D and yielded a relationship that had a standard error of 0.49 and a correlation coefficient of 0.78. The equation from the third step, which addded logA, had a standard error of 0.42 and a correlation coefficient of 0.84. The next step added K and the equation had a standard error of 0.38 and a correlation coefficient of 0.87. The final step added P and resulted in an equation that had a standard error of 0.36 and a correlation coefficient of 0.89.

The solution from the final step was transformed back to the form of the original model equation and the regression coefficients were rounded off, which yielded the following equation:

$$Q_s = [4.25\, K^{1.47}\, R^{1.15}\, (\log A)^{2.71}\, 1.19^D]/P^{0.72} \quad (5)$$

This equation is the prediction equation for increased suspended-sediment yield in a stream system due to rainfall-induced erosion of soil from highway construction areas. It predicts the effects of soil erodibility, rainfall, size of disturbed area, slope conditions on that area, and proximity of construction to the stream.

RELIABILITY OF EQUATION

Three criteria were used to judge the effectiveness of the prediction equation. First, the signs of the regression coefficients should be in accord with physical principles. In other words, the result should satisfy the desire for a rational form. The equation passed this test. It would predict an increase in sediment yield with increases in soil erodibility, storm-erosion index, construction area exposed, and average height of cut-and-fill work. It also predicts that sediment yield would decrease as the proximity factor increases.

The second criterion, the standard error of estimate, which measures the agreement between predicted and observed values of sediment yield, was noted above in terms of the logarithmically transformed data. The standard errors (in percentages) based on the final form of the prediction equation were found to be +127 and -56. This means that about two-thirds of the measured sediment-yield values fall within the range of +127 percent and -56 percent of the predicted values from the equation. Although this is a large range of error, it is not exceptional when compared with other sediment-transport prediction methods (14). The degree of confidence placed in the results from the use of the equation should be based on this measure of reliability.

Finally, the correlation coefficient, which measures the proportion of the variation in the dependent variable that can be explained by the variation in the independent variables, was noted above to be equal to 0.89 for the final form of the equation. This result is quite good, which indicates that the general form of the equation does fit the relationship well.

It may also be noted that the range of factor values found in this study should be adequate to include most conditions met in applying the prediction equation. Care must be taken in attempting to extrapolate the equation to situations that fall outside the range of factor values that were measured in these projects.

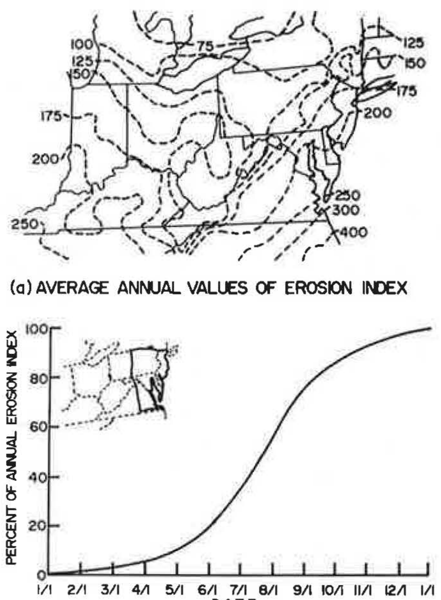
APPLICATION OF SEDIMENT-YIELD EQUATION

Because of the dynamic construction process, the factor values would change rapidly through the construction progress. Unlike applications of the USLE to agricultural cases in which many of the factors remain constant and seasonal changes are related to a cropping-management factor, all the highway sediment-yield factors may change in relatively short time periods. The size of the area cleared and grubbed usually changes significantly in a matter of days. The proximity factor may change as the size of the area cleared increases, depending on its location relative to the stream. Earthwork generally progresses at a slower pace but would usually be completed in one construction season. As the work progresses, different subsoils may be exposed, which causes changes in the average K-value for the area. A storm with any magnitude of R could occur at any time in the process.

An estimate of the sediment yield at a point in a stream system from a particular storm may be accomplished by a straightforward application of the prediction equation. It would require the evaluation of the K-, A-, D-, and P-factors for the construction site and the calculation of the R-value from rain-gage data for the storm.

For planning and design functions, estimates must be made in probabilistic terms because of the nature of the rainfall. Estimates of the average annual sediment yield from a proposed highway project may be made by phasing estimates of construction progress quantified by using the changing values of the soil and construction factors with respect to time with average values of storm R through the same period. These latter values may be estimated from data presented in Agriculture Handbook 282 (1), which gives an isoerodent map of average annual erosion index values and the erosion-index distribution curves, an example of which is shown in Figure 3. Since the prediction equation does not relate Q_s to R linearly, estimates should be made of sediment yield by using weekly or semiweekly values of R, which approximate individual storm values,

Figure 3. Erosion-index variation.



