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Application of a Revised Local Government Annual Reporting System for Estimation of Non-Point Source Reductions in Agricultural Watersheds

Water-Resources Investigations Report 03–4297

U.S. Department of the Interior
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By G.A Payne[1], E.H. Mohring[2], and R.M. Goldstein[1]

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Conversion Factors and Abbreviations

Multiply	By	To obtain
Inch (in.)	2.54	centimeter
Foot (ft)	0.3048	meter
Mile (mi)	1.609	kilometer
Acre	4047	square meter
Square mile (mi^2)	2.59	square kilometer
Cubic foot (ft^3)	0.2832	cubic meter
Pound (lb)	0.4536	kilogram
Ton	0.9072	megagram
Tons per cubic foot ($tons/ft^3$)	3.20	megagram per cubic meter
Pounds per square yard per year ($lbs/yd^2/yr$)	0.5425	kilograms per square meter per year
Pounds per acre per year (lbs/acre/yr)	1.12	kilograms per square meter
Tons per acre per year (lbs/acre/yr)	2.24	megagrams per square meter
Tons per cubic foot ($tons/ft^3$)	32.03	megaram per cubic meter

Acronyms

A	Area
AC	Units Applied
BMP	Best Management Practice
BWSR	Minnesota Board of Water and Soil Resources
CA	Contributing Acres
CF	Correction Factor
D	Distance
FLEVAL	Feedlot Evaluation Model
FS	Filter Strip
LARS	Local government Annual Reporting System
PA	Phosphorus after
PB	Phosphorus before
PR	Phosphorus reduction
RUSLE	Revised Universal Soil Loss Equation
SD	Soil density
SDR	Sediment Delivery Ratio
SEDA	Sediment delivery after
SEDA0	Preliminary sediment delivery after
SEDB	Sediment deliver before
SEDB0	Preliminary sediment delivery before
SEDR	Sediment Reduction
SLA	Soil Loss After
SLB	Soil Loss Before
SLR	Soil Loss Reduction
SLT	Sediment Loss Treated
SOIL	Clay, silt, sand, and peat
TAC	Technical Advisory Committee
USGS	U.S. Geological Survey
VOLV	Volume voided
W	Width of filter strip
YR	Years

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ABSTRACT

The Minnesota Board of Water and Soil Resources uses an algorithm based system called LARS (Local government Annual Reporting System) to estimate the amount of non-point nutrients and sediment prevented from reaching the State's aquatic systems when new land-use best-management practices are applied. Since the initiation in 1995, LARS has not been updated. The Technical Advisory Committee reviewed significant findings since 1995 for incorporation into the LARS algorithm. These algorithms estimate the amount of sediment and primarily phosphorus retained in a basin as a result of each best-management practice. The program was intended to be simple and small enough to be installed on computers used by local government offices in the mid-1990's. The most important update to the LARS algorithms was a more accurate sediment delivery ratio. The new sediment delivery ratio improved the accuracy of the LARS algorithms.

INTRODUCTION

The Minnesota Board of Water and Soil Resources (BWSR) works with local units of government to accomplish a variety of management and planning functions. These often involve instituting best-management practices (BMPs) to achieve soil and water conservation benefits. When projects are implemented, such as erosion control or water-quality improvement practices, there is increasing expectation that results will be measured and benefits quantified.

By the mid-1990's, the BWSR determined that annual reports received from local governments did not provide an efficient way to determine measurable results or benefits. In cooperation with the Minnesota Pollution Control Agency and others, the BWSR instituted an electronic reporting system in 1995. This became known as LARS (Local government Annual Reporting System). LARS is a state-wide database application that was distributed to local governments to document implemented BMPs, estimate reductions in non-point source contaminates reaching surface waters, and to generate an annual report containing this information for the BWSR. Fundamental to the LARS software are the algorithms that estimate the amount of non-point source contaminants prevented from reaching surface waters. These algorithms estimate the amount of sediment and primarily phosphorus retained in a basin as a result of each BMP. The program was intended to be simple and small enough to be installed on computers used by local government offices in the mid-1990's.

As local governments acquired increasingly sophisticated computers, geographic information systems, and data communication links, an improved and updated version of LARS became feasible. An improved version would streamline the transfer of information through the use of internet-based geographic information system mapping and database software accessible to local government offices through a central network server. Updating LARS presented an opportunity to apply new information about nutrient dynamics and sediment delivery to modify the contaminant reduction algorithms, thereby improving estimates of non-point source reductions and associated water-quality benefits.

The U.S. Geological Survey (USGS) and the BWSR began a cooperative project in 2001 to provide enhancements to the LARS contaminant reduction algorithms, and begin the linkage of LARS estimates to actual improvements in water quality by investigating the relation of BMP implementation to non-point source contaminant reductions

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and stream water quality. The goals of the cooperative project were to form a Technical Advisory Committee (TAC) to examine new information gained since 1995, and apply that information to update the algorithms.

The TAC met in five sessions, June-October 2001, to review published research in soil science and watershed hydrology, discuss new developments in BMP applications, build consensus on technical issues, and set short and long-term goals for a revised LARS. The TAC reached consensus on a short-term revision affecting the sediment delivery ratio used in LARS calculations and identified enhancements to LARS that need long-term development. The BWSR and USGS continued this process during November 2001-May 2002 by evaluating additional written comments from TAC members pertaining to the technical elements of a revised LARS.

PURPOSE AND SCOPE

The purpose of this report is to document the revisions to the LARS algorithms and application of a revised LARS for estimation of non-point source reduction, in agricultural watersheds and evaluation of strengths and limitations of using LARS calculations to predict stream water quality, and to discuss further research needed to investigate the relation of BMPs to non-point source reductions and stream water quality. This report reviews the findings of the TAC and documents the process and rationale for the changes made to LARS algorithms. The discussion and findings contained in this report are a consensus of the TAC, BWSR, and the USGS.

ACKNOWLEDGMENTS

The authors thank the Technical Advisory Committee for their input in the fields of soil science, agriculture, civil engineering, water quality, and other fields related to evaluating agricultural BMPs. Expertise was gathered from the following agencies through the TAC: Minnesota Pollution Control Agency, Minnesota Department of Agriculture, U.S. Department of Agriculture Natural Resources Conservation Service, University of Minnesota, Minnesota Board of Water and Soil Resources, and U.S. Geological Survey.

REVISIONS TO THE LOCAL GOVERNMENT ANNUAL REPORTING SYSTEM

This portion of the report addresses the revisions made to the LARS algorithms for estimating the amount of non-point source contaminants prevented from reaching surface waters by the implementation of BMPs. It summarizes the findings of the TAC and the application of the new information.

LOCAL GOVERNMENT ANNUAL REPORTING SYSTEM CONTAMINANT REDUCTION ESTIMATES

The current LARS program has built-in estimates of the non-point source contaminant reductions due to BMPs for sediment and phosphorus from soil erosion or runoff. Specific algorithms address: (1) sheet and rill erosion, (2) gully stabilization, (3) stream and ditch bank stabilization, (4) filter strip projects, (5) wind erosion treatment (user specified), and (6) other estimated contaminant reduction (user specified) (Appendix 1).

The estimates use either the Revised Universal Soil Loss Equation (RUSLE) (Renard and others, 1991), or a volumetric calculation to simulate soil loss reduction. Sediment Delivery Ratios (SDRs) based on the distance to the receiving water body and the estimated soil loss reduction are applied to estimate sediment reduction. Reduction of phosphorous (associated with sediment particles) is derived from sediment delivery and a coefficient based on soil type. The wind erosion and other estimated contaminant reductions offer no calculations, just a place to enter estimates made by other LARS users.

SEDIMENT DELIVERY RATIO

The SDR is a key component in LARS estimates of BMP benefits from reduced sediment. The SDR is based on an approximate relation between SDR and distance from the edge of the agricultural field to the receiving surface water. Calculation of benefits begins with application of the RUSLE to estimate soil erosion at a field edge before and after installation of a BMP. The difference is the soil erosion benefit at the field edge (the amount of soil that is not transported beyond the BMP). The water-quality benefit for the receiving water body is dependent on the amount of the sediment that is retained between the field edge and the proportion that reaches the water body. The amount of sediment reaching a water body divided by the amount in transport at the field edge is the SDR. As a result, the SDR decreases as distance to the receiving surface water increases. The amount of sediment deposition between the field's edge and a water body is site specific and depends on factors such as particle size, slope, and terrain features. The SDR in individual applications cannot be determined with precision, but needs to conform to a generalized model that approximates average delivery conditions for a region.

