GIS Sediment Delivery Model Report

Lake Redstone Protection and
Rehabilitation District
PO Box 313
LaValle, Wisconsin 53941

MSA Project No. 640003

April 2002

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EXECUTIVE SUMMARY

The Geographic Information System (GIS) Sediment Delivery Model for the Lake Redstone Watershed was performed by MSA Professional Services, Inc. (MSA) for the Lake Redstone Protection and Rehabilitation District (LRPRD). The study was performed to serve as a tool to identify and rank critical sites in the watershed where sediment delivery is acting as a significant source of phosphorous (P) to Lake Redstone. Lake Redstone is a 612 acre man-made lake located in Sauk County. The approximately 30 square mile watershed is located in both Sauk and Juneau Counties.

The Snell Model was selected to evaluate the Lake Redstone watershed data. The Snell model uses the Universal Soil Loss Equation (USLE) to estimate the potential average annual soil loss from rural areas. The Snell Model then ranks the terrain capability for transporting sediment to a stream by determining the delivery ratio, which is the proportion of the eroded soil which reaches the stream. The calculation is based on the distance to the stream, the slope, the amount of vegetation, the ability of water to infiltrate into the soil, and soil particle size. The third step of the Snell Model was to determine priority management areas by overlying the areas with high soil loss with the high sediment delivery areas. The results identify critical areas where the potential sediment loss from the farm tracts is high and the potential for the sediment to be transported to the stream is high.

The model identified eight farm tracts with total soil loss estimates from high delivery areas at greater than 80 tons/years. It is recommended to ground truth or field verify the top ranked farm tracts to establish that the model results are accurate. The results of the ground truthing should be then be used to determine the Best Management Practices (BMPs) appropriate for the farm tract. Best Management Practices include practices such as buffer strips, contour strip cropping, grassed waterways, diversions, and streambank stabilization which can be implemented to minimize sediment transport to the lake.

INTRODUCTION

The Geographic Information System (GIS) Sediment Delivery Model for the Lake Redstone Watershed was performed by MSA Professional Services, Inc. (MSA) for the Lake Redstone Protection and Rehabilitation District (LRPRD). Sediment delivery is a large component of degraded water quality at Lake Redstone, with approximately 35 to 45% of the phosphorus (P) entering the lake each year originating from field runoff (MSA 2000). The model was performed to serve as a tool to identify and rank critical sites in the watershed where sediment delivery is acting as a significant source of P to Lake Redstone. The study was funded in part by a Lake Planning Grant from the State of Wisconsin.

BACKGROUND

Lake Redstone is a man-made lake located in Sauk County. The lake encompasses 612 acres, is 0.3 miles wide, 3.7 miles long, and has a maximum depth of 36 feet. The watershed is located in both Sauk and Juneau Counties and covers approximately 30 square miles. The watershed is shown in Figure 1.

The lake is heavily used by both the property owners and the general public. There is a Sauk County park and beach on the south side of the lake near the community of La Valle. There are three public boat ramps located on the lake. The lake is a popular fishing resource during both the summer and winter months.

The lake is classified as mesotrophic to eutrophic. Shortly after the lake was filled, algal blooms and sediment were observed in the bays and water clarity was significantly reduced. Several studies concluded that levels of P in the lake were sufficiently high enough to cause nuisance blue-green algal blooms (UW 1981a, UW, 1981b).

PREVIOUS AND CURRENT LAKE MANAGEMENT EFFORTS

In 1976, the Lake Redstone Protection and Rehabilitation District (LRPRD) was formed by lake residents for the restoration and protection of water quality in the lake. Since that time, the District has been actively involved with water quality issues.

A study performed in 1981 by the University of Wisconsin evaluated the degradation of water quality. It concluded that the watershed was the principal contributor of nutrients to the lake (UW 1981a). The major sources of nutrients identified in the watershed included sediment loss from cropland and surface runoff from livestock barnyards. Septic systems were not considered to be a major source of nutrients for the lake.

A 1997 study performed by the WDNR using a mathematical model known as BATHTUB. The results indicated that the watershed, including both runoff from livestock barnyards and sediment loss, was the source of 66% of the yearly P loading to the lake (WDNR 1997). The results of this study confirmed the previous results that the majority of the P loading into the lake was from the watershed. It has been estimated that the P loading originating from sediment loss from field runoff is approximately 35 to 45% of the total P loading to the lake (MSA 2000).

The LRPRD applied for, and received a Lake Planning Grant in 1996 to conduct an inventory of livestock operations. The P loading from each operation was estimated using the Wisconsin Barnyard Runoff mathematical model (BARNY) for each livestock barnyard within the watershed. A total of 71 livestock operations were evaluated. The findings were used to identify high loading operations. The results indicated that 75% of the potential phosphorus loading from animals was attributed to barnyards contributing over 45 pounds of P per year. The LRPRD has subsequently evaluated Best Management Practices (BMPs) on these farms. Project cost estimates were evaluated in terms of P reduction and projects with the lowest cost/benefit ratios were selected.

The LRPRD has funded the construction of clearwater diversions at several barnyards. The District also received a Environmental Quality Incentive Program (EQIP) grant from the US Department of Agriculture (USDA) to implement BMPs at farms within the watershed. Under the EQIP program, funds are available for cost-sharing projects implementing BMPs. The EQIP program started in 2001 and extends until 2003. Combining the reductions in P loading from finished projects and committed projects, an approximate 57% reduction in total P loading from barnyards in the watershed is estimated.

METHODS

SELECTION OF THE MODEL

Various non-point source pollution models were reviewed as part of the current study. The intent of the model review was to determine which sediment delivery model was appropriate to use for the watershed. At the initiation of the project, some existing models were being modified and combined with geographical information systems (GIS). The goal was to select a model that determines soil delivery in a small watershed and has the ability to rank the sites. The model also needed to interface with ARC/VIEW or ARC/INFO.

The project was first conceived in 1998 and several applicable mathematical models were initially reviewed at that time. One software program considered in all 2000 was called Better Assessment Science Integrating Point and Nonpoint Sources (BASINS). The model was written by US EPA. BASINS is a very powerful program with a wide range of features. It integrates GIS and sediment modeling into one package. However, the program works with the Soil and Water Assessment Tool (SWAT) model which was not finished when the selection decisions were needed. Also, BASINS was complex to learn, data intensive, and was limited in its ability to be modified.

Another program reviewed was SWAT, which was developed by the USDA. The concept applied to this project, but it did not factor in the effects of buffers. Also, the ARC/VIEW version was not available when the selection decisions were needed.

Another model reviewed was Agricultural Nonpoint Source Pollution Model (AGNPS). The strengths of AGNPS were the model's ability to apply BMPs relating to production agriculture, and to accept cost analysis for BMPs as input. However, it requires meteorological and hydrogeologic data, and it was based on single storm events.

The Snell Model was recommended by John Panuska, WDNR Agriculture Engineer, and Michelle Bridson Richardson, Dane County Land Conservation Department, GIS Specialist, who had used the Snell Model in a research project while employed with the WDNR. After reviewing the other available models, the Snell Model was selected because local resources were available with working knowledge of the model, it computes annualized delivery, and it could be applied to smaller watersheds.

THE SNELL MODEL

The Snell Model (Snell 1984) was selected to evaluate the Lake Redstone watershed data. The Snell Model uses a delivery ratio concept mathematical model to identify and rank critical sites. It can estimate the potential average annual soil loss from rural areas, the terrain capability to transport sediment to a stream, and the priority management areas for diffuse source sediment pollution. The model was developed in 1984, prior to the widespread use of GIS technology. The model was modified to utilize GIS technology to map the watershed and identify spatial intersections. This was accomplished using a spatial modeling program that reads resource information such as topography and soils, and presents the results (areas) to the user. Aerial photos of the watershed were incorporated into the GIS system. The location and area of farm tracts were determined from the photos. The soil delivery maps were created using the watershed map (Figure 1) as a base map, and adding additional layers of information to it. The data types and sources and how the data was prepared for GIS are presented in Appendix A.

