Ruscom River, Big Creek, and Hillman Creek Water Quality Study: Verification of the Lands Directorate Sediment Yield Model

(September 1987 - May 1988)

Essex Region Conservation Authority

July, 1988

Preface

This report is the result of a nine month study carried out by the Essex Region Conservation Authority, in cooperation with Ministry of the Environment.

The purpose of this study was to continue the efforts initiated in a previous study, to verify the sediment yield model developed by Environment Canada (Lands Directorate) in the flat clay plains of Essex County and to provide additional baseline data for future studies.

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INTRODUCTION

Essex County is representative of flat glacial plains, in which are found intensive row crops and extensive artificial drainage and numerous soil types, especially clays. During periods of heavy rainfall, the heavy clay soils become saturated, leading to overland runoff and soil erosion. Soil erosion in rural areas is one of the major contributors to non-point source sediment pollution in the Great Lakes Basin. Therefore, it is vital that the worst eroding areas are identified and remedial measures applied as quickly as possible.

To help identify high erosion areas, Environment Canada (Lands Directorate) developed the soil loss model. The model uses soil loss equations and delivery ratios to locate regions of high, medium, and low sediment loadings. Known as priority management areas, these regions can then be targeted for remedial measures. Since the Lands Directorate Model was developed in rolling hills, it was not verified in the flat, artificially drained areas in the Southwestern Ontario Regions. Thus, a need clearly existed to verify this model for these conditions. This study was part of a continued effort to calibrate the Lands Directorate Model in the *Essex* and other clay plains common to Southwestern Ontario. A similar study was initiated by Environment Canada in February 1985 and ended in September, 1986. This study began in September 1987, and finished in June 1988.

Changes From The Previous Report

Although minor changes were implemented, this program was identical in goals and procedures to the previous studies (refer to Allsop 1987). The sample sites remained the same except for two, which will be noted later in this report. All data, reports, and results from the earlier study were available for use in this study. Furthermore, staff involved in the earlier study were consulted for methodology and data analysis procedures. Other changes included a more elaborate soil mapping analysis. Subwatershed boundaries and areas were also recalculated using new drainage maps.

Study Objectives

This study like the previous study, was designed to address the following objectives:

1) to examine sediment and phosphorus flux within the Ruscom River, Hillman Creek and Big Creek watersheds,
2) to correlate phosphorus flux with sediment delivery,
3) to determine possible relationships between land use and sediment/phosphorus delivery to streams, and
4) to verify and calibrate the Lands Directorate soil loss model for the identification of priority non-point source erosion areas in Essex County.

This report provides the results of this study and compares them with those of the previous study, in order to accomplish the above objectives.

WATERSHED DESCRIPTION

Climate

Essex County , located in Southwestern Ontario, is generally the warmest area in the province. The average temperatures are 7.56°C in the spring and 20.98°C in the summer. The autumn and winter averages are 11.08°C and - 3.5°C. The warmest month in the year is July (22.12°C) while the coldest is January (-4.88°C). The various locales in Essex County usually do not vary more than 1.5°C from the normal.

The precipitation for the Essex County area is illustrated in Table 1 under the monthly normal column. These values are normals for the Windsor airport weather station. The Essex County region normally receives the largest average monthly precipitation in June (85.9 mm), and the lowest in February (52.9 mm). The normal monthly precipitation for the various locales in Essex County usually do not vary more than 15 mm from the normals calculated for the Windsor station, with the exception of this year.

Table 1 shows a comparison between the actual amount of precipitation acquired for this study period and the normals. First, monthly precipitation for September, November, December, and February was higher than normal levels. The rest of the months within the study period had lower than normal precipitation. The spring months experienced drought conditions since less than half the normal amount of rainfall fell in this period. March 1988 received 31.6 mm as opposed to the normal 73.4 mm, April 1988 received 54.1 mm instead of the normal 80.7, and May received 30.0 mm instead of 81.2 mm.

Table 1. Monthly Precipitation Sums - Windsor Airport Weather Station.

Month:	Actual Measured (mm)	Monthly Normal (mm)
September 1987	112.2	70.0
October 1987	56.3	61.8
November 1987	91.8	68.9
December 1987	122.0	69.9
January 1988	31.9	53.9
February 1988	58.2	52.9
March 1988	31.6	73.4
April 1988	54.1	80.7
May 1988	30.0	81.2
June		85.9
July		82.7
August		83.2

Study Area

The study area included the following sampling stations:

Station # 1 - Ruscom River at Highway 401, Rochester Township

Station # 2 - Ruscom River at Concession Road 5 (Lot 28, Concession 5), Rochester Township

Station # 3 - Ruscom River at County Road 8 (Lot 30, Concession 4), Rochester Township

Station # 4 - Ruscom River at County Road 14 (Lot 19, Concession 8), Gosfield North Township

Station # 5 - Ruscom River at Concession Road 8 (Lot 24, Concession 7), Gosfield North Township

Station # 6 - Replaced with Ruscom #13

Station # 7 - Hillman Creek at 12-13 Sideroad (Lot 237, Concession N.T.R.), Mersea Township

Station # 8 - Big Creek at Concession Road 10 (Lot 12, Concession 10), Tilbury West Township

Station # 9 - Big Creek at Concession Road li (Lot 17, Concession 10), Mersea Township

Station #10 - Big Creek at Concession Road 11 (Lot 14, Concession 10), Mersea Township

Station #11 - Drain (emptying into Ruscom River) at Concession Road 9 (Lot 23, Concession 9), Gosfield North Township

Station #12 - Ruscom River at County Road 14 (Lot 4, Concession 8), Mersea Township

Station #13 - Ruscom River at Concession Road 6 (lot 2, Concession 7)

Station #14 - Hillman Creek at Jones Sideroad Mersea

Map 1 illustrates the location of each sampling station. Ruscom station #6 was replaced with Ruscom Station #13. Hillman station #14 was added to improve the sampling in Hillman Creek. For further information on each of the watersheds refer to the various Appendixes.

Sub-watershed Areas

Since the previous study, a more detailed analysis was conducted to calculate the area of each sub-watershed. Updated artificial drainage maps were used to recheck the runoff flow patterns associated with each subwatershed. New areas were estimated in both km^2 and hectares. Table 2 compares the new subwatershed areas with the previous study's. Minor differences were noticed with some of the subwatershed areas and corrections were made (Ruscom 4, Hillman 7, Ruscom 12).

Sub-watershed Soil Types

In this study, soil mapping was redone for each of the sub-watersheds. Many distinctive soil types were identified in each of the three watersheds. For example, the Ruscom watershed has 16 different soils, with the major being Brookston clay (70%). The Big Creek watershed has three soil types with Brookston clay representing 97% of the area. Hillman watershed has seven 6 different soils with Berrien Sandy Loam being most dominant (70%). A formal breakdown of the soils in each watershed and subwatershed is given in Appendix B. The accompanying soil maps are included in Appendix D.


TILBURY NORTH
TILBURY EAST
ROCHESTER
TILBURY WEST
GOSFIELD NORTH
MERSEA
GOSFIELD SOUTH
ROMNEY
1
2
3
4
5
6
7
8
9
10
11
12
13
14
N
COUNTY OF
ESSEX
(EAST)

Table 2. Calculated Areas for Subwatersheds

Subwatershed Areas	Previous Study	Present Study	
	(ha)	(km^2)	(ha)
Ruscom 1	12300	120.52	12052
Ruscom 2	3740	39.5226	3952.26
Ruscom 3	610	5.6458	564.58
Ruscom 4	1782.5	6.5281	652.81
Ruscom 5	615	5.6508	565.08
Ruscom 6	462.5	4.052	405.2
Hillman 7	1295	11.1768	1117.68
Big Creek 8	5297.5	53.08	5308
Big Creek 9	337.5	3.457	345.7
Big Creek 10	1695	14.06	1406
Ruscom 11	132.5	1.0278	102.78
Ruscom 12	490	7.5476	754.76
Ruscom 13	220	2.7932	279.32
Hillman 14	2036	20.806	2080.6

The majority of the soils in the three watersheds, inherently, have very poor to fair drainage characteristics. Table 3 shows the drainage characteristics for each subwatershed.