Based on review by the TAC, the SDRs were considered the part of the LARS estimates most in need of reevaluation and improvement; therefore, a new SDR estimator was determined. The LARS system originally used a step function for the SDR that was set at 0.2 when the distance from field edge to a water body was less than 1,320 ft (fig. 1 and Appendix 1) (Minnesota Pollution Control Agency, 1995). For distances of 1,320 ft or greater, the SDR was set at 0.1. Review of watershed-sediment-yield data for Minnesota streams and SDR values computed from reservoir studies (Finkelson, 1978) suggested that the SDR function in LARS would likely overestimate sediment reductions when applied to watersheds that exceed 25 mi^2. The TAC reached consensus that the step function be replaced by a single logarithmic plot connecting points at 1 ft from the field edge (SDR of 1.0 or 100 percent delivery) and at 200,000 ft (SDR of 0.08 or 8 percent delivery) (Appendix 1). This relation for the new SDR estimator provided a better fit than the step function when it was applied to data from studies where distances from field edge to water bodies exceeded 1,320 ft. At distances less than 1,320 ft the new SDR may overestimate sediment delivery, but it was decided to retain it in the short-term and refine the relation in future LARS revisions using data from SDR-measurement studies as they become available.

ENHANCEMENTS FOR LOCAL GOVERNMENT ANNUAL REPORTING SYSTEM CALCULATIONS

The revised LARS calculations are shown in the Appendix 1. A RUSLE calculator was incorporated into the new system. This change is intended to simplify soil loss calculations by replacing the separate RUSLE soil-loss calculations that were made independently of LARS. Nutrient enrichment from sediment-borne phosphorus also is simplified by replacing tables of values with mathematical functions (fig. 2), requiring only that the user input soil type to initiate the enrichment calculation.

The new SDR estimator replaces the step function in sheet and rill erosion control and gully control calculations. The SDR estimator also has been added to calculations for riparian filter strips, where the area of the filter strip is credited for soil erosion benefit through the conversion of the filter strip area to permanent vegetative cover. A distance of one-half the width of the buffer strip is input as the distance from field edge to water body. This benefit is in addition to the benefit of the filter strip's treatment of runoff from uplands that drain to the filter strip.

APPLICATION OF LOCAL GOVERNMENT ANNUAL REPORTING SYSTEM FOR ESTIMATION OF NON-POINT SOURCE REDUCTIONS IN AGRICULTURAL WATERSHEDS

The BWSR recognized the need to relate implementation of BMPs to water-quality benefits. A uniform state-wide accounting application such as LARS provides a complete inventory of the number and type of all BMPs that are implemented. The soil-loss reduction estimations from LARS provide the added benefit of a means to calculate how much soil was kept in place, and therefore how much was prevented from reaching a stream or other water body. It would be desirable to calculate BMP implementations in a watershed, or the number of planned projects, and thereby predict the effect on a stream (the reduction in load). At a minimum, it would be desirable to establish that a certain amount or type of BMP implementation results in a water-quality improvement such as a decrease in sediment or nutrients. There is concern, however, whether the two main elements of the LARS calculation, RUSLE soil loss estimates, and the SDR, are an over simplification of a complex process and would provide accurate estimates of load reduction improvements in water quality; therefore the applicability of the RUSLE and SDR need to be evaluated for small and large watersheds.

SMALL WATERSHEDS

The starting point for the LARS calculations, RUSLE soil loss estimates, are widely accepted and well researched, supported with empirical studies, and have undergone frequent refinement. The SDR remains as the factor least well known. Because the new SDR estimator may overestimate sediment delivery for transport distances less than 1,320 ft, research on SDRs in small watersheds is needed. At the farm-field scale (160 acres), the SDR can be measured by monitoring sediment delivery to a water body and dividing that load by the RUSLE estimate of soil loss at the field edge. Distances from field edge to water body at the farm-field scale would seldom exceed 1/2 mile, and most would be less than 1/4 mile, given the drainage density typical in most of the intensely cropped areas of Minnesota. Drainage density in much of Minnesota's cropland has increased because of ditching and tiling (Quade and others, 1980).

Surface inlets are commonly installed in tile lines within agricultural fields. Surface inlets effectively make tile lines part of the stream system and in most cases can be considered a water body for sediment delivery calculations. Little attenuation of the sediment load can be expected once the transported sediment enters the surface inlet, even though the tile may run for several thousand feet before discharging to a surface-water body. SDR determinations for cropped fields range from 0.02-0.10, but are greater where surface inlets are present, ranging from 0.1-0.2 (Moncrief and others, 2002), and 0.1-0.4 (Wilson and others, 1999; Burt and Wilson, in press). Farm-field

Revised Sediment Delivery Ratio relationship for LARS

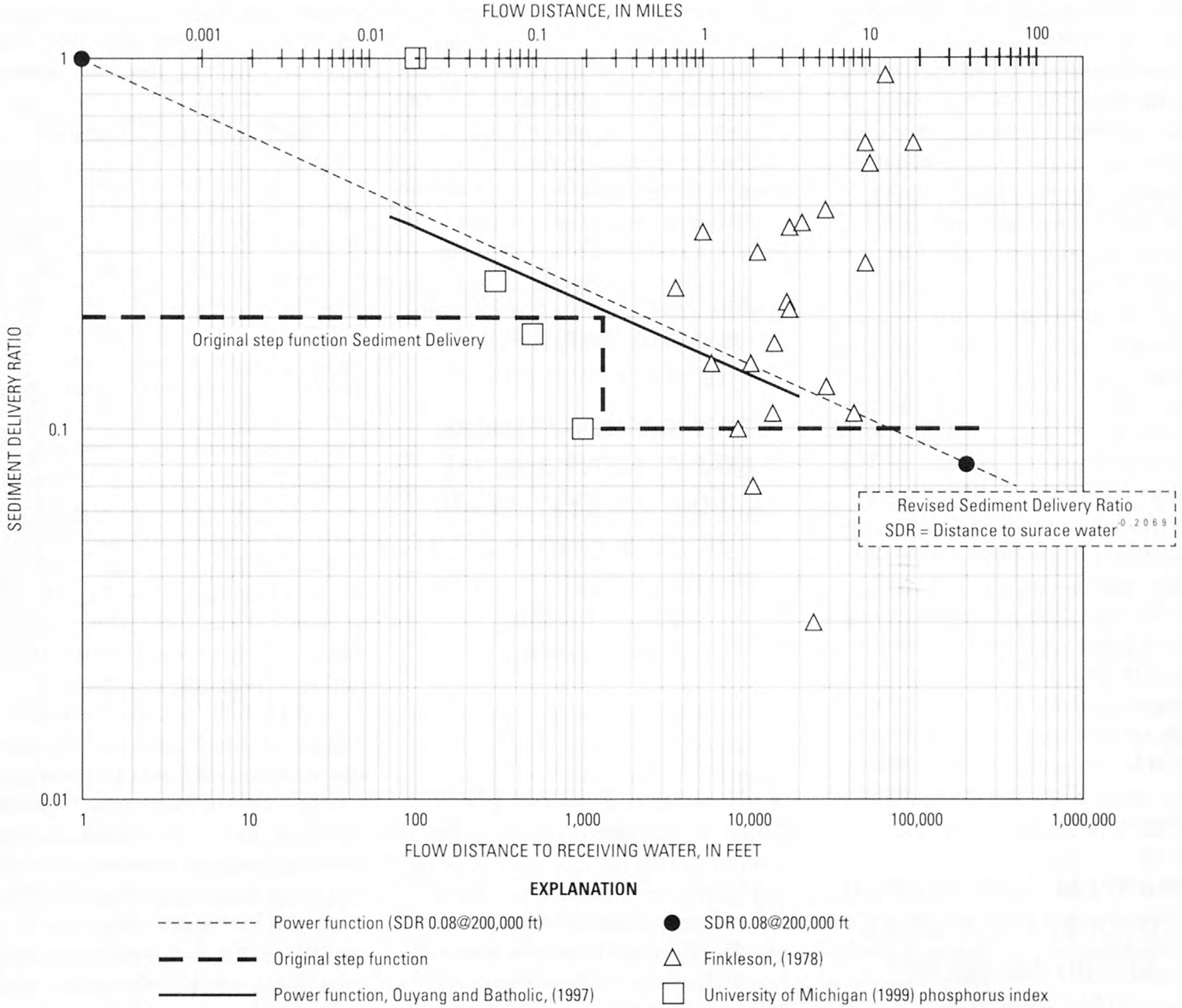

Figure 1. Sediment delivery ratio proposed for LARS. (Data are from Finkleson, 1978; Ouyang and Batholic, 1997; University of Michigan; and Moncrief and others, 2002.)

scale SDRs are likely to vary with soil type and landscape features across Minnesota's cropped areas, but given a sufficient number of measurements, reasonable average and technically supportable regional SDR values should be attainable.