The Snell model uses the Universal Soil Loss Equation (USLE) to estimate the potential average annual soil loss from rural areas. The USLE calculates the average soil loss from sheet and rill erosion by evaluating rainfall, the erodibility of the soil, the slope, soil cover, and erosion control factors to calculate average soil loss in tons per acre per year. The soil erosion data was collected from the County Land Conservation Departments (LCDs). The average annual soil loss data was evaluated in two different ways. First, by determining the farm tracts with very high soil loss (>4 tons/acre/year). The farm tracts were then ranked according to soil loss/ acre. Second, by identifying the potential soil loss per field for farm tracts with high soil loss by multiplying the tons/acre/year by the field size. The farm tracts with potential soil loss greater than 80 tons/field/year were then ranked.

The second step of the Snell Model was to estimate the terrain capability to transport sediment to a stream by determining the delivery ratio. The delivery ratio is the proportion of the eroded soil which reaches the stream. The delivery ratio depends on 5 main factors. These include the distance to the stream, the ground surface slope, the amount of vegetation, the ability of water to infiltrate into the soil, and soil particle size. The distance to the stream and the amount of vegetation were determined using GIS methodology and interpretation of the aerial or the photos. The slope, soil infiltration data, and soil partical size were obtained from NRCS soil survey data and incorporated into the GIS database.

The model uses these factors to rank the capability of the land to transport sediment as high, medium or low. High ranked areas included non-buffered or narrowly buffered (<100 m) land near a stream, poorly drained soils, and steep slopes. The steps used in the model are as follows:

1. Depressions are ranked as low delivery.
2. Steep slopes (>12%) are ranked as high.
3. Land buffered with thick surface cover are ranked low.
4. Areas with high infiltration soils are ranked low.
5. Areas within 100 m of stream not previously ranked are ranked high.
6. Moderation infiltration soils greater than 0.5 km from a stream are ranked low.
7. Narrow buffers (<100 m) on or below steep slopes near streams are ranked high. Areas buffered by wide (>100 m) vegetated areas are ranked low.

8. Poorly and very poorly drained soil within 250 m of stream are ranked high if they were not previously ranked.
9. High ranked areas with steep slopes, but separated by a >100 m wide non-ranked area from another high ranked area are ranked as moderate.
10. All areas not previously ranked are ranked as moderate.

The methodology for classifying the terrain types, and the ranking system for determining the terrain capability to transport sediment to a stream for the Snell Model is presented in greater detail in Appendix B.

The third step of the Snell Model was to determine priority management areas where high soil loss areas are located in high sediment delivery areas. This was done by overlying the results of the soil loss map based on the USLE, with the results of the soil delivery map. The resulting map locates critical areas where the potential sediment loss from the field is high and the potential for the sediment to be transported to the stream is high. It was assumed that sediment delivered to a stream within the watershed would eventually be transported to Lake Redstone and act as a P source for the lake.

RESULTS

Over 600 farm tracts are present within the Lake Redstone watershed which are shown on Figure 1. Of these farm tracts, 146 are considered to have high soil loss, with soil loss estimates greater than 4 tons/acre/year. The high soil loss farm tracts are shown on Figure 2. Table 1 ranks the high soil loss farm tracts based on the USLE soil loss estimates. Seven farm tracts had soil loss estimates greater than 10 tons/acre/year and estimates as high as 27.2 tons/acre/year were identified within the watershed. The equation for the USLE and the parameters used to calculate the USLE for each high loss farm tract are also included in Table 1.

Table 2 ranks the farm tracts with soil loss estimates greater than 4 tons/acre/year, and greater than 80 tons/tract/year. Twenty-two farm tracts were identified as potentially losing greater than 80 tons of soil each year. These farm tracts are shown on Figure 2. The estimated soil loss for the highest ranked farm tract was 305 tons/tract/year. Three farm tracts were estimated to lose greater than 200 tons/year, and 14 were over 100 tons/year.

Figure 3 presents the potential capability of the land to transport sediment to a stream within the watershed. The Snell model ranked the potential sediment delivery capability of the land to transport sediment to a stream as high, medium or low. Because the watershed is highly dissected by streams and the high topographic relief, a large portion of the watershed was ranked as high soil delivery areas. The low soil delivery areas were usually located on the plateaus between the streams.

Figure 4 presents the high priority farm tracts. The high priority farm tracts have soil loss greater than 4 tons/acre/year and are located within the high soil delivery areas. Portions of one hundred and fourteen high soil loss farm tracts were located within high soil delivery areas. Table 3 lists the high priority farm tracts.

The total soil loss from the portion of the farm tract within the high delivery area was estimated based on the USLE soil loss estimates multiplied by the number of acres located within the high delivery area. The farm tracts were ranked according to the total soil loss from the high delivery areas. The estimates of total soil loss from the high delivery areas ranged from 0.08 to 166.65 tons/tract/year. Soil loss estimates from eight of these farm tracts were greater than 80 tons/year. Five of the farm tracts (Tracts 1519-9, 147-7, 9606-5, 16-2, and 16-1) have soil loss estimates from high delivery areas greater than 100 tons/years. Farm tracts 16-4 (98 tons/year), and 1377-7 (89 tons/year) ranked high in both Table 2 and Table 3. The estimates of total soil loss for the entire tract and from the portion of the tract within the high delivery areas are included in Table 3.

RECOMMENDATIONS

The objective of the study was to identify and rank critical areas in the watershed where field runoff from farm fields may be contributing the majority of P rich sediment to Lake Redstone. The model identified farm tracts with high estimates of soil loss, and then determined the areas with high potential for the soil runoff to be delivered to streams. The model then ranked these potential critical areas based on soil loss estimates.

The model identified 22 farm tracts with soil loss greater than 80 tons/year. The model estimated that fifteen of the farm tracts lose greater than 100 tons/year, and 8 lose between 130 and 305 tons/year (refer to Table 2). The model also identified eight farm tracts with total soil loss from high delivery areas greater than 80 tons/years (refer to Table 3). Five of the farm tracts were ranked high both in Table 2 and Table 3 (Tracts 1519-9, 147-2, 9606-5, 16-4, and 1377-7).

It is recommended to field verify or ground truth the top eight ranked farm tracts listed in Table 3, which have soil loss estimates from the high delivery areas in these farm tracts are greater than 80 tons/years. Ground truthing describes the process of visiting the site to inspect the site and collect information about the current land use practices. Because the results of the model are based in part on interpretation of aerial photos and crop rotation plans provided by the USDA, ground truthing is recommended to verify the accuracy of the interpretations of the aerial or the photos and the model.

During the site visit the farm tract and the land leading to the adjacent stream should be inspected for evidence of soil erosion. The current crop rotation plans for each of the tracts should be reviewed. The results of the ground truthing should then be used to determine the BMPs appropriate for the farm tract. The owner and/or tenant farmer should be informed about BMPs and encouraged to implement the ones appropriate for the farm tract. Best Management Practices include practices such as buffer strip, contour strip cropping, grassed waterways, diversions, and streambank stabilization.

REFERENCES

[1] Snell, E.A. 1984, A Manual for Regional Targeting of Agricultural Soil Erosion and Sediment Loading to Streams; Working Paper No. 36 , Land Directorate, Environmental Conservation Service, Environmental Canada, Ottawa, Ontario, Cat. No En 73-4/36E, ISBN 0-662-13192-4

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UW 1981a Lake Redstone: A Water Quality and Management Study - Water Resources Management Workshop. IES Report 115.