The Ruscom watershed has 79.1 % poor draining soils, 13.7 % fair to poor draining soils, and 1.7 % well drained soils. Big Creek watershed has 99.7 % poor draining soils, with the rest ranking as fair to poor draining soils. Hillman watershed deviates with 82.9 % fair to poor and 7.8 % well drained soils.

Topography and Drainage

As mentioned previously, the natural drainage in the three watersheds is poor, or fair to poor, with nearly level topography. Table 4 illustrates the average percent slope within each subwatershed. Slopes range from 0.059 for the Big Creek 10 subwatershed, to 0.361 for the Hillman 7 subwatershed. Artificial drainage produces a major impact on natural drainage since subsurface tiles and drains are used extensively. Essex County rivers are characterized by heavy runoff during the spring and precipitation events, and low to zero flows in the summer months.

Table 3. Percent Soil Drainage of the subwatersheds

Sub Watershed	very poor	poor	fair to poor	good	good to excessive	well drained	variable
Ruscom 1	0.23	79.13	13.71	2.56	1.35	1.762	0.93
Ruscom 2	0.37	52.91	33.763	8.62	1.55	2.79	----
Ruscom 3	----	67.74	27.82	----	----	----	----
Ruscom 4	0.4	32.8	34.4	32.4	----	----	----
Ruscom 5	2.97	41.95	40.25	----	4.24	2.97	----
Hillman 7	0.35	1.18	77.08	----	----	16.22	5.17
Big Creek 8	----	99.76	0.234	----	----	----	----
Big Creek 9	----	100	----	----	----	----	----
Big Creek 10	----	99.47	0.53	----	----	----	----
Ruscom 11	----	45.24	54.76	----	----	----	----
Ruscom 12	1.34	55.33	26.33	----	8.67	8.33	----
Ruscom 13	5.6	45.6	28.8	----	----	20.0	----
Hillman 14	0.001	5.02	82.98	----	----	7.87	3.99
Overall weighted average	0.142	76.833	17.44	1.587	0.837	1.935	2.415

Table 4. Average Percent Slope for Watersheds

Ruscom 1	0.1084
Ruscom 2	0.1739
Ruscom 3	0.1653
Ruscom 4	0.20
Ruscom 5	0.08921
Ruscom 6	0.1906
Hillman 7	0.3613
Big Creek 8	0.08386
Big Creek 9	0.10055
Big Creek 10	0.05912
Ruscom 11	0.13885
Ruscom 12	0.17722
Ruscom 13	0.2892
Hillman 14	0.2706

Land Use

Land use in the three watersheds was the same as in the previous study, with minor changes since two new sub-watersheds were added to this study. Three major types of agriculture were identified. The first type included continuous row crops which are defined as corn crops occasionally rotated with soybeans. The second was corn systems which included wheat rotated with corn and soybeans. The third type was extensive field crops which included vegetables and other high cash value crops. Within the Ruscom watershed, continuous row cropping dominated, accounting for 75.7% of all agricultural practices, corn systems was second with 14.3%. Big Creek watershed had 76.2% of its area in corn systems and 19.5% in continuous row crops. Hillman Creek watershed had more of a mixture with 39.9% in extensive field crops, 27.4% in continuous row crops and 21.5% in corn systems. Appendix A has a detailed breakdown of the land use in each subwatershed.

METHODOLOGY

This study was based on sediment and phosphorus loading into the streams of Essex County from non point sources. Parameters measured in this study included water velocity (m/sec) and concentrations of suspended sediment, total phosphorus and soluble reactive phosphorus (mg/L). These measurements were then combined to provide loading values per unit area (mg/sec/km^2) for each station.

Sub-watershed Selection and Ranking

Several factors affected the selection of the subwatersheds. The main criteria in selecting the sites was to represent the range of conditions found in the Lands Directorate Methodology. The twelve sub-watersheds represent a cross-section of low, medium, and high priority management areas. The sub-watersheds were arbitrarily ranked relative to one another as high, medium, or low sediment loaders according to the percentage of low, medium, and high priority management areas in each (Table 5). The average loading, and ranking determined for each sub-watershed through sampling could then be compared with the loadings and ranking predicted by the Lands Directorate methodology. (Allsop *et al.*, 1987). Furthermore, all sampling sites were chosen near a road for easy access to the water.

The Ruscom River, Big Creek, and Hillman Creek watersheds were selected based on the following criteria:

a) Two of the river systems (Hillman Creek, and Big Creek) were sites of an extensive environmental study (PLUARG), during which background data on watershed characteristics, water quality and flow were collected.

b) The topography, soils, cropping practices and drainage within the watersheds are representative of the low lying clay plains of Essex and Kent Counties. Hence, this allows extrapolation of the results from the Essex County watersheds to other watersheds.

Two sites were added to the present study: Ruscom 13 and Hillman 14. Site No. 13, located on the Ruscom River, was selected to replace Site No. 6.

Table 5. Arbitrary Subwatershed Ranking - Estimated Using Lands Directorate Priority Management Areas

Station	Low Priority Management Area (%)	Medium Priority Management Area (%)	High Priority Management Area (%)	Arbitrary Ranking
Ruscom 11	0.0	57.0	43.0	High
Ruscom 3	0.7	82.9	16.4	High
Ruscom 2	17.3	77.6	5.1	High
Ruscom 1	18.8	84.4	1.8	Medium
Hillman 14	19.9	78.3	1.8	Medium
Hillman 7	20.6	74.4	2.0	Medium
Ruscom 4	25.7	70.5	3.0	Medium
Ruscom 5	33.6	64.1	2.3	Medium
Big Creek 9	3.9	96.1	0.0	Medium
Big Creek 8	14.3	85.7	0.0	Medium
Ruscom 13	21.7	78.3	0.0	Medium
Big Creek 10	25.0	75.0	0.0	Medium
Ruscom 6	33.1	66.9	0.0	Low
Ruscom 12	47.0	53.0	0.0	Low

This site was eliminated because a drainage ditch was located at the sampling point and it was felt this might reduce the accuracy of discharge measurements. Hillman 14 was added since Site No. 7 was the only station representing the Hillman watershed. Therefore, it was decided that a second station in this watershed would increase data integrity. Appendix D contains watershed area maps with sampling sites.

Water Sampling

Water samples were gathered on a weekly basis and during spring melt and precipitation events. Precipitation events totalling less than 10 millimeters were usually not sampled except during spring melt and saturated soil conditions.

The order of sampling during weekly runs was based on the best driving route. However, during precipitation events it was important to collect samples during peak flow. The various sites attained peak flows at different times. This was further complicated by factors such as uneven precipitation events across the three watersheds. In general, the sites in a smaller watershed peaked first. So an attempt was made to visit these sites early in the sampling run. During peak flow, samples were taken using bridge sampling apparatus, since it was unsafe to wade.

Water samples were collected by directly placing a 500 millilitre bottle into the current by hand in low water levels. In medium and high water levels, a depth integrated sampler was used to collect the water sample. The unit was attached to a wading rod or cable system depending on the water level. The sampling method followed the recommended procedures as outlined in "Hydromatic Field Manual" (Terzi, 1981).

The water samples were sent to the Ministry of the Environment laboratory in London for analysis. Prior to shipment, 50 milliliters of each sample were filtered and transferred to another bottle. This second sample was then tested for soluble reactive phosphorus. The remaining 450 milliliters of water was tested for suspended sediment and total phosphorus. The results from each sample were noted in milligrams per litre. The method of analysis followed the procedures described in "Standard Method in the Examination of Water and Wastewater" (Environment Canada, 1983).

Measuring River Discharge and Developing Stage-Discharge Curves

The velocity of the water within the channel was measured with a current metre at even points across the channel. The number of points were based on 5% of channel width. Methods for measurement are described in detail by Terzi (1981). Velocities were measured using wading equipment during low levels and sounding equipment from bridges during high flows.

Channel information such as width, depth, and velocity was entered into a computer program which calculated river discharge in m^3/sec using the mid-section method. Staff gauge readings were also taken during each flow measurement. As a result, stage-discharge curves were developed for low flow conditions. High water conditions were negligible in this study, as such, the stage-discharge curves for high levels are not completed.