A refined SDR for short distances (at farm-field scale), incorporated into the revised LARS contaminant reduction estimate, would be helpful for improving estimates of contaminant reduction at the first-order stream (farm-field scale). Such a tool would be useful for local water planning, in which a goal is to determine the number and type of practices needed to produce a beneficial response within that local area. This approach may prove beneficial when a first-order stream reach has been identified as not attaining water-quality goals because of non-point source inputs.

LARGE WATERSHEDS

Hydrologic systems become more complex at increasing scales larger than first-order streams. Complexity increases because of processes that, while present in small watersheds,

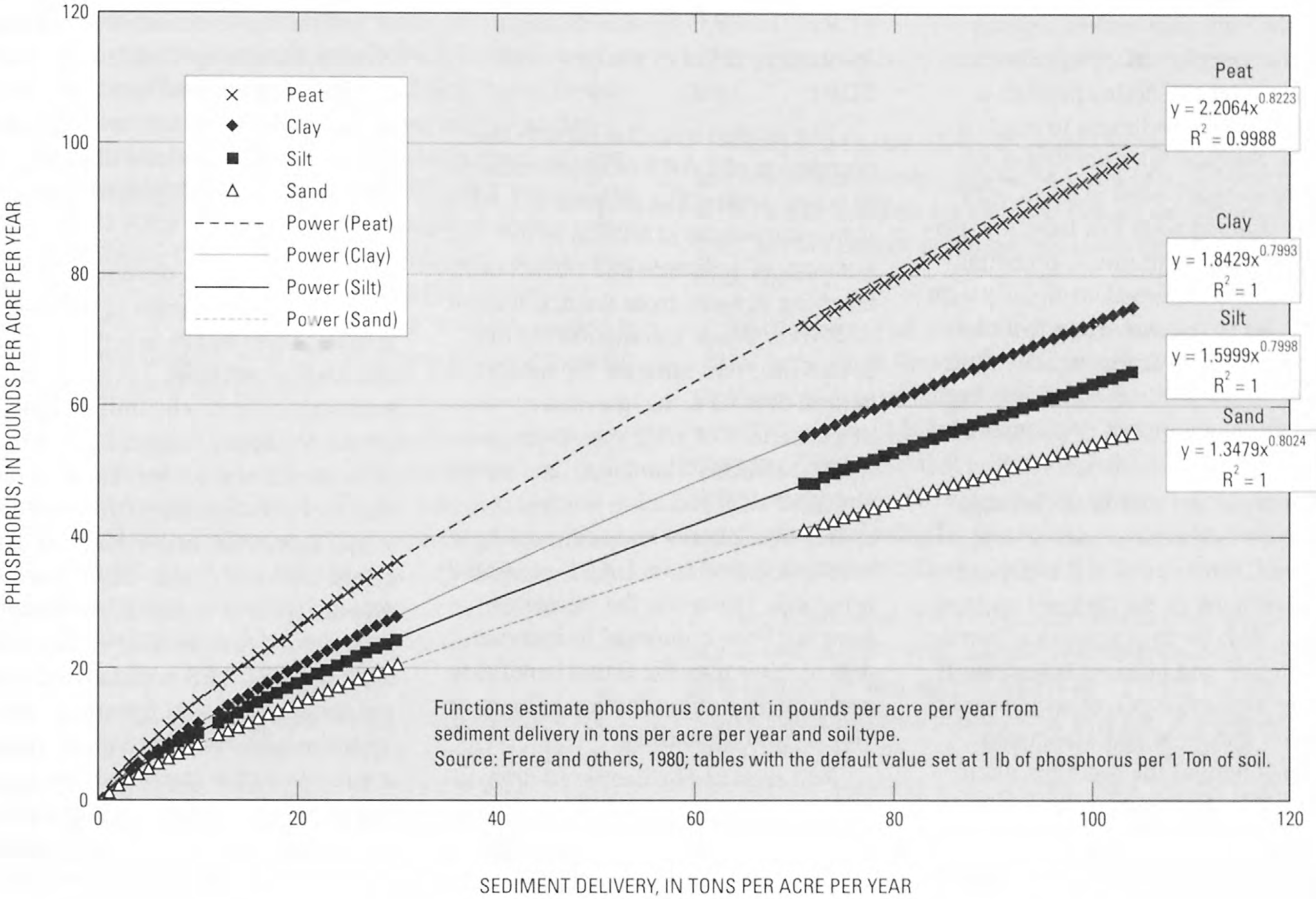

Figure 2. Phosphorus content of sediment delivered by sheet and rill erosion.

tend to exert more influence as watershed size increases. Sediment processes that often become significant in larger watersheds include floodplain deposition, channel aggradation/degradation, and bank erosion.

Floodplain deposition increases as streams become larger. Floodplain width tends to increase as the river and watershed increase in size. The amount of sediment deposited on the floodplain is directly related to the width of the floodplain and influenced by slope and density of vegetated cover. The farther runoff must travel before entering a stream the more likely is of that sediment will be deposited on the floodplain. Deposition and aggradation act on the sediment delivered to the large-watershed stream from upland areas and affect the SDR. Degradation and bank erosion represent an additional source of sediment, which is unrelated to the SDR of field-source sediment, but commonly adds to the total sediment load of larger streams, thereby causing an increase in SDR compared to small watersheds. A correction could be made for bank erosion, but bank erosion is not easily quantified, and rates are stream and reach specific. Many of the large watersheds contain flood-control reservoirs or chains of lakes that trap sediment, lowering sediment yields at stream mouths, which decreases the SDR. All of these factors increase the difficulty of attempting to extrapolate contaminant-reduction estimates calibrated for small watersheds to downstream reaches of large rivers in large watersheds.

Due to uncertainties related to watershed size, the accuracy of contaminant estimates diminishes to a point of impracticality with increasing watershed size. Based on experience and knowledge, the TAC, BWSR, and the USGS judged this condition will likely be reached at second to third order streams draining less than 100-200 mi^2.

IMPLICATIONS OF EVALUATION

Two major questions remain regarding LARS. The first question is the hydrologic effect of surface-inlet tile drains on SDRs. SDRs affect the accuracy of LARS. The SDR will vary with soil type and composition, land cover, topography, vegetation, duration and intensity of rainfall, distance from the receiving waters, and the other factors that affect hydrology. Surface-inlet tile drains provide a direct route for sediment to reach a stream. Surface-inlet tile drains are most commonly used in areas with poorly drained soils that have low permeability and high runoff potential. Such areas are drained artificially with tile drains to remove water from low-lying fields. Tile drains usually direct sediment laden runoff water into excavated drainage ditches or channelized streams

During construction of drainage ditches and stream channelization, soil removed from the channel is deposited on either bank of the channel creating a berm. This berm is a physical barrier to sediment and nutrient laden runoff. During a runoff event, overland runoff deposits sediment and associated nutrients behind the drainage ditch berm while the runoff water infiltrates to the drainage ditch and is channeled downstream to a larger stream. When surface-inlet tile drains are used to further accelerate field drainage, sediment and nutrient laden runoff is funneled down the surface-inlet tile drain and flows through the tile under the drainage ditch berm directly into the drainage ditch or receiving stream. The surface-inlet tile drain can circumvent any benefit of channel berms, riparian vegetation, or velocity reduction and sediment settling.