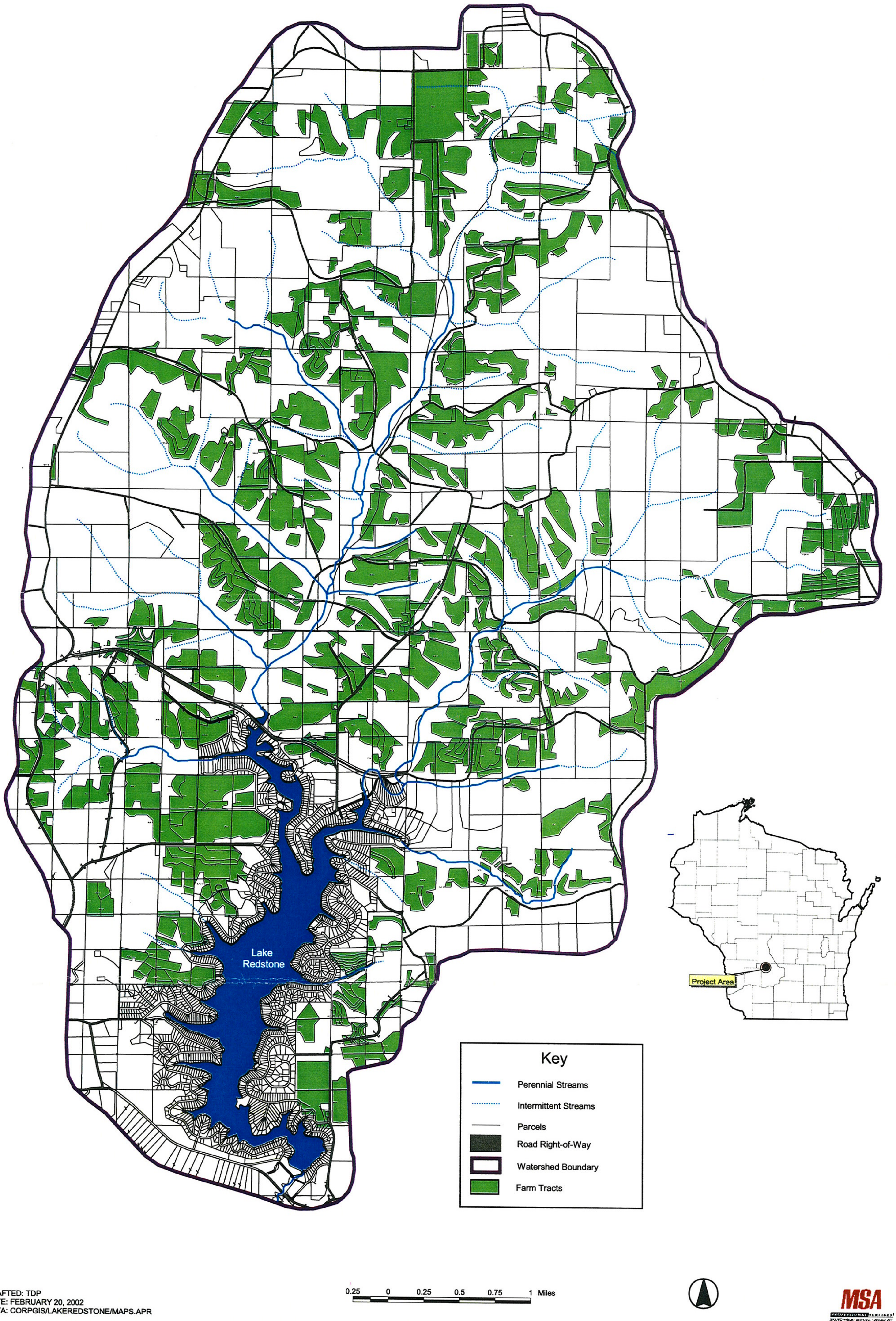
UW 1981b Lake Redstone: Water Quality and Management.

WDNR, 1997 Water Quality Model Study for Lake Redstone, Sauk County.

FIGURES

Figure 1

Lake Redstone Watershed
Farm Tracts Map



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Lake Redstone Watershed
High Soil Loss Farm Tracts Map