The measurement of stage (water level) was also automatically recorded at one station in each of the three watersheds using the Stevens level recorders. The recorders were housed in wooden and steel huts. Ruscom 1 station is monitored by

Environment Canada and has a well developed stage-discharge curve. Thus, flow measurements were not taken at this station.

Calculating Loadings

The final step in preparing for analysis was the calculation of sediment and phosphorus loadings. Each sampling day's discharge (m^3/sec) was multiplied with the corresponding concentrations of sediment, phosphorus, and soluble reactive phosphorus to provide the instantaneous loading for each parameter (mg/sec). The loadings were then divided by their respective sub-watershed areas to provide the unit area loadings (mg/sec/km^2). Expressing the loadings on a unit area basis allowed for comparison between the sub-watersheds. These values were then used for analysis and comparison with Lands Directorate methodology.

RESULTS

Concentrations

Tables 6 and 7 provide the average concentrations of total phosphorus and suspended sediment for the three watersheds. The difference in concentrations clearly shows that more sediment reached all streams in the previous study. As well, the previous study experienced approximately 1.5 times greater phosphorus 12 concentrations. For example, Hillman Creek's concentrations of sediment were more than double in the former study compared to the present.

Table 6. Average Total Phosphorus Concentrations for each Watershed (mg/L)

	Previous Study (May 1985- May 1986)	Present Study (September 1987- May 1988)
Ruscom	0.24	0.182
Hillman	0.54	0.309
Big Creek	0.45	0.3085

Table 7. Average Suspended Sediment Concentrations for each Watershed (mg/L)

	Previous Study (May 1985- May 1986)	Present Study (September 1987- May 1988)
Ruscom	77.9	58.84
Hillman	119.6664	49.5365
Big Creek	67.1	55.90

Loadings

Examination of the suspended sediment and phosphorus loadings (Tables 8-10) illustrates how widely these parameters varied both within the watersheds and between the two studies. Tables 8 and 9 provide the average phosphorus and sediment unit area loads for each watershed. In the previous study, Big Creek watershed had the highest average phosphorus loading (38.13 $mg/s/km^2$), while Hillman watershed was highest in the current study (19.43 $mg/s/km^2$). Suspended sediment was just the opposite where Hillman watershed was the highest loading in the previous study (13,361.2 $mg/s/km^2$) and Big Creek watershed was highest in the current study (3,603.76 $mg/s/km^2$). Table 10 lists the suspended sediment loads in tonnes/year/hectare for both studies. This, along with Tables 8 and 9, clearly show that all watersheds in the present study loaded lower than the previous. This is due to the low level of precipitation and light spring melt. This current study therefore, represents the lower extreme of climatic conditions and event flows.

ANALYSIS

Beales

The Beale's Ratio was used to produce unbiased estimates of mean daily and yearly loadings of suspended sediment and total phosphorus for each station. The Beale's method requires flow data for both sample and non-sample days for a one year period.

Table 8. Average Total Phosphorus Loads for each Watershed (mg/s/km^2)

	Previous Study (May 1985- May 1986)	Present Study (September 1987- May 1988)
Ruscom	26.799	5.52
Hillman	34.438	19.43
Big Creek	38.13	12.0

Table 9. Average Suspended Sediment Loads for each Watershed (mg/s/km^2)

	Previous Study (May 1985- May 1986)	Present Study (September 1987- May 1988)
Ruscom	11308.065	1433.61
Hillman	13361.2	1156.34
Big Creek	11662.24	3603.76

Table 10. Sediment Loading Averages For Watersheds (Tonnes/Year/hectare)

	Previous Study (May 1985- May 1986)	Present Study (September 1987- May 1988)
Ruscom 1	7.1577	0.330869
Ruscom 2	4.4308	0.36805
Ruscom 3	8.7838	1.084636
Ruscom 4	1.1203	0.13817
Ruscom 5	0.9733	0.24377
Ruscom 6	1.5024	- - - -
Hillman 7	4.2136	0.45159
Big Creek 8	2.5066	1.964957
Big Creek 9	6.421	1.12542
Big Creek 10	2.0678	0.319065
Ruscom 11	3.9991	0.77312
Ruscom 12	0.56148	0.089862
Ruscom 13	- - - -	0.58833
Hillman 14	- - - -	0.27773

However, Ruscom #1 was the only station in the study area that had daily flow data. In order to include the other stations, it was assumed in the previous study that their flows were proportional to flows measured at Ruscom #1. This assumption could be made only if date parity was maintained between stations (Allsop *et. al.* 1987). In this way, loading estimates could be obtained for all thirteen sub-watersheds.

It was also found in the first study that Beale's method was most accurate when the loadings for suspended sediment and total phosphorus were divided into four strata (Allsop *et al.).* The high flows ranged from 9 m/sec or greater, medium flows from 0.9 to 9 m/sec, and low flows were less than 0.9 m/sec. The fourth strata represented four-fold flow increases on a day to day basis. It was felt that four-fold increases provided a better differentiation between normal high flows dependent on seasonal effects as opposed to high flows caused by storm events or spring melt.

Data for Ruscom 1 was first subdivided into the four strata. The mean sample and mean daily flows, and their ratios, were calculated for each stratum. The remaining stations are then stratified according to the dates used for Ruscom 1. This meant that, in some cases, a station on a given date may have experienced moderate flow whereas Ruscom 1 stratified as high. However, since date parity had priority over flow, data for that station, on that date, was also entered into the high category. Finally, the ratios calculated for Ruscom 1 were used for the other stations to replace their missing daily discharges.

Due to the small database collected in the nine month study period, the Beale's model could not provide accurate annual estimates. There were also no high flows or four-fold increases recorded within the period. Thus, estimates were done only for suspended sediment in the low and medium strata (Table 11), were not calculated for total phosphorus.

Some discrepancies were noted when the Beales data for the low and medium strata were compared with those of the previous study (Table 11 and Table 12). The estimates for the present study had some higher values in both strata when compared to those of the previous study. This could be due to the lack of data in the present study. Whatever the cause, the current Beales loading should be viewed cautiously, since the missing data has more than likely reduced their accuracy.

ANOVA

The rationale for analysis of variance is to analyze for variation either between or within samples. Two scenarios may be viewed. When samples are taken at random from a common sample area, it is reasonable to expect that variations within the samples will be nearly the same as the variation between the samples, since both variations represent the same sample area. However, when samples are taken from different sample areas (alternative hypothesis) , the variation within each sample (ie: different dates) is a reflection of the variation within the sample area, whereas variations between samples (ie: different stations) is a reflection of the difference between the sample areas. The F-ratio, which indicates these variances, will be greater if there is significant differences between the sample areas.

Table 11. Beale's Estimate Suspended Sediment Loading (September 1987 - May 1988).

Station	Beale's Low Stratum (kg/day)	Beale's Medium Stratum (kg/day)
Ruscom 1	----	----
Ruscom 2	104.89	13678.51
Ruscom 3	60.86	1217.8
Ruscom 4	34.39	499.96
Ruscom 5	47.77	1368.08
Hillman 7	74.24	1164.4
Big Creek 8	155.36	17885.55
Big Creek 9	4.21	785.77
Big Creek 10	34.65	8319.5
Ruscom 11	17.75	27.11
Ruscom 12	6.75	422.39
Ruscom 13	54.60	1686.83
Hillman 14	91.22	3964.07

Table 12. Beale's Estimate Suspended Sediment Loading (May 1985 - May 1986).

Station	Low Loading (kg/day)	Medium Loading (kg/day)	High Loading (kg/day)	Yearly Average (kg/day)
Ruscom 1	946.0	12439.2	386937.40	26747.22
Ruscom 2	760.9	1370.8	251767.9	10297.9
Ruscom 3	15.7	222.88	4532.5	2184.13
Ruscom 4	60.1	215.6	2556.1	629.08
Ruscom 5	47.0	946.21	4383.33	685.71
Ruscom 6	46.8	95.5	4311.3	554.39
Hillman 7	78.5	7210.2	9770.4	2640.26
Big Creek 8	58.2	2974.5	231599.1	8858.38
Big Creek 9	13.4	127.58	13907.2	1175.98
Big Creek 10	71.2	465.3	31478.9	1620.21
Ruscom 11	2.83	3.87	72.66	212.13
Ruscom 12	25..99	123.4	1317.12	407.23

ANOVA was performed to determine if there were any significant differences between the stations for suspended sediment, total phosphorus, and soluble reactive phosphorus. With the exception of suspended sediment, ANOVA found no difference in the loadings between the sub-watersheds. However, the model was weak and not fully reliable due to the low amount of data for all parameters. The ANOVA analysis for suspended sediment showed a significant difference between the subwatersheds, but on a low explanation level. To isolate where differences occurred, ANOVA was performed three times, once for each watershed (Ruscom, Big Creek, Hillman Creek). These tests indicated that the significant difference in sediment loading was between some of the Ruscom stations. Analysis for the other two watersheds (Big Creek, Hillman) concluded no significant difference between their sub-watersheds for suspended sediment.