Application of LARS algorithms in a tile-drained area with these types of soils would use an SDR that is too low. With surface-inlet tile drains, the actual SDR would be greater. Surface-inlet tile drains confound the use of SDRs. The first question then is to resolve the effect of tile drains on SDRs.

The second question regards the correlation of LARS to improvements in water quality. The purpose of LARS is to estimate the reduction in the amounts of sediment and phosphorus reaching streams from the application of BMPs. While calculations in the LARS program estimate the terrestrial benefit of BMPs, the question remains of the benefit of BMPs to water quality. The effects of land use, land cover, and BMPs for reducing non-point source phosphorus and sediment have been calculated from LARS generated estimates. However, the estimates have not been compared to instream data to determine the actual benefits to water quality: the reduction in loads or yields from the basins.

Soil erosion has increased dramatically due to agricultural cultivation (Walling, 1999). The rate of soil erosion has increased from 0.0055-0.0368 lbs/yd^2/yr in natural areas to 0.92-31.27 lbs/yd^2/yr under cultivation, and the yield of sediment in rivers of highly agricultural basins has increased approximately five times as a result of human activity (Walling, 1999). While agricultural production and the amount of land under cultivation in Minnesota may not decrease and therefore reduce sediment yields, land use and BMPs may reduce erosion and improve water quality. Within Minnesota, the Minnesota River Basin has the greatest amount of agricultural land use, greater than 80 percent of the basin is farmed, and the Minnesota River has the greatest concentrations of sediment and nutrients of any large river in Minnesota (Stark and others, 1996). Sediment and nutrient non-point inputs to streams are influenced by erosion and artificial drainage throughout the highly agricultural basin.

The BWSR has developed LARS to quantify the benefits of alternative land uses and BMPs to reduce erosion and loss of nutrients. LARS is an evolving system. The initial algorithms are being revised based on state-of-the-science information on regional soil characteristics, soil erosional processes, and the effects of different land-use conservation practices on nutrient and sediment transport. Still needed are the field experiments to adjust the LARS pollutant reduction estimates to account for artificial drainage systems and to more closely approximate the measured instream water quality. A wide-scale analysis of the various current land-use practices and associated loads and yields of nutrients and sediment would be of great value to evaluating the accuracy of LARS estimates. Practices that contribute to improving water quality include riparian buffer zones (Osborne and Kovacic, 1993; Barling and Moore, 1994; Lee and others, 2000; Stauffer and others, 2000), wetland restorations (Kovacic and others, 2000), modified tile drain inlets, and use of BMPs for cropping (conservation tillage, contour farming, terracing, terrace outlets, grassed water ways, strip cropping, crop rotation, and residue management) (Waters, 1999 and references cited within).

SUMMARY

In 1995, the Minnesota Board of Water and Soil Resources (BWSR) instituted an electronic system for reporting the benefits of agricultural best management practices (BMP) throughout the state. This system was known as LARS (Local government Annual Reporting System). The LARS software also includes algorithms that estimate reductions in the amount of non-point source contaminants reaching streams.

The U.S. Geological Survey and BWSR began a cooperative project during 2001 to provide enhancements to LARS and investigate the relation of BMP implementation to non-point source reductions and stream water quality. As part of this process the non-point source reduction estimates have been revisited through a Technical Advisory Committee

(TAC) formed by gathering expertise in the fields of soil science, agriculture, civil engineering, water quality, and fields relating to evaluating agricultural BMPs. The TAC reached consensus on a short-term revision affecting the sediment delivery ratio used in LARS calculations and identified enhancements to LARS that need long-term development. This report documents revisions to LARS, and application of a revised LARS for estimation of non-point source reductions in agricultural watersheds, and evaluation of strengths and limitations of using LARS calculations to predict stream water quality, and discuss further research needed to investigate the relation of BMPs to non-point source reductions and stream water quality.

The current LARS calculations use either the Revised Universal Soil Loss Equation or a volumetric calculation to simulate soil-loss reduction. Sediment delivery ratios (SDRs) based on the distance to the receiving water body and the estimated soil loss reduction are applied to estimate sediment reduction. Attached phosphorus reduction is derived from sediment delivery and a coefficient based on soil type.

The LARS system originally used a step function for SDR that was set at 0.2 when the distance from field edge to a water body was less than 1,320 feet. For distances of 1,320 feet and greater, the SDR was set at 0.1. The TAC reached consensus that the step function be replaced by a single logarithmic plot connecting points at 1-foot from the field edge (100 percent delivery) and at 200,000 feet (8 percent delivery).

Farm-field scale SDRs are likely to vary with soil type and landscape features across Minnesota's cropped areas. SDR determinations for cropped fields range from 0.02-0.10, but are greater when surface inlets are present, ranging from 0.1-0.2.

Hydrologic systems become more complex at increasing scales larger than first-order watersheds. Floodplain deposition increases as streams become larger. The farther that runoff must travel before entering a stream increases the amount of sediment that will be deposited on the floodplain. When one attempts to calculate an SDR empirically for a large watershed using large-river sediment loads as a divisor there is an over estimation of the SDR.

Implications of this evaluation are summarized according to two major questions that remain regarding LARS. The first is the accuracy of SDRs and LARS estimates where surface-inlet tile drains are present. Surface-inlet tile drains provide a direct route for sediment to reach a stream. The second question is the relation between the effects of a BMP in a watershed and improvements in water quality.

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APPENDIX 1—SEDIMENT DELIVERY RATIOS AND LARS ALGORITHMS FOR CONTAMINANT REDUCTION ESTIMATES

This appendix contains the sediment delivery ratios (SDR) (fig. 1) and revised algorithms used by LARS to estimate nutrient and sediment reductions from various BMPs. The changes that have been made to the various algorithms are presented first then the presentation for each estimation method includes the calculation with a flow diagram. Two current (2003) methods (wind erosion treatment and other estimated contaminant reductions) are included but remain unchanged. The BMPs that are addressed are:

1. Sheet and rill erosion control
2. Gully stabilization
3. Stream and ditch bank stabilization
4. Filter strip projects
5. Wind erosion treatment
6. Other estimated contaminant reduction

The SDR estimator for sheet and rill erosion is based on an approximate relation between SDR and distance from the edge of field to the surface water. The relation is defined by a power function passing through two points (fig. 1):

Distance (ft)	Sediment Delivery Ratio
200,000	0.08
1	1

Figure 1 shows the relation of the new SDR estimator to the current "step function" used in LARS. Of all the distances to surface water recorded in LARS for land and water treatment projects, nearly one-half are 0. For these the SDR of 1 is appropriate, assuming they are riparian. There is some concern that for short distances to surface water between 0 and several hundred feet, the relation may overestimate sediment delivery (and therefore sediment reduction). A possible solution is to use a different relation for short distances after field scale research is completed.

REVISED CONTAMINANT REDUCTION ESTIMATES

Current (2003) revisions include:

1. Changes in SDR and use of an SDR estimator algorithm (fig. 1)
2. Correction of errors in filter strip calculations.
3. Use of SDR estimator in the filter strip calculations.
4. Sediment-borne phosphorus for different amounts of sediment delivery is factored in using an algorithm based on the soil characteristics (fig. 2).

Other short term additions/changes to consider for implementation:

1. Adjusting the SDR curve for short distances (< 500 ft.)
2. SDRs for gully stabilization.
3. Use of a (much lower—for example, 8 percent) "Basin-level" SDR, to apply to all practices in a watershed for gross calculation of combined sediment yield and sediment reduction.
4. "Basin-level" percentage correction factor—a "toggle switch" to change between yields for field's edge, minor watershed, major watershed, and basin.
5. Nutrient Management "toggle switch:" is there a nutrient management plan in place (yes/no)?
6. Include Feedlot Evaluation Model (FLEVAL)

The following descriptions and flowcharts present a description of the current LARS calculations with proposed short-term revisions. Some input and output terms include "before" and "after" in descriptions, which refers to before or after implementation of BMPs

SHEET AND RILL EROSION CONTROL

Erosion before and after implementation of BMPs, estimated using the Revised Universal Soil Loss Equation (RUSLE), are required inputs (fig. 3). A SDR is calculated based on the distance from the edge of field to the water resource of concern (fig. 1). The SDR is applied to estimate sediment reduction. Sediment-attached phosphorus reduction is calculated using functions relating phosphorus content to sediment delivery (fig. 2).