Figure 2

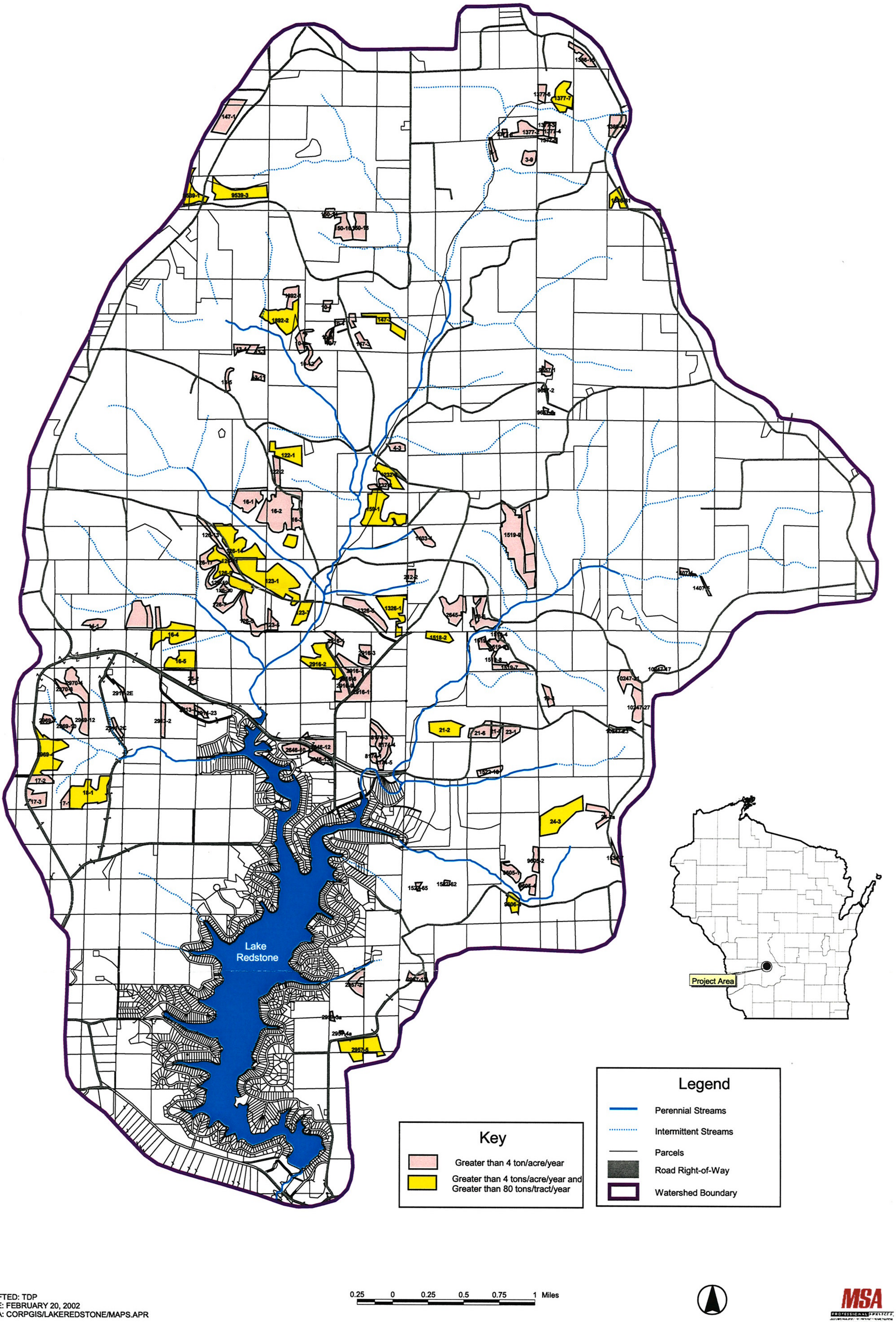

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Figure 3

Lake Redstone Watershed
Proposed Sediment Delivery Ranked Areas

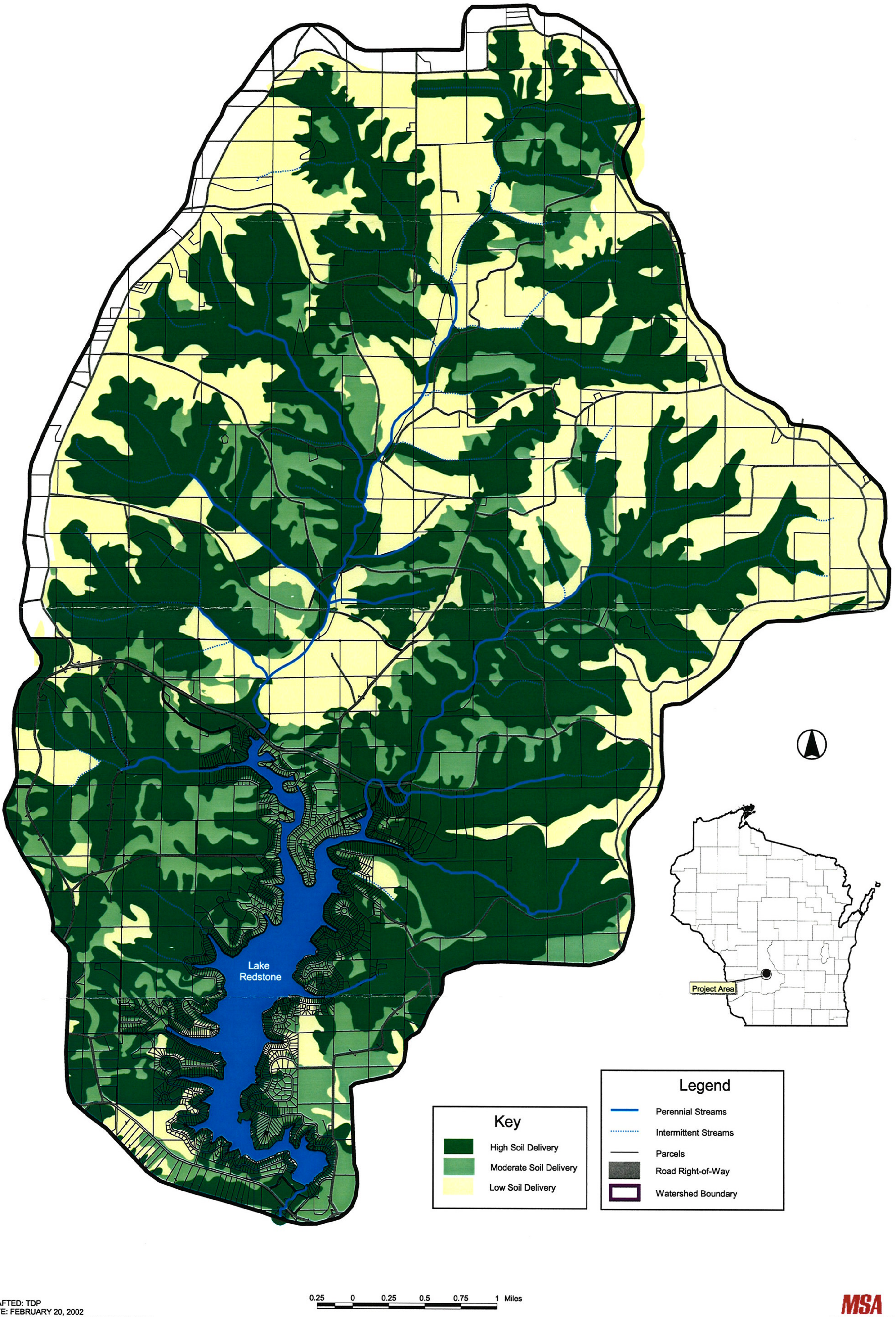

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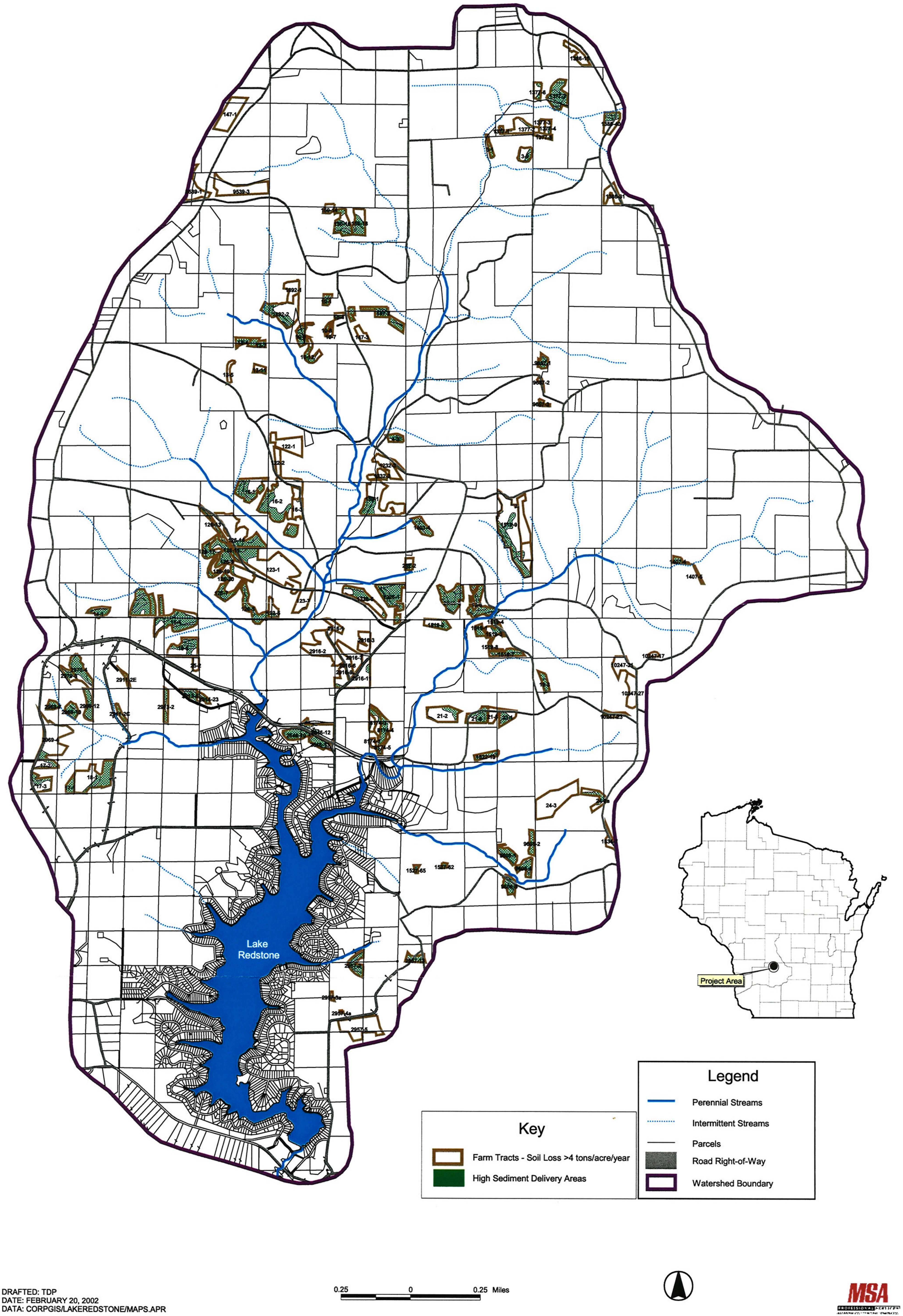
Figure 4