Cluster Analysis

Cluster analysis was used to rank the thirteen subwatersheds according to their unit area loading of suspended sediment and total phosphorus. This analysis grouped subwatersheds into three general clusters: high, medium and low erosion potential, thus allowing for comparison with the groups ranked arbitrarily using Lands Directorate Methodology. The average linkage cluster analysis method was used on the SAS system at the University of Windsor.

Table 13 compares the cluster analysis results from the previous and present studies, along with the arbitrary ranking. Despite the lack of precipitation and snow melt events in this study, the cluster analysis results were similar to those of the first study. The major differences between the two studies included: Ruscom 11 clustering high instead of medium as in the previous study, Ruscom 1 clustering medium instead of high, and Big Creek 8 clustering very high instead of medium. However, when this study's clusters are compared with the arbitrarily ranked groups (Table 13) it is interesting to note that Ruscom 11 and 1 loaded as predicted. Subwatersheds 8 and 13, on the other hand, loaded higher than predicted in the first study, when some of the highest flows and concentrations at Big Creek 8 were missed due to equipment failure. Had this data been obtained, it is possible that station 8 would have clustered higher than expected in the previous study as well. Big Creek 9 also loaded higher than anticipated, and Ruscom 4 lower, but this was also found to be the case in the previous study. Overall, perhaps with the exception of Big Creek 8, the cluster analysis ranking was similar to the predicted ranking, even though precipitation was far below normal levels.

Relationship between Suspended Sediment and Total Phosphorus

The relationship between sediment and phosphorus can be expressed as a ratio (TP/SS). The higher the ratio, the greater the amount of total phosphorus loaded relative to sediment. Table 14 compares the average ratios for each watershed from the previous and present studies. A more formal breakdown of the ratios for each subwatershed in the study is included in Appendix F. From Table 14, it is evident that the ratios from the previous study were consistently higher for all watersheds. In the previous study, the Hillman watershed ranked highest for phosphorus loading relative to sediment loading, while Ruscom ranked second, and Big Creek third. When these rankings were compared with the present study, Hillman still ranked highest but Big Creek ranked second instead of third. However, this was not unexpected, since in both studies Big Creek and Ruscom watersheds ratios were very close in value, probably due to their similar soil compositions.

Table 13. Comparison of Cluster Analysis.

Previous Study (May 1985 - May 1986)	Present Study (September 1987- May 1988)	Arbitrary Ranking
LOW	**LOW**	**LOW**
Ruscom 4	Ruscom 4	Ruscom 12
Ruscom 5	Ruscom 12	Ruscom 6
Ruscom 6		
Ruscom 12	**LOW-MEDIUM**	**MEDIUM**
	Ruscom 5	Big Creek 10
MEDIUM	Hillman 14	Ruscom 13
Ruscom 11		Big Creek 8
Hillman 7	**MEDIUM**	Big Creek 9
Big Creek 8	Ruscom 1	Ruscom 5
Big Creek 10	Ruscom 2	Ruscom 4
	Hillman 7	Hillman 7
MEDIUM-HIGH	Big Creek 10	Hillman 14
Ruscom 2		Ruscom 1
Big Creek 9	**HIGH**	
	Ruscom 3	**HIGH**
HIGH	Ruscom 11	Ruscom 2
Ruscom 1	Ruscom 13	Ruscom 3
Ruscom 3	Big Creek 9	Ruscom 11
	VERY HIGH	
	Big Creek 8	

Table 14. Average Phosphorus/Sediment Ratios For Each Watershed.

	Previous Study (May 1985- May 1986)	Present Study (September 1987- May 1988)
Ruscom	0.0220625	0.0040998
Hillman	0.2155	0.009438
Big Creek	0.0185	0.0042077

Hillman on the other hand, is composed of mostly sandy loams. Apparently, the sandy soil or the cropping practices found on the sandy soil contributes to the increased phosphorus loading relative to the sediment loading. This will be discussed further in the next section.

Relationship Between Loading and Land Use

Some of the factors that affect sediment loading to water bodies include soil type, slope, topography, precipitation, snow melt and land use. The way these elements interact to increase or decrease loading is a complex process. However, given the relatively uniform terrain, slope, soil, and rainfall in Essex 18 County, it was felt that examination of land use systems might provide insight into the causes of increased soil loss in some of the study's subwatersheds.

In the previous study, the areas of different land use were determined for each subwatershed. The subwatersheds which ranked as high and medium loaders were then placed in one group, and those ranked as low into another. Next, the total area for each land use was found for the two groups and expressed as a percentage (Table 15). Since the results of this study's cluster analysis were similar to those of the previous study, these figures (Table 15) were used once again to illustrate that certain forms of land use were more characteristic of higher or lower loading subwatersheds.

The most outstanding pattern observed was the high percentage of continuous row crops (76%) found in the high-medium loading subwatersheds. In comparison, low loading subwatersheds had only 31% of their total area in this cropping system. Continuous row crops include large, mainly single-crop fields planted either with corn or beans on a non-rotational basis or with corn and beans in rotation.

It was also found that corn systems were more prominent in low-loading subwatersheds (46%) than in high-medium loaders (13%). This is a rotational system of corn, and soybeans, occupying at least 40% of an area with the remainder in grains, hay, or pasture.

Finally, there was a greater percentage of horticultural crops (25%) such as tobacco, vegetables, and fruits in the low loading subwatersheds. These crops occupied less then 5% of the total area in the higher loading subwatersheds. The low loaders also had a slightly higher combined percentage (2%) of orchards, woodlots and idle farmland.

It was not surprising that continuous row crops were more common in higher loading subwatersheds. The lack of grains or pasture in this system mean that most of the area is bare, and therefore, vulnerable to runoff and soil erosion especially in late fall and early spring, the times of peak runoff. Corn systems, on the other hand, may have as much as 60% of their area under grains and pastures, thus helping to protect a larger percentage of land from overland runoff. Grain's, for example, provide some cover during the critical loading months of November, and March. Corn systems also provide additional protection by rotating crops. The practice of rotation improves soil structure, especially if it includes legumes or grains underseeded with red clover. Improved soil structure allows for better infiltration of rain water with less overland runoff and erosion.

Table 15. Comparative Table of Land Use Systems.

	Sub-watersheds Clustering Medium- High in Loading of Sediment (% Land Base)	Sub-watershed Clustering Low in Loading of Sediment (% Land Base)
Continuous Row Crops	76.10	32.56
Corn Systems	13.14	47.48
Hay System	0.45	0.07
Mixed System	0.78	0.97
Grain System	0.11	0.00
Extensive Field Vegetables	4.74	12.67
Orchard System	2.58	1.08
Tobacco	0.18	1.05
Market Gardens	0.00	0.05
Peaches	0.00	0.35
Peaches and Cherries	0.00	0.04
Berries	0.00	0.10
Nurseries	0.00	0.03
Idle Agricultural Land	0.05	0.46
Woodland	1.64	2.53
Extraction	0.00	0.31
Built-up	0.23	0.25

Although horticultural systems such as vegetables and tobacco were more common in the low loading subwatersheds, these crops actually increase the probability of erosion. Like continuous row crops, these systems traditionally leave large areas of soil unprotected during critical loading periods. However, unlike the continuous row crops these crops are grown on loamy to sandy soils which have better infiltration and less runoff. Also, cover cropping is becoming more common in these soil types, providing protection from erosion in the fall through spring. This illustrates how soil type and erosion control practices can influence both rainwater infiltration, runoff and the resulting sediment /phosphorus loading.