Changes from the original version of LARS include:

1. Use of the SDR estimator algorithm to estimate sediment delivery coefficient
2. Sediment enrichment for sediment-borne phosphorus is factored in using functions estimating P content (lbs/acre/yr) from sediment delivery (tons/acre/yr) and soil type (fig. 3). The functions come from Frere and others (1980) tables with the default value set a 1.0 lb of phosphorus per 1 ton of soil.

Inputs:

(Local ID, project code, location data, major and minor watersheds, water resource protected)

RUSLE before **SLB** [soil loss before per acre (tons/acre/yr)]

RUSLE after **SLA** [soil loss after per acre (tons/acre/yr)]

SOIL type (clay, silt, sand, peat) (Appendix 2, table 1)

AC = units applied (acres)

CA = contributing acres

D = distance to surface water

Soil Loss Reduction (from fields)

SLR = SLB – SLA, Soil Loss Reduction per acre (tons/acre/yr)

SLR = SLR*AC, Soil Loss Reduction (tons/yr)

Sediment Reduction (from receiving surface water)

SEDB0 = SLB * SDR, Preliminary sediment delivery before per acre (tons/acre/yr)

SEDA0 = SLA * SDR, Preliminary sediment delivery after per acre (tons/acre/yr),

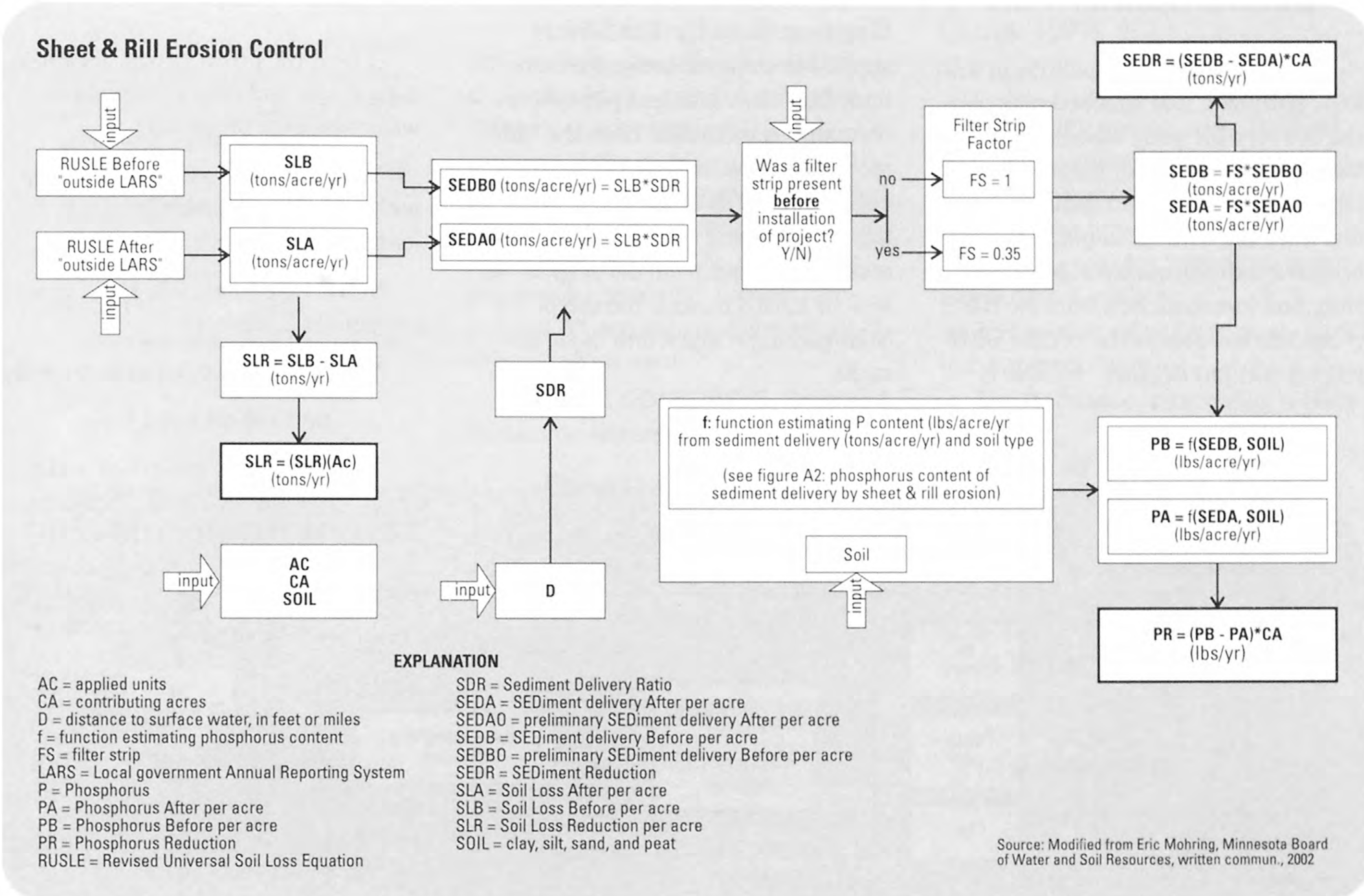

Figure 3. Local government Reporting System program flow chart to estimate sediment and phosphorus reductions for sheet and rill erosion control.

where **SDR** = sediment delivery ratio, calculated from the algorithm.

Pre-existing filter/buffer strip

Was a filter strip present before the installation of the project?

NO: FS = 1

YES: FS = 0.35

The filter strip factor (FS) modifies the preliminary sediment delivery (SEDA, SEDB) estimates to account for removal of sediment by the filter strip. It represents the fraction of sediment passing through the filter strip. If no filter strip was previously installed, the preliminary sediment reduction estimate is not modified (FS = 1). An estimate of the relative gross effectiveness of filter strips for sediment reduction is 65 percent (Pennsylvania State University, 1992). If the filter strip is judged to be functioning properly[1] then the estimate of 65 percent sediment removal (FS=0.35) is used.

SEDB = FS * SEDB0 (tons/acre/yr) sediment delivery before per acre (tons/acre/yr)

SEDA = FS * SEDA0 (tons/acre/yr) sediment delivery after per acre (tons/acre/yr)

SEDR = (SEDB – SEDA)*CA, Sediment reduction (tons/yr)

Phosphorus Reduction

PB = f(**SEDB**, **SOIL**), phosphorus before per acre (lbs/acre/yr)

PA = f(**SEDA**, **SOIL**), phosphorus after per acre (lbs/acre/yr),

where f is the function estimating P content (lbs/acre/yr) from sediment delivery (tons/acre/yr) and soil type (Appendices 1 and 2 respectively).

PR = (**PB** – **PA**)*__CA__, phosphorus reduction (lbs/yr)

[1]The filter strip credit should be given to a site that provides the following:
A. A healthy stand of grasses predominated by varieties of stem grasses versus blade grasses.
B. The stand of grass should be wide enough to impede the flow it receives (estimated ranges depend on the grass and the energy of the runoff. Widths can be as low as 10 ft for switch grass as much as more common values of 66 ft).
C. Delivery of the runoff must remain in a thin overland flow pattern and not be channelized.
D. The delivery of the run-off from the credited area cannot be bypassed around or through the filter strip by a ditch, tile intake, side inlet or channel.

GULLY STABILIZATION

The estimates for reductions in soil loss, sediment, and attached phosphorus delivery for gully stabilization are based on calculation of volume voided per year (fig. 4). The estimate assumes that once the BMP is in place, the stabilized condition controls gully erosion. Soil loss reduction from the BMP is equal to soil erosion before the BMP project was put in place. A SDR is assigned based on characteristics of flow from the gully. The SDR is applied to estimate sediment reduction. Sediment-attached phosphorus reduction is estimated from the sediment reduction, default phosphorus content of 1.0 lb of phosphorus per 1 ton of soil, and a correction for soil texture. Changes from the original version of LARS include the use of the SDR estimator algorithm in certain cases.