Lake Redstone Watershed
High Priority Farm Tracts



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TABLES

Table 1
High Soil Loss Farm Tracts
Lake Redstone Watershed

TRACT	ACRES	SOIL	ROTATION	R	K	LS	C	P	A	TOTAL
123-7	9.0	RzC2	Con't Corn	150	0.37	1.40	0.350	1	27.2	245
9606-5	6.4	NaC2	2C-O-3H	160	0.32	7.20	0.057	1	21.0	134
147-2	8.9	UfD2	2C-O-3H	150	0.37	2.29	0.120	1	15.3	136
147-1	3.5	LfD2	2C-O-3H	150	0.37	2.29	0.120	1	15.3	53
122-1	20.0	UfD2	2C-O-3H	150	0.37	2.29	0.120	1	15.3	305
8174-4	4.0	LfD	2C-O-3H	160	0.37	3.48	0.060	1	12.4	49
2957-2	7.0	NIC	4C-O-4H	160	0.32	1.95	0.100	1	10.0	70
23-1	7.0	NIE	C-O-3H	150	0.32	4.08	0.050	1	9.8	69
147-3	4.0	LfC2	2C-O-3H	150	0.37	1.40	0.120	1	9.3	37
122-2	4.1	LfC2	2C-O-3H	150	0.37	1.40	0.120	1	9.3	38
1519-3	4.9	LfD2	2C-g-gs-4H	160	0.37	2.80	0.080	0.7	9.3	45
1519-1	3.6	LfD2	2C-g-gs-4H	160	0.37	2.80	0.080	0.7	9.3	33
1519-9	27.0	NID2	2C-g-gs-4H	160	0.37	2.80	0.080	0.7	9.3	251
1519-4	1.0	LfD2	2C-g-gs-4H	160	0.37	2.80	0.080	0.7	9.3	9
1519-5	0.4	LfD2	2C-g-gs-4H	160	0.37	2.80	0.080	0.7	9.3	4
1232-3	9.7	UfD2	2C-O-4H	150	0.37	2.60	0.090	0.7	9.1	88
1232-1	1.4	UfD2	2C-O-4H	150	0.37	2.60	0.090	0.7	9.1	13
1386-31	9.3	Uf	C-O-4H	150	0.37	3.48	0.044	1	8.5	79
2916-6	5.6	LfD	C-O-3H	160	0.37	2.81	0.050	1	8.3	47
2916-1	4.6	LfD	C-O-3H	160	0.37	2.81	0.050	1	8.3	38
9605-1	7.2	LfD2	C-O-3H	160	0.37	2.80	0.050	1	8.3	60
9605-4	6.7	LfD2	C-O-3H	160	0.37	2.80	0.050	1	8.3	56
9605-2	4.2	LfD2	C-O-3H	160	0.37	2.80	0.050	1	8.3	35
1519-7	5.8	NID2	2C-g-gs-4H	160	0.32	2.80	0.080	0.7	8.0	47
1519-8	1.7	NID2	2C-g-gs-4H	160	0.32	2.80	0.080	0.7	8.0	14
3-9	5.4	UfE	C-O-3H	150	0.24	4.08	0.050	1	7.3	40
1527-65	1.1	NrE	C-O-3H	160	0.37	2.90	0.040	1	6.9	8
21-2	14.5	LfD2	C-O-3H	160	0.37	2.30	0.050	1	6.8	99
21-6	8.9	LfD2	C-O-3H	160	0.37	2.30	0.050	1	6.8	61
1527-62	1.1	LfD	2C-O-3H	160	0.37	2.30	0.050	1	6.8	7
1407-4	2.0	RzD2	C-O-5H	150	0.32	2.81	0.050	1	6.7	13
1407-5	2.0	RzD2	C-O-5H	150	0.32	2.81	0.050	1	6.7	13
16-5	14.8	LfD2	C-O-3H	150	0.37	2.30	0.050	1	6.4	94
10-9	6.5	LfD2	C-O-3H	150	0.37	2.30	0.050	1	6.4	41
14-1	5.2	LfD2	C-O-3H	150	0.37	2.30	0.050	1	6.4	33
16-4	4.4	LfD2	C-O-3H	150	0.37	2.30	0.050	1	6.4	28
150-14	4.0	LfD2	C-O-4H	150	0.37	2.30	0.050	1	6.4	26
4-3	3.8	LfD2	2C-O-4H	150	0.37	2.30	0.050	1	6.4	24
16-2	3.5	LfD2	C-O-3H	150	0.37	2.30	0.050	1	6.4	22
10-1	3.0	LfD2	C-O-3H	150	0.37	2.30	0.050	1	6.4	19
16-3	2.8	LfD2	C-O-3H	150	0.37	2.30	0.050	1	6.4	18
10-4	1.9	LfD2	C-O-3H	150	0.37	2.30	0.050	1	6.4	12
1377-7	13.2	LfC2	2C-O-4H	150	0.37	1.41	0.080	1	6.3	83
1377-2	9.3	LfC2	2C-O-4H	150	0.37	1.41	0.080	1	6.3	58
1377-5	3.4	LfC2	2C-O-4H	150	0.37	1.41	0.080	1	6.3	21

Table 1
High Soil Loss Farm Tracts
Lake Redstone Watershed

TRACT	ACRES	SOIL	ROTATION	R	K	LS	C	P	A	TOTAL
1377-3	2.8	LfC2	2C-O-4H	150	0.37	1.41	0.080	1	6.3	18
1377-4	2.3	LfC2	2C-O-4H	150	0.37	1.41	0.080	1	6.3	14
1377-6	1.7	LfC2	2C-O-4H	150	0.37	1.41	0.080	1	6.3	11
1377-1	0.8	LfC2	2C-O-4H	150	0.37	1.41	0.080	1	6.3	5
1386-40	7.1	Lf	2C-O-4H	150	0.37	1.41	0.079	1	6.2	44
126-11	3.6	UfE	Hay	150	0.37	3.50	0.030	1	5.8	21
126-13	2.4	UfE	Hay	150	0.37	3.50	0.030	1	5.8	14
17-3	9.8	LfD2	C-O-4H	160	0.37	2.30	0.040	1	5.4	53
17-4	6.3	LfD2	C-O-4H	160	0.37	2.30	0.040	1	5.4	34
17-2	6.1	LfD2	C-O-4H	160	0.37	2.30	0.040	1	5.4	33
2913-5	3.9	Lf	C-O-3H	160	0.37	2.30	0.040	1	5.4	21
17-1	3.8	LfD2	C-O-4H	160	0.37	2.30	0.040	1	5.4	21
8174-1	2.0	LfC	Wheat	160	0.37	1.41	0.130	0.5	5.4	11
8174-2	2.0	LfC	Wheat	160	0.37	1.41	0.130	0.5	5.4	11
8174-3	2.0	LfC	Wheat	160	0.37	1.41	0.130	0.5	5.4	11
8174-5	2.0	LfC	Wheat	160	0.37	1.41	0.130	0.5	5.4	11
2916-2	21.5	LfD	C-O-3H	160	0.37	2.81	0.090	0.35	5.2	113
2916-11	12.4	LfD	2C-O-3H	160	0.37	2.81	0.090	0.35	5.2	65
2916-7	10.4	LfD	2C-O-3H	160	0.37	2.81	0.090	0.35	5.2	54
2916-9	7.1	LfD	2C-O-3H	160	0.37	2.81	0.090	0.35	5.2	37
2916-3	6.8	LfD	2C-O-3H	160	0.37	2.81	0.090	0.35	5.2	36
123-1	41.0	LfD2	C-O-4H	150	0.37	2.29	0.040	1	5.1	209
123-5	5.0	LfD2	C-O-4H	150	0.37	2.29	0.040	1	5.1	25
10-7	2.0	UfE	C-O-3H	150	0.24	3.53	0.050	0.8	5.1	10
10-8	1.5	UfE	C-O-3H	150	0.24	3.53	0.050	0.8	5.1	8
9539-3	22.2	WdC	C-B (no-till)	150	0.24	1.41	0.100	1	5.1	113
9539-1	17.0	WdC	C-B (no-till)	150	0.24	1.41	0.100	1	5.1	86
126-9	15.6	RzB/C	3C-O-3H	150	0.37	1.40	0.130	0.5	5.1	79
1518-2	21.0	Lf	2C-O-3H	160	0.40	1.32	1.320	0.045	5.0	105
9657-1	5.9	Lf	C-O-4H	150	0.37	2.21	0.040	1	4.9	29
9657-3	4.9	Lf	C-O-4H	150	0.37	2.21	0.040	1	4.9	24
9657-2	2.8	Lf	C-O-4H	150	0.37	2.21	0.040	1	4.9	14
1232-2	2.7	LfC2	2C-O-4H	150	0.37	1.40	0.090	0.7	4.9	13
19-3	3.9	NlD2	C-O-4H	160	0.32	2.30	0.040	1	4.7	18
1534-7	2.0	WwB	3C-O-3H	160	0.37	0.53	0.150	1	4.7	9
212-3	36.0	Lf	Pasture	150	0.37	4.21	0.020	1	4.7	168
212-2	3.0	Lf	Pasture	150	0.37	4.21	0.020	1	4.7	14
10247-27	10.0	VaB	4C-O-3H	160	0.32	0.53	0.170	1	4.6	46
159-1	32.9	UfD2	3C-O-3H	150	0.24	2.80	0.130	0.35	4.6	151
1892-2	22.0	LaF	C-O-4H	150	0.37	2.21	0.037	1	4.5	100
2969-10	8.0	NlE	C-gs-3H	160	0.32	5.00	0.050	0.35	4.5	36
150-16	7.0	LfD2	C-O-4H	150	0.37	2.30	0.035	1	4.5	31
150-18	6.0	LfD2	C-O-4H	150	0.37	2.30	0.035	1	4.5	27
126-14	26.5	LfD2	2C-O-3H	150	0.37	2.30	0.100	0.35	4.5	118
16-4	21.9	LfD2	C-O-3H	150	0.37	2.30	0.050	0.7	4.5	98