Finally, woodlots, orchards and idle farmland were somewhat more common in the low-loading subwatersheds. These systems provide a high degree of soil protection and reduce erosion and delivery accordingly.

In summary, while a number of factors contribute to soil erosion and delivery to water bodies, land use systems can play a major role in the process. The general trends observed after comparing uses with the high and low loading subwatersheds indicated that this is the case in Essex County.

CONCLUSIONS

The following summarizes the significant findings from this study compared with the results from the previous study (Allsop *et al.*, 1987).

1. While concentrations of total phosphorus and sediment attained high levels primarily during peak flows in the previous study, the opposite was true

throughout this study. This study had half to two-thirds the normal amount of precipitation, with no major storm events and therefore, no comparable peak flows and concentrations.

2. In the previous study most sub-watersheds experienced their highest peak loadings of phosphorus and sediment in the month of March, during the spring thaw. Due to the mild conditions and below normal precipitation experienced during the present study, no evident spring thaw occurred. This provided only low loading values in March.

3. In this study, the highest sediment and phosphorus ratio was experienced in the Hillman watershed. The previous study also had similar ratios, with Hillman having a ratio twice that of the other two watersheds. Hillman, therefore, loads more units of phosphorus for every unit of sediment. Why this is happening is unclear, and merits further attention in future studies that include more sampling stations on Hillman Creek and checks for sources of phosphorus other than sediment.

4. The Beales Ratio Estimator was used to provide unbiased, annual estimates of sediment and phosphorus loadings. However, the small data base and lack of high flow data for this study reduced the accuracy of the estimates. Estimated loadings were provided only for the low and medium strata of suspended sediment, and these could not be readily compared with Beales data from the previous study.

5. Analysis of Variance (ANOVA) showed no significant difference in the loading of total or reactive phosphorus between the thirteen subwatersheds. However, there was some weak difference found between the subwatersheds in the loading of suspended sediment. When tested further, this small difference was found to occur between some of the stations in the Ruscom watershed. Overall it appeared, at least from the small amount of data available for this study, that there was either little or no variation in the loading of sediment or phosphorus between the subwatersheds.

6. Cluster Analysis arranged the subwatersheds into low, medium and high loading groups similar to those from the previous study. It was also found that the clustered groups basically agreed with the groups predicted by the Lands Directorate methodology. The most notable discrepancies included: Big Creek 8 clustering high instead of medium as it did in the former study and in the predicted ranking, Ruscom 13 clustering high instead of medium as predicted, and Big Creek 9 clustering higher than predicted in both studies. It is possible that these stations are loading somewhat higher than predicted by the Lands Directorate model. This could be confirmed, and most likely explained in a long term study where the Lands Directorate maps are analyzed and ground checked for errors. However, overall the model proved to be relatively accurate in predicting high priority management areas in the flat, imperfectly drained conditions of Essex County.

7. Once again it was found that subwatersheds experiencing higher sediment and phosphorus loadings had a greater percentage of clay soils within their areas. These subwatersheds also had the majority of their land base in continuous row

crops where the soil was left without cover and vulnerable to erosion during the critical loading months in spring and fall.

Overall, like the study before it, this study has shown that the Lands Directorate model is relatively accurate in predicting areas of high soil delivery within Essex County, even during periods of below normal precipitation. While the previous study illustrated the potential for high concentrations and loadings in Essex County Rivers, this study provided a view of the effects of extreme climatic conditions, such as drought. However, the Lands Directorate model was designed to be tested with data collected over an extended period. Further long term monitoring is necessary to obtain sufficient data for explaining those factors of loading not due to annual or seasonal variation. Future efforts should also include a study of the effects of soil conservation measures, so that soil erosion and delivery to streams may be reduced to more acceptable levels in the long run.

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Various Drainage Maps, Ontario Ministry of Agriculture and Food, drawn 1985, 1984 Mersea Township Rochester Township Tilbury West Township Tilbury North Township.

APPENDIX A:

Land Use

AGRICULTURAL LAND USE SYSTEMS - KEY

Symbol	System
P	Continuous Row Crop
C	Corn System
M	Mixed System
MG	Grain System
H	Hay System
HG	Pasture System
G	Grazing System
KF	Extensive Field Vegetables
KM	Market Gardens/Truck Farms
KT	Tobacco System
RN	Nursery
PE	Peaches
CH	Cherries
PC	Peaches-Cherries
O	Orchards
V	Vineyards
OV	Orchard-Vineyard
VO	Vineyard-Orchard
BE	Berries
A1	Idle Agricultural Land
A2	Idle Agricultural Land
Z	Woodland
Zp	Pastured Woodland
Zr	Reforestation
B	Built-Up
E	Extraction (Quarry)

Agricultural Land Use Systems (percent)

Ruscom1	
BU	0.3
C	14.3
H	0.5
M	1.1
MG	0.2
KF	3.9
OE	1.9
KT	0.3
Al	0.1
Z	1.7
P	75.7
Ruscom2	
C	5.3
KF	4.5
OR	5.6
Z	1.5
H	0.4
P	82.7
Ruscom3	
C	16.3
KF	14.5
H	0.8
p	68.4
Ruscom4	
C	3.1
KF	15.1
OR	4.9
Z	2.7
P	74.2
Ruscom5	
KF	17.5
KT	1.8
KM	0.5
H	1.3
Z	3.7
P	75.2
Ruscom6	
C	59.4
KF	13.0
KT	2.0
Z	1.9
OR	1.4
M	4.5
A2	1.3
PE	0.6
P	15.9
Hillman7	
BU	1.1
EXT	2.1
KF	50.8
Pp	33.8
Z	2.6
KT	4.2
PE	2.3
OR	1.5
PC	0.3
BG	0.3
KM	0.2
Al	0.5
A2	0.3
Big Creek8	
P	19.5
Z	2.1
KT	0.1
KF	0.3
KR	0.1
Al	0.4
M	1.2
C	76.2
BU	0.1
Big Creek9	
P	41.8
Z	2.4
C	55.8
Big Creek10	
P	22.5
Z	1.8
M	1.9
Al	0.9
C	72.6
BU	0.3
Ruscom11	
KF	50.3
P	49.7
Ruscom12	
C	29.4
KT	5.6
KF	37.7
BE	1.3
OR	2.2
Z	8.0
P	25.8

Ruscom13	
P	13.9
KF	1.7
C	40.1
Hillman14	
OR	1.5
KF	39.9
PC	0.3
PE	2.2
KT	2.9
Z	2.2
R	0.1
KM	0.1
MG	0.2
B	0.9
E	1.0
Al	0.8
BE	0.2
C	21.5
P	27.4

APPENDIX B:

Soil Types

Soil Types - Key

Symbol	**Soil Name**
Clay Soils	
Bc	Brookston Clay
Toc	Toledo Clay
Cc	Clyde Clay
Jc	Jeddo Clay
Cac	Caistor Clay
Pc	Perth Clay
Clay Loams	
Pcl	Perth Clay Loam
Cacl	Caistor Clay Loam
Bc1	Brookston Clay Loam
Silt Loam	
Tos	Toledo Silt Loam
Loams	
Bg	Burford Loam
Bg-s	Burford Loam Shallow Phase
H1	Harrow Loam
F1	'Farmington Loam
P1	Parkhill Loam
P-r	Parkhill Loam Red Sand Spot Phase
Fine Sandy Loams	
Tfs	Tuscola Fine Sandy Loam
Cdl	Colwood Fine Sandy Loam
Sandy Loams	
Hs	Harrow Sandy Loam
Fsl	Fox Sandy Loam
Bel	Berrien Sandy Loam
C-s	Caistor Sand Spot Loam
B-s	Brookston Clay Sand Spot Phase
Was	Wauseon Sandy Loam
Sands	
Gs	Granby Sand
Bel	Berrien Sand
Ps	Plainfield Sand
Es	Eastport Sand
Miscellaneous Soils	
B.L.	Bottom Land
Ma	Marsh
M	Muck