(a) AVERAGE ANNUAL VALUES OF EROSION INDEX

(b) EROSION INDEX DISTRIBUTION CURVE

determined from the above sources. Handbook 282 also lists 5, 20, and 50 percent probability values of annual R, which could be employed in a similar fashion to estimate those probability values of annual sediment yield from construction. With this method, the timing of critical construction phases could be scheduled to occur during periods of average lower R-values.

The capacity of an erosion-control device could be established from an estimate of the sediment yield from the area being controlled. In this case, the critical combination of soil and construction factor values for the area would be substituted along with the design storm R-value into the prediction equation. Handbook 282 lists expected magnitudes of single-storm erosion-index values for frequencies of 1, 2, 5, 10, and 20 years for many locations east of the Rocky Mountains. A design storm period of two years would seem reasonable given that these devices are temporary and the low probability that the design storm would occur when the other factor values are in a critical combination condition.

CONCLUSIONS

This study has been conducted with the objective of developing an equation for predicting suspended-sediment yields in stream systems during periods of rainfall-induced erosion of disturbed soils common to uncontrolled highway construction. Factors that quantify soil erodibility, rainfall, construction phases, and relative highway location effects have been either adopted from the literature or developed for the study. A regression equation (Equation 5) was derived from 278 sets of values of these factors, which were computed from data collected in five watersheds.

The general form of the equation satisfies rational relationships. Sediment yield increases with soil erodibility, storm-erosion index, size of area cleared and grubbed, and average height of cut-and-fill work. It decreases with an increasing proximity factor. Since D is an exponent, the equation predicts sediment yield from a cleared area before earthwork has begun.

The reliability of the prediction is indicated by the standard errors of the estimate. They were found to be +127 and -56 percent. This large range is far from satisfactory but not unusual in sediment-transport studies. Results from applications of the equation should be interpreted as estimates rather than as accurate predictions. In addition, the correlation coefficient of 0.89 for the assumed linear relationship between the logarithmically transformed data indicated that the assumption was reasonable. It is also concluded that adequate ranges of values of the factors were obtained from the five watersheds to permit the equation to be applied to most highway construction sites, and extrapolation outside these ranges is not recommended.

The results of this study should be of great value to the highway engineer. By application of the prediction equation, the location of a proposed highway may be established for minimum sediment yield. Increasing the distance from a stream increases P and hence would tend to decrease Q_s. But D would then usually tend to increase due to steeper terrain and hence Q_s would tend to increase. An optimum location, from the aspect of sediment yield, could be found.

Highway construction has often been blamed for excessive increases in sediment in adjacent streams, but methods have not been readily available to quantitatively evaluate this accusation. The prediction equation may be employed to estimate the quantity of sediment carried by a stream as a result of a particular storm on construction-site conditions at the time. It may also be used to estimate the total yield produced over the life of the project. In addition, highway construction often occurs in connection with the construction of housing developments, shopping centers, industrial parks, and other kinds of urban expansion. This equation may be employed to estimate the portion of the sediment yield due to highway construction.

This study was conducted by using data that generally showed little effect from erosion and sediment-control measures. The result may thus be used as a basis for comparison to evaluate the effectiveness of control methods. The equation may also be employed to determine the design capacity for catchment devices.

ACKNOWLEDGMENT

The data from White Deer Creek and the Muddy Run tributary and the general model development were part of a research project conducted by Bucknell University under the sponsorship of the Pennsylvania Department of Transportation (PennDOT) and the Federal Highway Administration (FHWA). It was coordinated by William G. Weber and Foster C. Sankey of PennDOT. The data from the Conodoguinet Creek tributary, Appelman's Run, and Stream Valley Run were collected by the U.S. Geological Survey (USGS) under the sponsorship of PennDOT and the Pennsylvania Department of Environmental Resources, USGS, and FHWA. They were provided by Lloyd Reed of the USGS. Much of the soil and construction phase data were obtained from PennDOT files.

REFERENCES

1. W.H. Wischmeier and D.D. Smith. Rainfall Erosion Losses from Croplands East of the Rocky Mountains. Agricultural Research Service, U.S. Department of Agriculture Handbook 282, 1965, 47 pp.
2. W.H. Wischmeier, C.B. Johnson, and B.V. Cross.