Inputs:

(Local ID, project code, location data, major and minor watersheds, water resource protected)

VOLV volume voided (ft^3) ((top width + bottom width)/2)* depth * length

SOIL type (clay, silt, sand, peat) (Appendix 2, table 1)

YR number of years to form gully

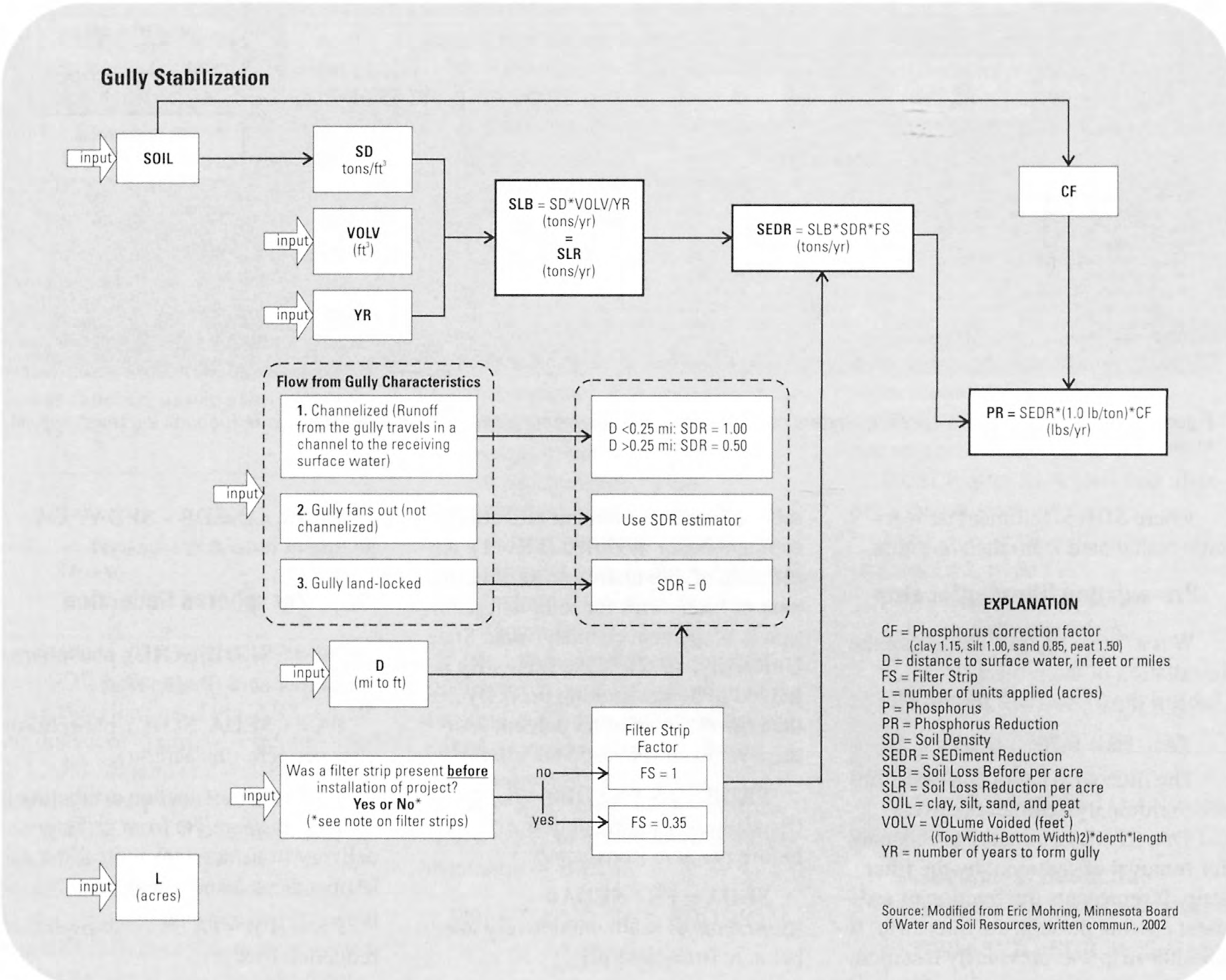

Figure 4. Local government Reporting System program flow chart to estimate sediment and phosphorus reductions for gully stablization.

Characteristics of flow from gully

1. Is the flow from the gully channelized? (Does runoff from the gully travel in a channel to the receiving surface water?)
2. Does the gully outlet fan out? (Is flow not channelized?)
3. Is the gully site land-locked (no outlet to receiving surface water)?

D = distance to receiving surface water

Soil Loss Reduction

SD = soil density (tons/ft^3), (Appendix 1, table 2)

SLB = SD*VOLV/YR, Soil loss before (tons/yr)

Assumed equal to:

SLR = Soil Loss Reduction (tons/yr)

Sediment Reduction

Assign SDR based on the characteristics of flow from the gully.

Channelized

D < 0.25 mi: SDR = 1.00
D > 0.25 mi: SDR = 0.5

Not channelized - gully fans out

Use SDR estimator

Land-locked

SDR = 0

(This is a change from the current LARS system)

Pre-existing filter/buffer strip

Was a filter strip present before the installation of the project?

NO: FS = 1
YES: FS = 0.35

The filter strip factor (FS) modifies the preliminary sediment reduction (SDR), or SLR, estimates to account for removal of sediment by the filter strip. It represents the fraction of sediment passing through the filter strip. If no filter strip was previously installed, the preliminary sediment reduction estimate is not modified (FS = 1). An estimate of the relative gross effectiveness of filter strips for sediment reduction is 65 percent (Pennsylvania State University, 1992) If the filter strip is functioning properly[1] then the estimate of 65 percent sediment removal (FS = 0.35) is used.

SEDR = SLB*SDR*FS, Sediment Reduction (tons/yr)

Phosphorus Reduction

CF = correction factor for soil texture (Appendix 2, table 3)

PR = SEDR *(1.0 lb/ton)*CF, phosphorus reduction (lbs/yr)

STREAM AND DITCH BANK STABILIZATION

The estimates for reductions in soil loss, sediment, and attached phosphorus delivery for bank stabilization are based on an estimate of volume voided per year (fig. 5). The estimate assumes that once the BMP is in place, the stabilized condition controls bank erosion. Soil loss reduction from the BMP is equal to soil erosion before the BMP project was put in place. The SDR = 1 because the practice is adjacent to the receiving surface water. Sediment-attached phosphorus reduction is estimated from the sediment reduction, a default phosphorus content of 1.0 lb of phosphorus per 1 ton of soil, and a correction for soil texture.

Selection of the average lateral recession rate is critically important. Lateral recession is the thickness of soil eroded from a bank surface (perpendicular to the face) in an average year. It is given in feet per year (Michigan Department of Environmental Quality, 1999)

Inputs:

(Local ID, project code, location data, major and minor watersheds, water resource protected, etc.)

VOLV volume voided (ft^3)

SOIL type (clay, silt, sand, peat) (Appendix 2, table 1)

YR number of years to erode bank to current position

D = 0 distance to receiving surface water

SDR = all soil loss reduction is sediment reduction

Soil Loss Reduction

SD soil density (tons/ft^3) - from table (Appendix 2, table 2)

SLB = SD*VOLV/YR Soil Loss Before (tons/yr)

Assumed equal to:

SLR Soil Loss Reduction (tons/yr)

Sediment Reduction

SEDR = SLB = SLR Sediment Reduction (tons/yr)

Phosphorus Reduction

CF correction factor for soil texture (Appendix 2, table 3)

PR = SEDR *(1.0 lbs/ton)*CF, phosphorus reduction (lbs/yr)

FILTER STRIP PROJECTS

The non-point source reduction benefits (soil loss reduction, sediment reduction, phosphorus reduction) from filter strip projects are estimated by summing the benefits from:

1. Reductions from the area of the filter strip, through the conversion of the filter strip area to permanent vegetative cover.