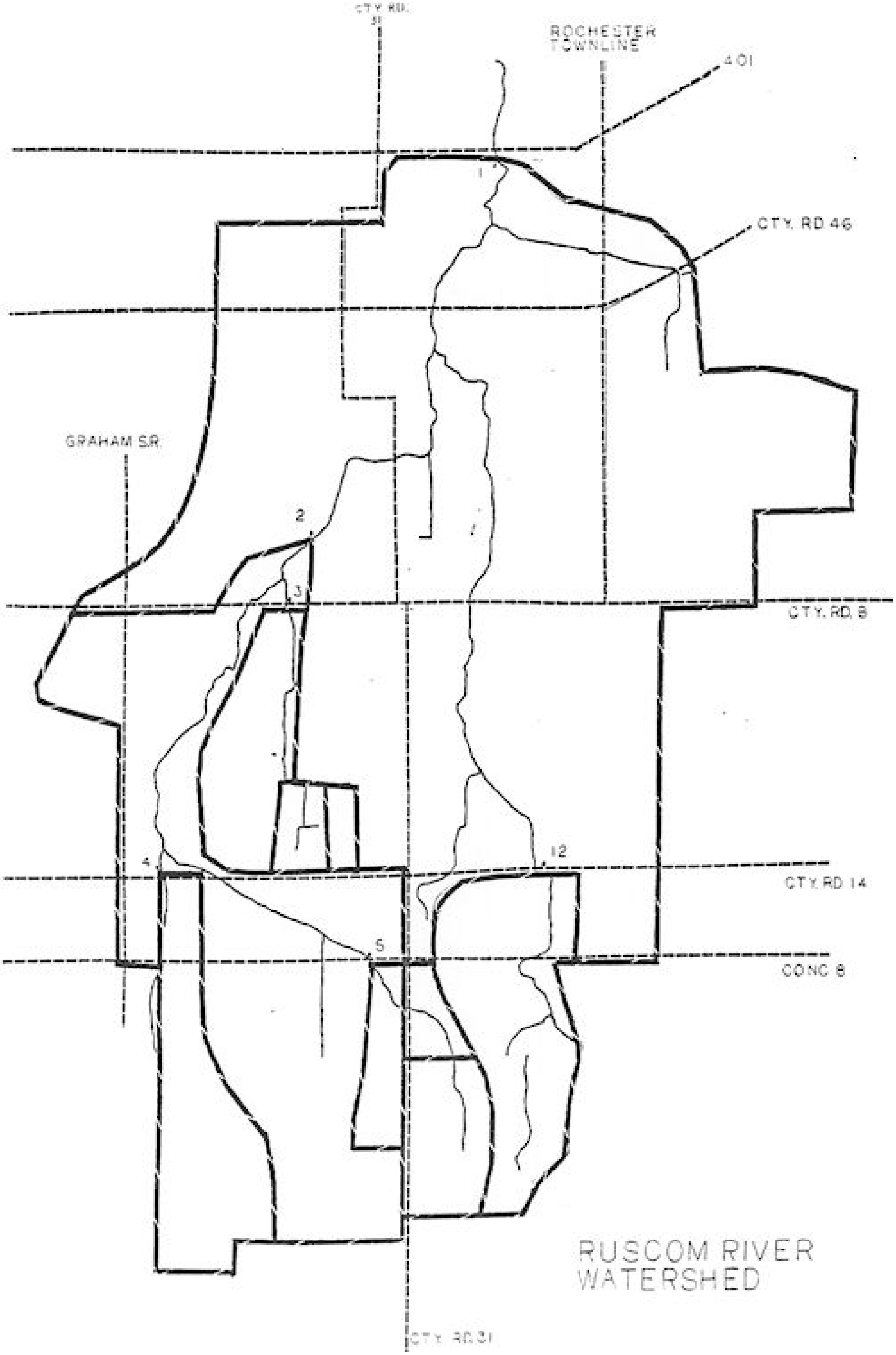
Soil Type	% Soil	Drainage
Ruscom 1 120.52km^{2}Area		
Berrien Sand Loam	3.30	Fair to Poor
Brookston Clay	70.23	Poor
Berrien Sand	1.14	Good to Excessive
Bottom Land	0.93	Variable
Brookston Clay Loam	4.73	Poor
Brookston Clay Sand Spot Phase	4.13	Poor
Burford Loam	1.33	Good
Caistor Clay	0.642	Fair to Poor
Colwood Fine Sandy Loam	0.041	Poor
Fox Sandy Loam	1.762	Well Drained
Harrow Loam	1.56	Good
Muck	0.23	Very poor
Parkhill Loam	2.74	Fair to Poor
Plainfield Sand	0.21	Good to Excessive
Parkhill Loam Red Sand Spot Phase	6.78	Fair to Poor
Tuscola Fine Sandy Loam	0.25	Fair to Poor
Ruscom 2 39.52km^{2}Area		
Brookston Clay	44.86	Poor
Brookston Clay Loam	7.93	Poor
Berrien Sandy Loam	4.58	Fair to Poor
Berrien Sand	0.93	Good to Excessive
Burford Loam	3.97	Good
Colwood Fine Sandy Loam	0.121	Poor
Fox Sandy Loam.	2.79	Well Drained
Harrow Loam	4.65	Good
Muck	0.37	Fair to Poor
Parkhill Loam	8.18	Fair to Poor
Plain Field Sand	0.62	Good to Excessive
Parkhill Loam Red Sand Spot Phase	20.26	Fair to Poor
Tuscola Fine Sandy Loam	0.743	Fair to Good
Ruscom 3 5.64km^{2}Area		
Brookston Clay	67.74	Poor
Berrien Sandy Loam	5.64	Fair to Poor
Parkhill Loam	22.18	Fair to Poor
Ruscom 4 6.53km^{2}Area		
Brookston Clay	29.2	Poor
Brookston Clay Loam	3.6	Poor
Berrien Sandy Loam	10.0	Fair to Poor
Burford Loam	14.0	Good
Harrow Loam	18.4	Good
Muck	0.4	Very Poor
Parkhill Loam Red Sand Spot Phase	24.4	Fair to Poor

Soil Type	% Soil	Drainage
Ruscom 5 5.65km^{2}Area		
Brookston Clay Loam	41.95	Poor
Berrien Sandy Loam	5.08	Fair to Poor
Fox Sandy Loam	10.59	Well Drained
Muck	2.97	Very Poor
Parkhill Loam	3.82	Fair to Poor
Plainfield Sand	4.24	Good to Excessive
Parkhill Loam Red Sand Spot Phase	31.35	Fair to Poor
Ruscom 6 4.05km^{2}Area		
Berrien Sandy Loam	6.10	Fair to Poor
Brookston Clay Loam	51.83	Poor
Parkhill Loam Red Sand Spot Phase	22.56	Fair to Poor
Muck	4.27	Very Poor
Fox Sandy Loam	15.24	Well Drained
Hillman 7 11.18km^{2}Area		
Berrien Sandy Loam	62.96	Fair to Poor
Bottom Land	5.17	Variable
Brookston Clay Sand Spot Phase	1.18	Poor
Caistor Clay	12.93	Fair to Poor
Fox Sandy Loam	16.22	Well Drained
Muck	0.35	Very Poor
Tuscola Fine Sandy Loam	1.19	Fair to Poor
Big Creek 8 53.08km^{2}Area		
Brookston Clay	97.50	Poor
Berrien Sandy Loam	0.234	Fair to Poor
Brookston Clay Sand Spot Phase	2.26	Poor
Big Creek 9 3.45km^{2}Area		
Brookston Clay	100.00	Poor
Big Creek 1014.06km^{2}Area		
Brookston Clay	91.11	Poor
Berrien Sandy Loam	0.53	Fair to Poor
Brookston Clay Spot Phase	8.36	Poor

Soil Type	% Soil	Drainage
Ruscom 11 1.03km^2Area		
Brookston Clay	45.24	Poor
Berrien Sandy Loam	9.52	Fair to Poor
Parkhill Loam	45.24	Fair to Poor
Ruscom 12 1.03km^2Area		
Berrien Sandy Loam	26.33	Fair to Poor
Brookston Clay Loam	35.33	Poor
Brookston Clay Sandy Spot Phase	20.0	Poor
Berrien Sand	8.67	Good to Excessive
Fox Sandy Loam	8.33	Well Drained
Muck	1.34	Very Poor
Ruscom 13 2.79km^2Area		
Brookston Clay Loam	45.6	Poor
Fox Sandy Loam	20.0	Well Drained
Parkhill Loam Red Sand Spot Phase	28.8	Fair to Poor
Muck	5.6	Very Poor
Hillman 14 20.81km^2Area		
Berrien Sandy Loam	70.89	Fair to Poor
Bottom Land	3.99	Variable
Brookston Clay Sand Spot Phase	5.02	Poor
Caistor Clay	6.27	Fair to Poor
Fox Sandy Loam	7.87	Well Drained
Muck	0.001	Very Poor
Tuscola Fine Sandy Loam	5.82	Fair to Poor