A Soil Erodibility Nomograph for Farmland and Construction Sites. Journal of Soil and Water Conservation, Vol. 26, 1971, pp. 189-193.
3. P.M. Swerdon and R.R. Kountz. Sediment Runoff Control at Highway Construction Sites. Pennsylvania State Univ., University Park, PA, Engineering Res. Bull. B-108, 1973, 120 pp.
4. Guidelines for the Control of Erosion and Sediment in Urban Areas of the Northeast. Soil Conservation Service, U.S. Department of Agriculture, Upper Darby, PA, 1970, 88 pp.
5. R.B. Vice, H.P. Guy, and G.E. Ferguson. Sediment Movement in an Area of Suburban Highway Construction, Scott Run Basin, Fairfax County, Virginia, 1961-1964. U.S. Geological Survey, Water Supply Paper 1951-E, 1969.
6. L.M. Younkin. Effects of Highway Construction on Sediment Loads in Streams. In Soil Erosion: Causes and Mechanisms; Prevention and Control. HRB, Special Rept. 135, 1973, pp. 82-93.
7. L.M. Younkin. Prediction of the Increase in Suspended Sediment Transport Due to Highway Construction. Bucknell Univ., Lewisburg, PA, Civil Engineering Res. Rept. 74-2, 1974, 126 pp.
8. G.B. Connelly. An Analysis of Suspended Sediment Transport in Steam Valley Run due to Highway Construction. Bucknell Univ., Lewisburg, PA, M.S. thesis, 1978, 84 pp.
9. W.H. Wischmeier and D.D. Smith. Rainfall Energy and Its Relationship to Soil Loss. Transactions of the American Geological Union, Vol. 39, 1958, pp. 285-291.
10. A.W. Zingg. Degree and Length of Land Slope as It Affects Soil Loss in Runoff. Agricultural Engineering, Vol. 21, 1940, pp. 59-64.
11. L.A. Reed. Effectiveness of Sediment-Control Techniques Used During Highway Construction in Central Pennsylvania. U.S. Geological Survey, Open-File Rept. 77-498, 1977, 79 pp.
12. R.S. Sterniak. An Analysis of Storm Turbidigraphs Affected by Highway Construction. Bucknell Univ., Lewisburg, PA, M.S. thesis, 1973, 87 pp.
13. T.A. Ryan, B.L. Joiner, and B.F. Ryan. Minitab, Student Handbook. Duxburg Press, North Scituate, MA, 1976, 162 pp.
14. American Society of Civil Engineers. Sedimentation Engineering. ASCE, New York, NY, Manuals and Reports on Engineering Practice 54, 1975, 745 pp.

Publication of this paper sponsored by Committee on Hydrology, Hydraulics, and Water Quality.

Evaluation of Filter Fabrics for Use in Silt Fences

DAVID C. WYANT

This study was conducted to develop tests that simulate field conditions and that could be used to generate information for the formulation of specifications for purchasing filter fabrics to be used to construct silt fences. Fifteen fabrics were subjected to seven tests devised to evaluate their performance. Two of the tests—laboratory filtering efficiency and warp tensile strength—have been adopted by the Virginia Department of Highways and Transportation for evaluating filter fabrics to be used on construction projects. Three of the four parameters found to be critical in the design of a silt fence—filtering efficiency, flow rate, and warp tensile strength—are ascertained by these two tests. A third test, to determine the fourth critical parameter (resistance to damage by ultraviolet rays), is reported but was not recommended to the department for use because of its lack of reproducibility. Further work on a method for evaluating this critical parameter is needed.

Because accelerated erosion can result from areas denuded during highway construction, the policy of the Virginia Department of Highways and Transportation is to employ protective measures on all projects and to establish vegetation as early as possible. In addition to vegetation, nonvegetative temporary erosion and sediment-control measures are needed to prevent the construction-generated silt from being carried into nearby waterways or onto adjoining properties. These nonvegetative measures are especially useful for the retention of silt before vegetation is established.

The department uses various types of nonvegetative-control measures to impede the flow of sediment-laden waters and to filter out sediment. The most commonly used measures are barriers made of straw, gravel or crushed stone, and brush. In very critical areas, however, the protection provided by these barriers has not been sufficient. Faced with this problem and recognizing that a large number of fabrics had been introduced to the highway industry for use as filter materials, in 1975 the department put into effect a special provision that allowed contractors to use fabrics to construct silt fences.

Different fabric manufacturers produce materials of different properties and use the results of different approval tests, such as those sanctioned by the American Society for Testing and Materials (ASTM) (1), as evidence of their quality. Also, the properties of the materials do not clearly relate to the properties desired of a fabric to be incorporated in a silt fence. Therefore, a study was initiated to develop tests that could be used to evaluate the properties of the fabrics and provide information that might aid in the development of specifications to be stipulated in purchasing them (2).

OBJECTIVE

The objective of the study was to develop information for the formulation of specifications for use in purchasing filter fabrics for building silt fences on highway construction projects. To achieve this objective, the performance desired of an installed silt fence made of fabric had to be established along with a valid estimation of what is reasonably achievable. Therefore, the first objective was to develop tests that closely simulated the conditions to which a silt fence is exposed. In addition, the tests were to be of a type that could be performed without any large investment in additional testing equipment.