Table 1
High Soil Loss Farm Tracts
Lake Redstone Watershed

TRACT	ACRES	SOIL	ROTATION	R	K	LS	C	P	A	TOTAL
16-1	14.0	LfD2	C-O-3H	150	0.37	2.30	0.050	0.7	4.5	63
126-5	11.0	LfD2	2C-O-3H	150	0.37	2.30	0.100	0.35	4.5	49
126-17	7.1	LfD2	2C-O-3H	150	0.37	2.30	0.100	0.35	4.5	32
126-7	6.7	LfD2	2C-O-3H	150	0.37	2.30	0.100	0.35	4.5	30
10-12	6.4	LfD2	C-O-3H	150	0.37	2.30	0.050	0.7	4.5	29
126-12	4.3	LfD2	2C-O-3H	150	0.37	2.30	0.100	0.35	4.5	19
126-19	3.2	LfD2	2C-O-3H	150	0.37	2.30	0.100	0.35	4.5	14
126-20	1.3	LfD2	2C-O-3H	150	0.37	2.30	0.100	0.35	4.5	6
2957-3a	1.8	NIC	C	160	0.32	0.58	0.300	0.5	4.5	8
2646-12	15.0	Lf	R-Wh-O-3H	160	0.37	3.17	0.059	0.4	4.4	66
2646-10	9.0	Lf	R-Wh-O-3H	160	0.37	3.17	0.059	0.4	4.4	40
2646-13	5.0	Lf	R-Wh-O-3H	160	0.37	3.17	0.059	0.4	4.4	22
10247-21	12.0	VaC2	2C-O-3H	160	0.32	1.44	0.060	1	4.4	53
25-2	2.8	LfC2	3C-O-3H	160	0.37	0.82	0.090	1	4.4	12
1403-4	3.0	Urne	2C-O-4H	150	0.37	2.60	0.100	0.3	4.3	13
1326-1	18.4	LfD2	2C-O-3H	150	0.37	2.60	0.030	1	4.3	80
1326-5	14.5	UfD2	2C-O-3H	150	0.37	2.60	0.030	1	4.3	63
2969-7	2.0	NIE	C-gs-2H	160	0.32	3.40	0.070	0.35	4.3	9
2911-2C	1.7	LfD2	H	160	0.37	7.20	0.010	1	4.3	7
2911-2E	1.6	LfD2	H	160	0.37	7.20	0.010	1	4.3	7
1522-13	2.0	LfD2	C-O-4H	160	0.37	2.30	0.044	0.7	4.2	8
24-3	27.3	VaC2	C-O-3H	160	0.37	1.41	0.050	1	4.2	114
18-1	26.4	LfC2	C-O-3H	160	0.37	1.41	0.050	1	4.2	110
2962-1	10.7	LfC2	C-O-3H	160	0.37	1.41	0.050	1	4.2	45
24-2a	7.5	WwC2	C-O-3H	160	0.37	1.41	0.050	1	4.2	31
21-5	4.5	LfC2	C-O-3H	160	0.37	1.41	0.050	1	4.2	19
2913-2	6.0	Lf	C-O-6H	160	0.37	1.90	0.037	1	4.2	25
2914-23	1.0	Lf	C-O-3H	160	0.37	1.80	0.065	0.6	4.2	4
2914-25	0.5	Lf	C-O-3H	160	0.37	1.80	0.065	0.6	4.2	2
2645-4	15.0	Lf	R-wh-O-3H	150	0.37	3.17	0.059	0.4	4.2	62
1892-1	8.2	LaF	2C-O-4H	150	0.37	1.41	0.053	1	4.1	34
2957-4a	0.9	LfD	C-O-3H	160	0.37	3.50	0.050	0.4	4.1	4
2970-3	6.1	LfD2	C-gs-H3	160	0.37	2.80	0.050	0.5	4.1	25
2957-13	4.6	LfD2	C-O-4H	160	0.37	2.50	0.040	0.7	4.1	19
13-4	3.3	UfD2	C-O-3H	150	0.24	2.30	0.050	1	4.1	14
13-5	2.8	UfD2	C-O-3H	150	0.24	2.30	0.050	1	4.1	12
13-11	2.4	UfD2	C-O-3H	150	0.24	2.30	0.050	1	4.1	10
3-1	2.4	UfD2	C-O-3H	150	0.24	2.30	0.050	1	4.1	10
13-6	15.8	UfD2	C-O-3H	150	0.24	2.30	0.050	1	4.1	65
13-7	1.8	UfD2	C-O-3H	150	0.24	2.30	0.050	1	4.1	7
13-12	0.4	UfD2	C-O-3H	150	0.24	2.30	0.050	1	4.1	2
1386-15	6.2	LfC2	C-O-3H	150	0.37	1.41	0.052	1	4.1	25
10247-11	6.3	VaB	3C-O-3H	160	0.32	0.53	0.150	1	4.1	26
10247-17	3.0	VaB	3C-O-3H	160	0.32	0.53	0.150	1	4.1	12
10247-23	3.0	VaB	3C-O-3H	160	0.32	0.53	0.150	1	4.1	12

Table 1
High Soil Loss Farm Tracts
Lake Redstone Watershed

TRACT	ACRES	SOIL	ROTATION	R	K	LS	C	P	A	TOTAL
2969-4	27.0	LfD2	C-gs-2H	160	0.37	2.80	0.070	0.35	4.1	110
2957-5	20.0	LfD2	2C-O-3H	160	0.37	2.80	0.070	0.35	4.1	81
2970-4	11.4	LfD2	C-gs-H2	160	0.37	2.80	0.070	0.35	4.1	46
2969-12	6.0	LfD2	C-gs-2H	160	0.37	2.80	0.070	0.35	4.1	24
2911-2B	3.4	NIE	C-O-3H	160	0.32	4.20	0.053	0.35	4.0	14
1522-6	3.5	LfC2	2C-O-4H	160	0.37	1.20	0.056	1	4.0	14
2957-3i	3.0	NIE	0-5H	160	0.32	4.30	0.020	0.9	4.0	12
2957-3e	2.8	NIE	0-5H	160	0.32	4.30	0.020	0.9	4.0	11
2957-3f	1.7	NIE	0-5H	160	0.32	4.30	0.020	0.9	4.0	7
212-5	15.0	Lf	R-wh-O-3H	150	0.37	1.21	0.059	1	4.0	59
212-1	10.0	Lf	R-wh-O-3H	150	0.37	1.21	0.059	1	4.0	40

Notes: R = Rainfall
K = Soil Erodibility Factor
LS = Slope Factor, based on slope length and slope gradient
C - Soil cover, crop or land use factor
P = erosion control practice factor
A = the average soil loss due to sheet and rill erosion in tons/acre/years
A= R x K x LS x C x P (USLE)
Total = the total average soil loss per tract in tons/tract/years