APPENDIX C:

Watershed Maps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CTY. RD. 8
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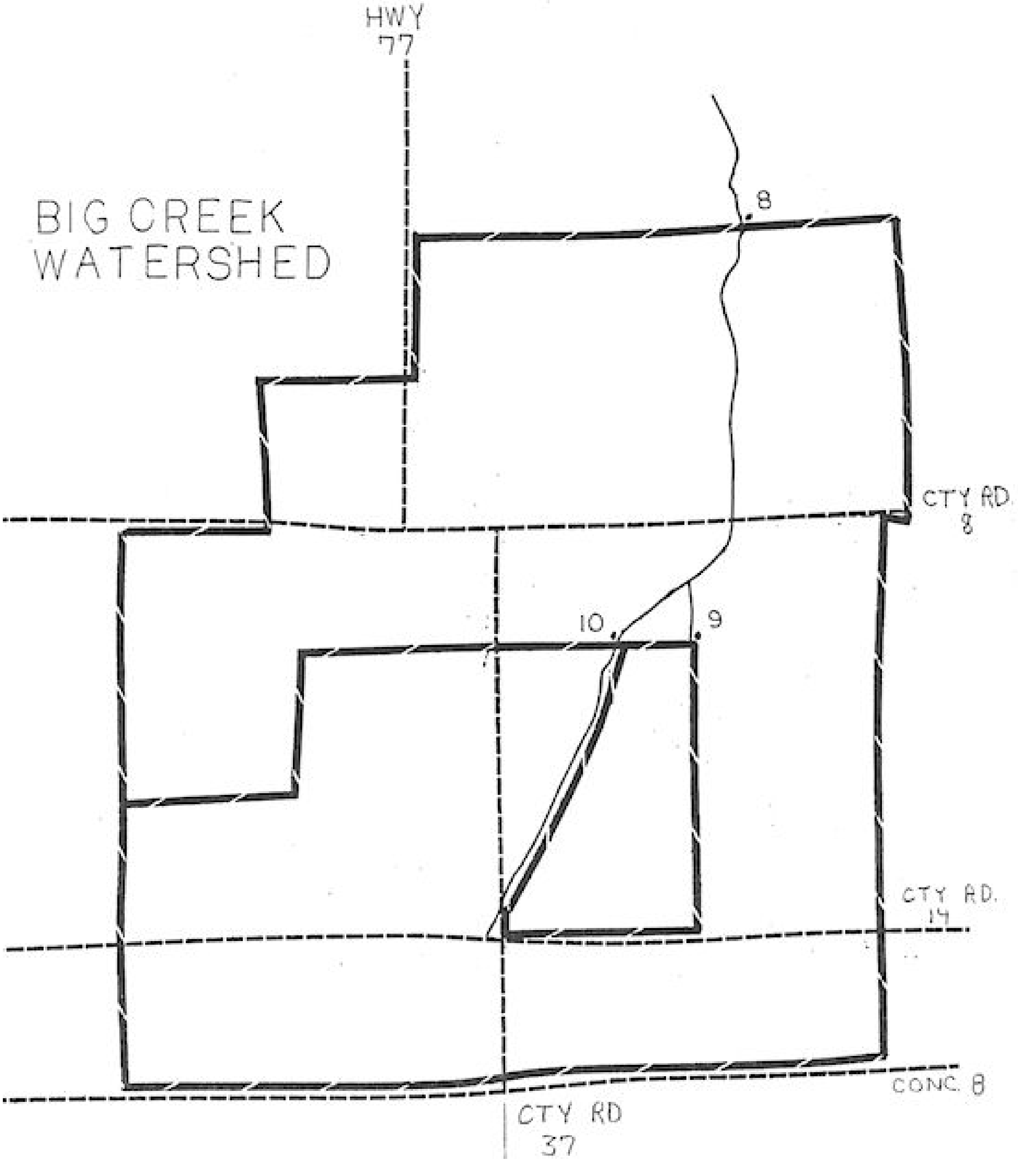
12
CTY. RD 14
5
CONC 8
RUSCOM RIVER WATERSHED
CTY. RD. 31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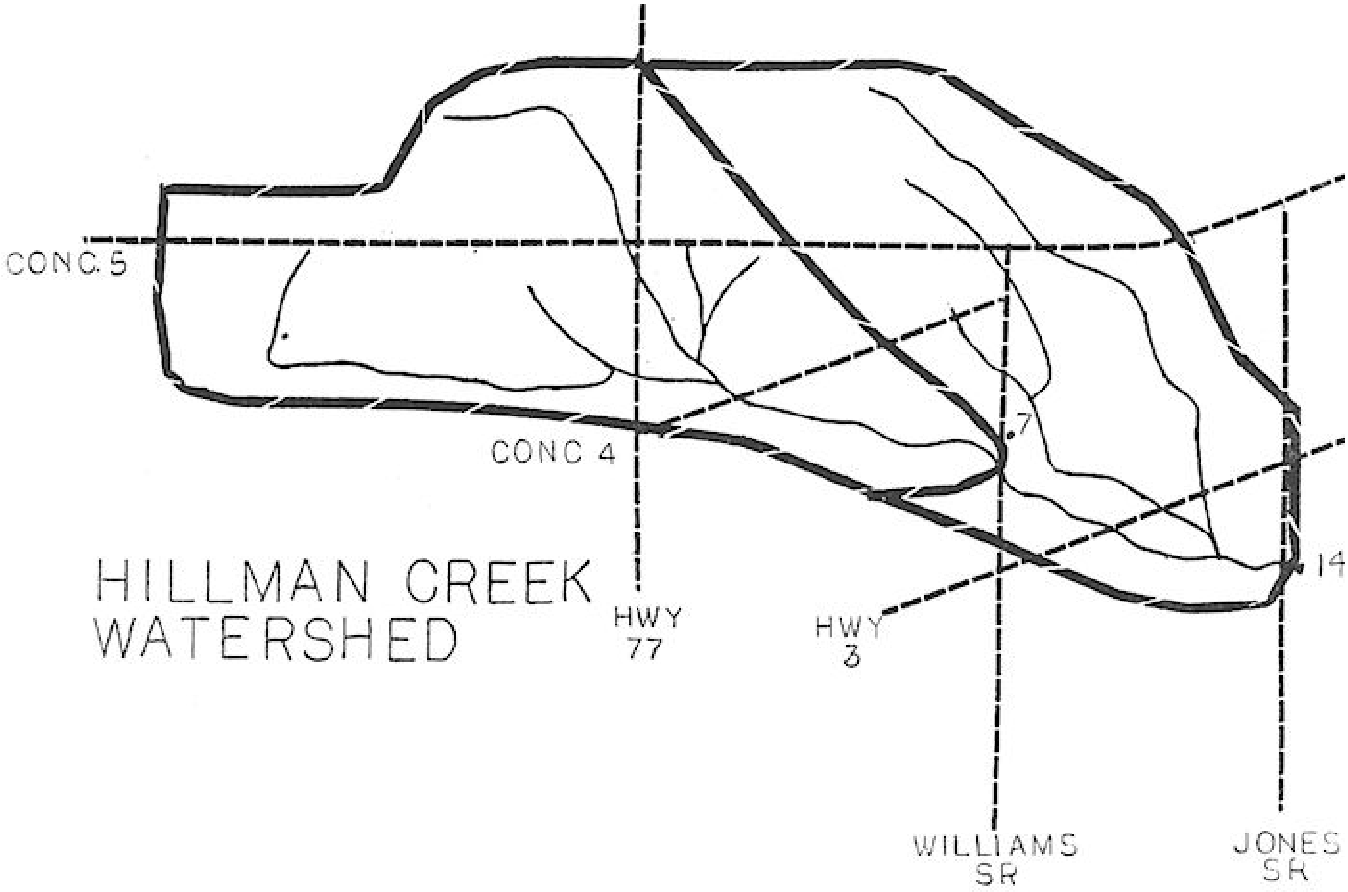
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CONC 4