---

[1]The filter strip credit should be given to a site that provides the following:
A. A healthy stand of grasses predominated by varieties of stem grasses versus blade grasses.
B. The stand of grass should be wide enough to impede the flow it receives (estimated ranges depend on the grass and the energy of the runoff. Widths can be as low as 10 ft for switch grass up to more common values of 66 ft).
C. Delivery of the runoff must remain in a thin overland flow pattern and not be channelized.
D. The delivery of the runoff from the credited area cannot be bypassed around or through the filter strip by a ditch, tile intake, side inlet or channel.

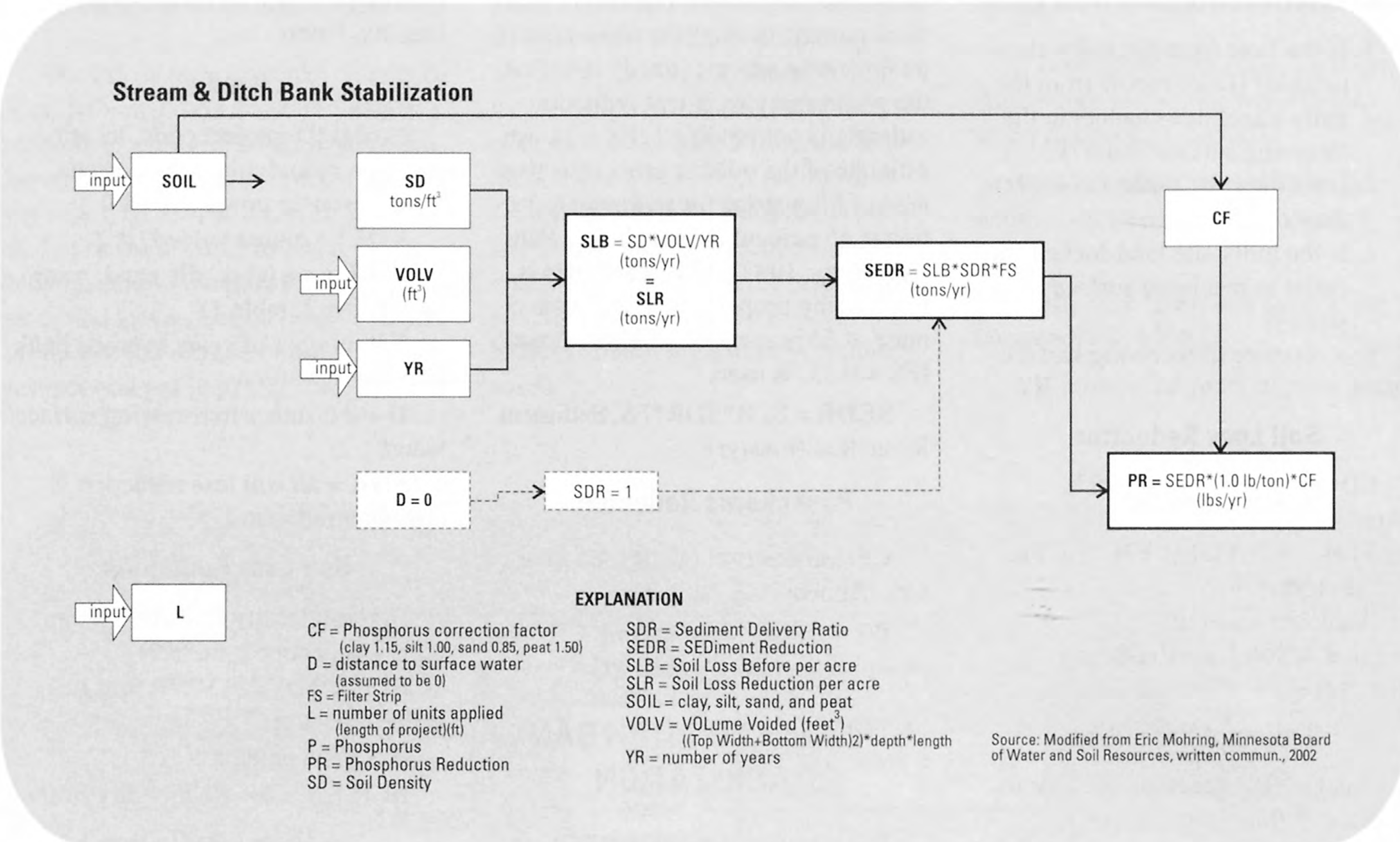

Figure 5. Local government Reporting System program flow chart to estimate sediment and phosphorus reductions for stream and ditch bank stabilization.

2. Reductions from the filter strip's treatment of runoff from the upland drainage area contributing to the filter strip.

Changes from the original version of LARS include:

1. Use of the SDR estimator algorithm and the filter strip width; and
2. Correction of errors in the sediment and phosphorus reduction calculations for upland runoff.

Area of Filter Strip

Inputs

RUSLE before $\mathbf{SLB}_{FS}$ soil loss before (from filter strip area) per acre (tons/acre/yr) (fig. 6)

RUSLE after $\mathbf{SLA}_{FS}$ soil loss after (from filter strip area) per acre (tons/acre/yr)

(Revised Universal Soil Loss Equation analyses usually done locally by the soil and watershed districts.)

$\mathbf{A}_{FS}$ = area of filter strip (acres)

$\mathbf{W}_{FS}$ = width of filter strip (ft)

SOIL (sand, silt, clay, peat)

Soil Loss Reduction

$\mathbf{SLR}_{FS} = \mathbf{SLB}_{FS} - \mathbf{SLA}_{FS}$ Soil Loss Reduction (from filter strip area) per acre (tons/acre/yr)

$\mathbf{SLR}_{FS} = \mathbf{SLR}_{FS} * \mathbf{A}_{FS}$ Soil Loss Reduction (from filter strip area) (tons/yr)

Sediment Reduction

$\mathbf{SEDB}_{FS} = \mathbf{SLB}_{FS} * \mathbf{SDR}_{FS}$ Sediment before per acre (tons/acre/yr)

$\mathbf{SEDA}_{FS} = \mathbf{SLA}_{FS} * \mathbf{SDR}_{FS}$ Sediment after per acre (tons/acre/yr)

Where $\mathbf{SDR}_{FS}$ = sediment delivery ratio for filter strip area. Calculated using the SDR estimator algorithm with an input distance of ½ width of filter strip. (This is a change from the original version of LARS)

$\mathbf{SEDR}_{FS} = (\mathbf{SEDB}_{FS} - \mathbf{SEDA}_{FS}) * \mathbf{A}_{FS}$ Sediment Reduction (tons/yr)

Phosphorus Reduction

$\mathbf{PB}_{FS}$ = f($\mathbf{SEDB}_{FS}$, **SOIL**) phosphorus delivery before per acre (lbs/acre/yr)

$\mathbf{PA}_{FS}$ = f($\mathbf{SEDA}_{FS}$, **SOIL**) phosphorus delivery after per acre (lbs/acre/yr)