Table 2
Farm Tracts With Soil Loss >80 Tons/Tract/Year
Lake Redstone Watershed

TRACT	ACRES	SOIL	ROTATION	R	K	LS	C	P	A	TOTAL
122-1	20.0	UfD2	2C-O-3H	150	0.37	2.29	0.120	1	15.3	305
1519-9	27.0	NlD2	2C-g-gs-4H	160	0.37	2.80	0.080	0.7	9.3	251
123-7	9.0	RzC2	Con't Corn	150	0.37	1.40	0.350	1	27.2	245
123-1	41.0	LfD2	C-O-4H	150	0.37	2.29	0.040	1	5.1	209
212-3	36.0	Lf	Pasture	150	0.37	4.21	0.020	1	4.7	168
159-1	32.9	UfD2	3C-O-3H	150	0.24	2.80	0.130	0.35	4.6	151
147-2	8.9	UfD2	2C-O-3H	150	0.37	2.29	0.120	1	15.3	136
9606-5	6.4	NaC2	2C-O-3H	160	0.32	7.20	0.057	1	21.0	134
126-14	26.5	LfD2	2C-O-3H	150	0.37	2.30	0.100	0.35	4.5	118
24-3	27.3	VaC2	C-O-3H	160	0.37	1.41	0.050	1	4.2	114
9539-3	22.2	WdC	C-B (no-till)	150	0.24	1.41	0.100	1	5.1	113
2916-2	21.5	LfD	C-O-3H	160	0.37	2.81	0.090	0.35	5.2	113
18-1	26.4	LfC2	C-O-3H	160	0.37	1.41	0.050	1	4.2	110
2969-4	27.0	LfD2	C-gs-2H	160	0.37	2.80	0.070	0.35	4.1	110
1518-2	21.0	Lf	2C-O-3H	160	0.40	1.32	1.320	0.045	5.0	105
1892-2	22.0	LaF	C-O-4H	150	0.37	2.21	0.037	1	4.5	100
21-2	14.5	LfD2	C-O-3H	160	0.37	2.30	0.050	1	6.8	99
16-4	21.9	LfD2	C-O-3H	150	0.37	2.30	0.050	0.7	4.5	98
16-5	14.8	LfD2	C-O-3H	150	0.37	2.30	0.050	1	6.4	94
1232-3	9.7	UfD2	2C-O-4H	150	0.37	2.60	0.090	0.7	9.1	88
9539-1	17.0	WdC	C-B (no-till)	150	0.24	1.41	0.100	1	5.1	86
1377-7	13.2	LfC2	2C-O-4H	150	0.37	1.41	0.080	1	6.3	83
2957-5	20.0	LfD2	2C-O-3H	160	0.37	2.80	0.070	0.35	4.1	81

Notes:
R = Rainfall
K = Soil Erodibility Factor
LS = Slope Factor, based on slope length and slope gradient
C - Soil cover, crop or land use factor
P = erosion control practice factor
A = the average soil loss due to sheet and rill erosion in tons/acre/years
A= R x K x LS x C x P (USLE)
Total = the total average soil loss per tract in tons/tract/years

Table 3
SEDIMENT DELIVERY MODEL RESULTS
LAKE REDSTONE WATERSHED

		USLE		GIS Sediment Delivery Model	
Tract Number	Acres (NRCS)	Soil Loss (tons/ac/yr)	Total Soil Loss (tons/tract/year)	Acres of High Delivery Areas	Total Soil Loss (Tons/tract/yr) From High Delivery Areas
1519-9	27*	9.3	251	17.92	166.65
147-2	8.9	15.3	136.2	9.98	152.7
9606-5	6.4	21.0	134.5	6.02	126.42
16-2	35	6.4	224.0	19.15	122.55
16-1	14	4.5	62.5	24.25	109.13
16-4	21.9	4.5	97.8	21.87	98.43
1377-7	13.2	6.3	82.6	14.09	88.79
8174-4	4	12.4	49.4	6.6	81.84
2957-2	7	10.0	69.9	8	80
1326-1	18.4	4.3	79.7	18.17	78.13
13-6	15.8*	4.1	64.82	15.82	64.82
2645-4	15	4.2	62.3	15.23	63.97
126-9	15.6	5.1	78.8	11.11	56.65
9605-1	7.2	8.3	59.7	6.69	55.53
16-5	14.8	6.4	94.5	8.63	55.24
18-1	26.4	4.2	110.2	13.01	54.64
9605-4	6.7	8.3	55.5	6.18	51.29
1519-7	5.8	8.0	46.6	5.85	46.8
126-5	11	4.5	49.1	10.33	46.48
1892-2	22	4.5	99.8	9.93	44.69
123-1	41	5.1	208.8	8.56	43.65
2970-4	11.4	4.1	46.3	10.26	42.06
21-6	8.9	6.8	60.6	6.08	41.35
126-14	26.5	4.5	118.4	9.02	40.6
10-9	6.5	6.4	41.5	6.23	39.88
23-1	7	9.8	68.5	4.05	39.69
150-16	7	4.5	31.3	8.61	38.75
147-1	3.5	15.3	53.5	2.41	36.88
9605-2	4.2	8.3	34.8	4.29	35.61
14-1	5.2	6.4	33.2	5.12	32.77
159-1	32.9	4.6	150.9	7.11	32.7
2646-10	9	4.4	39.9	7.05	31.02
150-18	6	4.5	26.8	6.87	30.92
1519-1	3.6	9.3	33.4	3.29	30.61
21-2	14.5	6.8	98.7	4.36	29.65
1326-5	14.5	4.3	62.8	6.81	29.28
1519-3	4.9	9.3	45.5	3.11	28.93
4-3	3.8	6.4	24.3	4.48	28.67
1403-4	3	4.3	13.0	6.53	28.07
126-17	7.1	4.5	31.7	6.13	27.59
2969-12	6	4.1	24.4	6.7	27.47
126-7	6.7	4.5	29.9	5.68	25.56
1386-40	7.1	6.2	44.0	3.97	24.61
17-3	9.8	5.4	53.4	4.41	23.81
2969-10	8	4.5	35.8	4.95	22.27
2913-5	3.9	5.4	21.2	4.1	22.14
16-3	2.8	6.4	17.9	3.45	22.07
3-9	5.4	7.3	39.7	2.97	21.69
126-11	3.6	5.8	21.0	3.58	20.77
17-1	3.8	5.4	20.7	3.72	20.09
2646-13	5	4.4	22.1	4.45	19.58
19-3	3.9	4.7	18.4	3.79	17.81
9657-1	5.9	4.9	28.9	3.62	17.74
1522-13	2	4.2	8.4	4.12	17.31
1518-2	21	5.0	105.4	3.35	16.75
10-12	6.4	4.5	28.6	3.72	16.73
17-2	6.1	5.4	33.2	3.01	16.26
10-1	3	6.4	19.1	2.54	16.25
2957-13	4.6	4.1	19.1	3.94	16.15
2646-12	15	4.4	66.4	3.58	15.75

Table 3
SEDIMENT DELIVERY MODEL RESULTS
LAKE REDSTONE WATERSHED

		USLE		GIS Sediment Delivery Model	
Tract Number	Acres (NRCS)	Soil Loss (tons/ac/yr)	Total Soil Loss (tons/tract/year)	Acres of High Delivery Areas	Total Soil Loss (Tons/tract/yr) From High Delivery Areas
1519-8	1.7	8.0	13.6	1.93	15.44
2913-2	6	4.2	25.0	3.66	15.37
1407-4	2	6.7	13.5	2.26	15.15
24-2a	7.5	4.2	31.3	3.49	14.65
126-19	3.2	4.5	14.3	3.18	14.31
1519-4	1.0	9.3	9.3	1.48	13.77
13-4	3.3	4.1	13.7	3.33	13.64
2969-4	27	4.1	109.7	3.05	12.51
2969-7	2	4.3	8.5	2.82	12.12
2970-3	6.1	4.1	25.3	2.8	11.48
1377-6	1.7	6.3	10.6	1.78	11.22
126-13	2.4	5.8	14.0	1.91	11.08
8174-3	2	5.4	10.9	2	10.8
2911-2C	1.7	4.3	7.2	2.31	9.93
2914-23	1	4.2	4.2	2.33	9.79
3-1	2.4	4.1	9.9	2.38	9.76
1407-5	2.0	6.7	13.5	1.31	8.78
1377-2	9.3	6.3	58.2	1.33	8.38
212-2	3	4.7	14.0	1.73	8.13
126-20	1.3	4.5	5.8	1.76	7.92
1527-65	1.1	6.9	7.6	1.07	7.38
8174-5	2	5.4	10.9	1.35	7.29
13-7	1.8	4.1	7.5	1.74	7.13
2911-2E	1.6	4.3	6.8	1.63	7.01
1377-1	0.8	6.3	5.0	1.09	6.88
123-7	9	27.2	244.9	0.25	6.8
123-5	5	5.1	25.5	1.25	6.37
1527-62	1.1	6.8	7.5	0.91	6.19
10-4	1.9	6.4	12.1	0.96	6.14
2916-11	12.4	5.2	65.0	1.12	5.82
9657-2	2.8	4.9	13.7	1.17	5.73
10-8	1.5	5.1	7.6	1	5.09
150-14	4.0	6.4	25.5	0.79	5.06
1377-4	2.3	6.3	14.4	0.65	4.09
2916-9	7.1	5.2	37.2	0.75	3.9
122-1	20	15.3	305.0	0.24	3.67
1377-5	3.4	6.3	21.3	0.56	3.53
8174-1	2	5.4	10.9	0.62	3.34
9657-3	4.9	4.9	24.0	0.67	3.28
1519-5	0.4	9.3	3.7	0.32	2.98
13-11	2.4	4.1	9.9	0.64	2.62
1386-15	6.2	4.1	25.3	0.62	2.54
8174-2	2	5.4	10.9	0.46	2.48
24-3	27.3	4.2	113.9	0.52	2.19
10-7	2	5.1	10.2	0.3	1.53
2957-3a	1.8	4.5	8.0	0.24	1.08
21-5	4.5	4.2	18.8	0.22	0.92
1892-1	8.2	4.1	34.0	0.18	0.74
2957-5	20	4.1	81.2	0.08	0.33
10247-23	3	4.1	12.2	0.07	0.29
2914-25	0.5	4.2	2.1	0.07	0.29
147-3	4	9.3	37.3	0.02	0.19
1377-3	2.8	6.3	17.5	0.02	0.13
1534-7	2	4.7	9.4	0.02	0.09
13-12	0.4	4.1	1.7	0.02	0.08