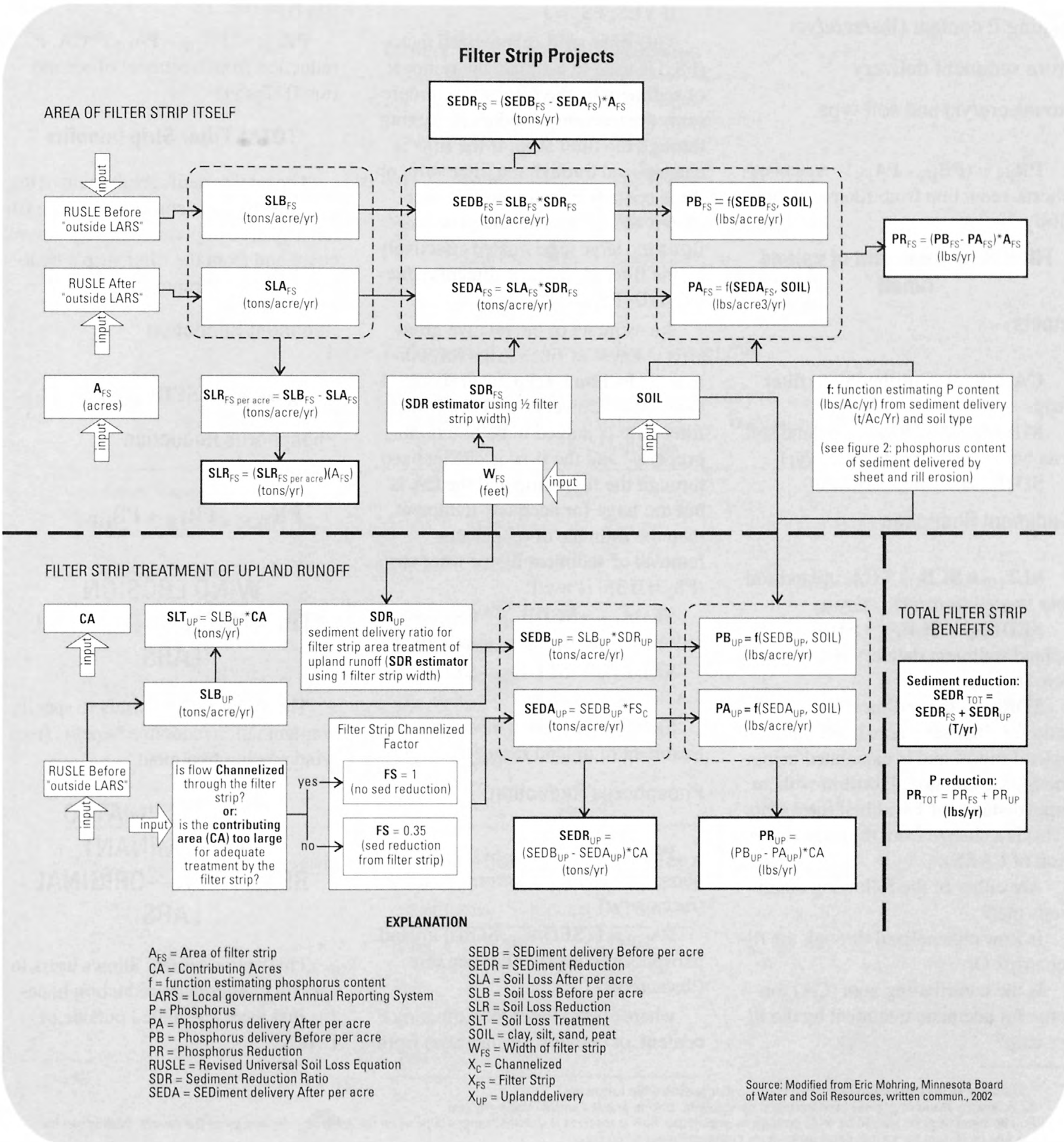

Figure 6. Local government Reporting System program flow chart to estimate sediment and phosphorus reductions for filter strip projects.

Where f is the function estimating P content (lbs/acre/yr) from sediment delivery (tons/acre/yr) and soil type.

$\mathbf{PR_{FS}} = (\mathbf{PB_{FS}} - \mathbf{PA_{FS}})^* \mathbf{A_{FS}}$ phosphorus reduction from filter strip area (lbs/yr)

Filter Strip treatment of upland runoff

Inputs

CA = acres contributing to filter strip

RUSLE before $\mathbf{SLB_{UP}}$, upland soil loss before per acre (tons/acre/yr)

SOIL (sand, silt, clay, peat)

Sediment Reduction

$\mathbf{SLT_{UP}} = \mathbf{SLB_{UP}} * \mathbf{CA}$, upland soil loss treated (tons/yr)

$\mathbf{SEDB_{UP}} = \mathbf{SLB_{UP}} * \mathbf{SDR_{UP}}$, upland sediment delivery before per acre (tons/acre/yr)

SDR_{UP} is the sediment delivery ratio for filter strip area treatment of upland runoff and is calculated using the SDR estimator algorithm with an input distance of 1 width of filter strip. (This is a change from the original version of LARS).

Are either of the following conditions met?

Is flow channelized through the filter strip? Or:

Is the contributing area (CA) too large for adequate treatment by the filter strip?

If NO: $FS_c = 0.35$

If YES: $FS_c = 1$

This filter strip channelized factor (FS_c) is used to estimate the removal of sediment by the filter strip. It represents the fraction of sediment passing through the filter strip. If the flow is channelized through the filter strip, or if the contributing area to the filter strip is too large or would generate flows too large to be treated effectively by the filter strip, the sediment reduction is 0 ($FS_c = 1$).

An estimate of the relative gross effectiveness of filter strips for sediment reduction is 65 percent (Pennsylvania State University, 1992). If the filter strip is judged to be functioning properly[1] and the flow is channelized through the filter strip and the CA is not too large for adequate treatment, then the estimate of 65 percent removal of sediment by the filter strip ($FS_c = 0.35$) is used.

$\mathbf{SEDA_{UP}} = \mathbf{SEDB_{UP}} * \mathbf{FS_c}$, upland sediment after per acre (tons/acre/yr)

$\mathbf{SEDR_{UP}} = (SEDB_{UP} - SEDA_{UP}) * CA$

Sediment reduction from filter strip treatment of upland runoff (tons/yr)

Phosphorus Reduction

$\mathbf{PB_{UP}} = f\,(SEDB_{UP}, SOIL)$, upland phosphorus delivery before per acre (lbs/acre/yr)

$\mathbf{PA_{UP}} = f\,(SEDA_{UP}, SOIL)$ upland phosphorus delivery after per acre (lbs/acre/yr)

where f is the function estimating P content, or delivery, (lbs/acre/yr) from sediment delivery (tons/acre/yr) and soil type (fig. 2).

$\mathbf{PR_{UP}} = (PB_{UP} - PA_{UP})^* CA$, P reduction from treatment of upland runoff (lbs/yr)

TOTAL Filter Strip benefits

The total benefits are the sum of the benefits from the conversion of the filter strip area to permanent vegetative cover and from the filter strip's treatment of upland runoff.

Sediment Reduction

$\mathbf{SEDR_{TOT}} = \mathbf{SEDR_{FS}} + \mathbf{SEDR_{UP}}$

Phosphorus Reduction

$\mathbf{PR_{TOT}} = PR_{FS} + PR_{UP}$

WIND EROSION TREATMENT—ORIGINAL LARS

This option allows users to specify contamination reduction benefits from wind erosion treatment.

OTHER ESTIMATED CONTAMINANT REDUCTION—ORIGINAL LARS

This option simply allows users to specify contaminant reduction benefits that were calculated outside of LARS.

[1] The filter strip credit should be given to a site that provides the following:
A. A healthy stand of grasses predominated by varieties of stem grasses versus blade grasses.
B. The stand of grass should be wide enough to impede the flow it receives (estimated ranges depend on the grass and the energy of the runoff. Widths can be as low as 10 feet for switch grass up to more common values of 66 feet).
C. Delivery of the runoff must remain in a thin overland flow pattern and not be channelized.
D. The delivery of the runoff from the credited area cannot be bypassed around or through the filter strip by a ditch, tile intake, side inlet or channel.

APPENDIX 2—SOIL PROPERTIES

Table 1. Soil texture classification

Clays	Silts	Sands
Clay	Silt	Sand
Clay loam	Loam	Loamy sand
Silty clay	Silt loam	Sandy loam
	Silty Clay Loam	Sandy clay loam
		Sandy clay

Table 2. Approximate dry density soil weights

[tons/ft^3, tons per cubic foot]

Soil textural class	Dry density tons/ft^3	Soil texture used for calculations	Dry density used for calculations tons/ft^3
Sands, loamy sands	0.055	sand	0.055
Sandy Loam	0.052		
Fine Sandy Loam	0.050		
Loams, sandy clay loams, sandy clay	0.045	silt	0.0425
Silt loam	0.042		
Silty clay loam, silty clay	0.040		
Clay loam	0.0375	clay	0.035
Clay	0.035		
Organic	0.011	peat	0.011

Table 3. Phosphorus correction factors for soil texture

Soil Texture	Correction Factor
Clay	1.15
Silt	1.00
Sand	0.85
Peat	1.50

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USGS

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