Notes: Acres from NRCS database do not always agree with acres for derived from GIS.
* indicates that NRCS acres data adjusted to agree with GIS data.

Appendix A

Data Sources and Data Preparation For Snell Model

Data Sources and Data Preparation For The Lake Redstone Watershed Snell Model

Data Types/Sources

Watersheds – contains sub-basins for each perennial stream segment. The data was produced from heads-up digitizing using a USGS DRG's and County orthophotos.

Steep Slopes – contains greater than 15% slopes. The data was derived from the Sauk County digital Soil Survey, and the heads-up digitizing of the Juneau County Soil Survey using the scanned soil survey and orthophotos as references. The soil survey database was queried for slope greater than 15% for each soils mapping unit.

Buffered Land Systems – contains thick (wide) forested land use areas. The data was produced from heads-up digitizing of the forested areas adjacent to streams using the USGS DRG's and the orthophotos as references.

High Infiltration Soils – contains soil-mapping units with high infiltration classifications according the soils database. The data was derived from the Sauk County digital Soil Survey, and the heads-up digitizing of the Juneau County Soil Survey using the scanned soil survey and orthophotos as references.

Buffered Streams – contains buffered perennial streams of 100 meters. The streams were produced from heads-up digitizing of the streams using the USGS DRG's and the orthophotos as references.

Moderate Infiltration Soils – contains soil-mapping units with moderate infiltration classifications according the soils database. The data was derived from the Sauk County digital Soil Survey, and the heads-up digitizing of the Juneau County Soil Survey using the scanned soil survey and orthophotos as references

Narrow Buffered Land Systems – contains narrow forested land use areas located between steep sloped areas and perennial streams. The data was produced from heads-up digitizing of the narrow forested areas adjacent to streams using the USGS DRG's and the orthophotos as references.

Poorly Drained Soils – contains soil-mapping units with poorly drained classifications according the soils database. The data was derived from the Sauk County digital Soil Survey, and the heads-up digitizing of the Juneau County Soil Survey using the scanned soil survey and orthophotos as references.

Farm Tracts – contains field boundaries for individual landowner's fields. The data was produced digitizing the boundaries using aerial photos as a reference.

Parcels – contains ownership areas. The data was produced in the first phase of the project from the scanning and digitizing of Rockford parcel maps.

Lakes –the data was produced using aerial photos as a reference.

Aerial Photo – contains the aerial photo image. The data was derived from the Orthophoto from both Juneau and Sauk County.

Data Preparation

Assimilation – data was organized into the Wisconsin Transverse Mercator Coordinate System from the following data sources:

Microstation data – existing farm tracts, parcels

Acquisition of new data – soils, orthophotos

Creation of new data – streams, buffered land systems, watersheds

Appendix B

Snell Model Processes

Snell Model Methodology for Ranking

I. Data Analysis (Primary) – contains the methodology *classification* for Mapping Terrain Capability to Transport Sediment to a Stream. An attribute called**Class** was created in the database to hold the value indicating if it was a high or low area. An additional field representing the reason for a high or low ranking was also added to each dataset for future referencing.

Mapping Terrain Capability to Transport Sediment to a Stream

Sub-basins – there were not any closed depressions created.

-low delivery classifications were **not applied** to the Class field.

Steep Slopes – were created as a new dataset by selecting all soil mapping units with a slope greater than 12%.

-All of these records were given a **high classification.**

Wide Buffered Land Systems – were created as a new dataset by selecting all digitized wide forest buffered areas.

-All of these records that were still blank (not ranked in Step 1 or Step 2) were given a **low classification.**

High Infiltration Soils – were created as a new dataset by selecting all soil mapping units that were identified in the soils database as high infiltration.

-All of these records were given a **low classification.**

Buffered Streams – were created as a new dataset by buffering perennial streams by 100 meters.

-All of these records that were still blank (not ranked in Steps 1-4) were given a **high classification.**

Moderate Infiltration Soils – were created as a new dataset by selecting all soil mapping units that were identified in the soil database as moderate infiltration.

-All of these records were given a **low ranking.**

Narrow Buffered Land Systems – were created as a new dataset by selecting all digitized narrow forest buffered areas between steep slopes and streams.

-All of these records were given a **high ranking.**

Poorly Drained Soils – were created as a new dataset by selecting all soil mapping units that were identified in the soils database as poorly drained soils and connected to a stream or within 250 meters.

-All of these records were given a **high ranking.**

High Ranking Separation – these areas were identified, evaluated and determined to **not be applied** into the ranking system.

II. Data Analysis (Secondary) – contains the methodology *legend ranking* for Mapping Terrain Capability to Transport Sediment to a Stream. An attribute called **Ranking** was created in the database to hold the value indicating its high or low ranking number.

Legend for Mapping and Ranking Terrain Capability to Transport Sediment to a Stream

Buffered Streams – land close to a stream with no factors lowering the ranking were given a **1High (H) ranking.**

Poorly Drained Soils – hydrologically active areas with no factors lowering the ranking were given a **2H ranking**.

Steep Slopes – steep slopes located less than 100 meters uphill of a stream and still blank (not ranked in previous steps) were given a **3H ranking**.

Narrow Vegetated Areas – relatively flat vegetated areas, which are too narrow (less than 100 meters) between a steep slope and a stream and still blank (not ranked in previous steps), were given a **4H ranking**.

Narrow Forest Buffers – a strip of land between a steep slope and a previous high ranking area which is too narrow (less than 100 meters) were given a **5H ranking**.

High Infiltration/Coarse Soils – relatively flat, high infiltration, coarse soil area which is too narrow (less than 100 meters) between a steep slope and watercourse were given a **6H ranking**.

Roadside Drainage – land located within 66 feet of the road centerline and still blank (not ranked in previous steps) were given a **7Medium (M) ranking**.

Low Infiltration Soils – land with low infiltration and fine textured soils located greater than .5 kilometers from a watercourse and still blank (not ranked in previous steps) were given a **8M ranking**.

Steep Slopes – steep slopes located greater than 100 meters from a previous high ranked step were given a **9M ranking**.

Steep Slopes – steep slopes that drain overland into a wide flat vegetated buffer zone were given a **10 Low (L) ranking**.

Vegetated Area – vegetated areas that have moderate infiltration and medium textured soils located greater than .5 kilometers from a watercourse were given a **11L ranking**.

Steep Slopes – vegetated areas that have moderate infiltration and medium textured soils located greater than .5 kilometers from a watercourse were given a **12L ranking**.