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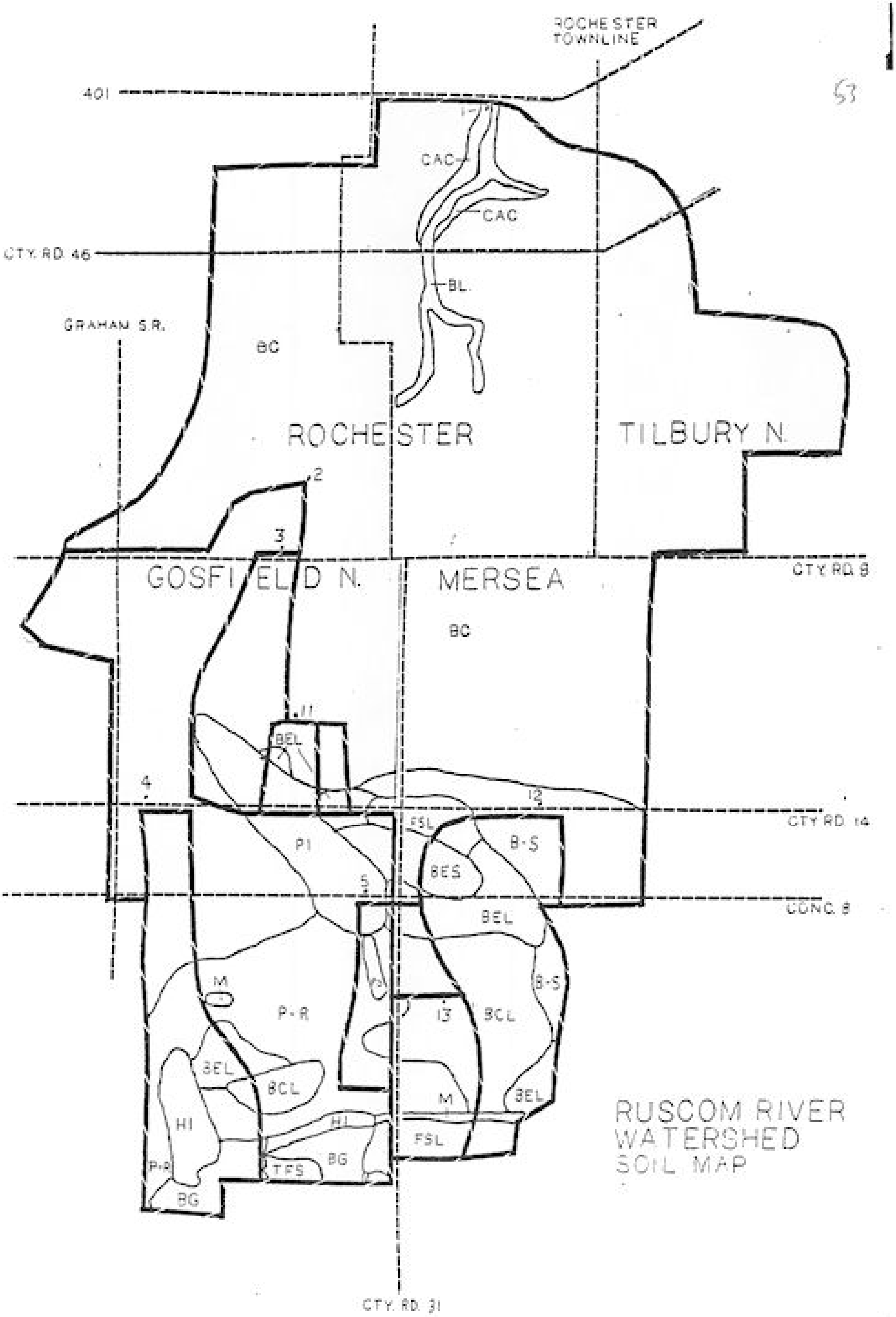
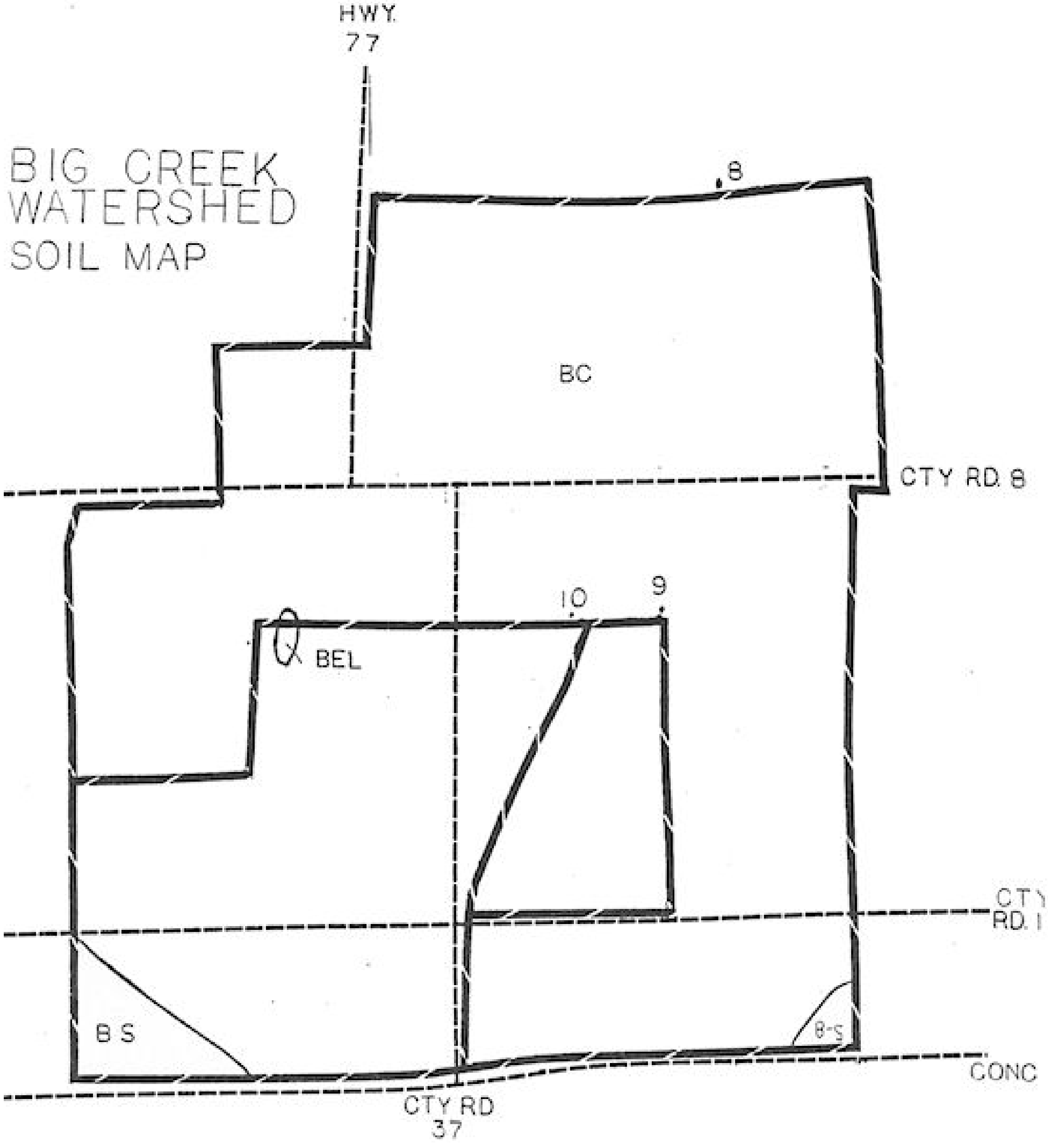
77
HWY
3
WILLIAMS
SR
JONES
SR

APPENDIX D:

Soil Maps



RUSCOM RIVER
WATERSHED
SOIL MAP


HWY. 77
BIG CREEK WATERSHED SOIL MAP
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9
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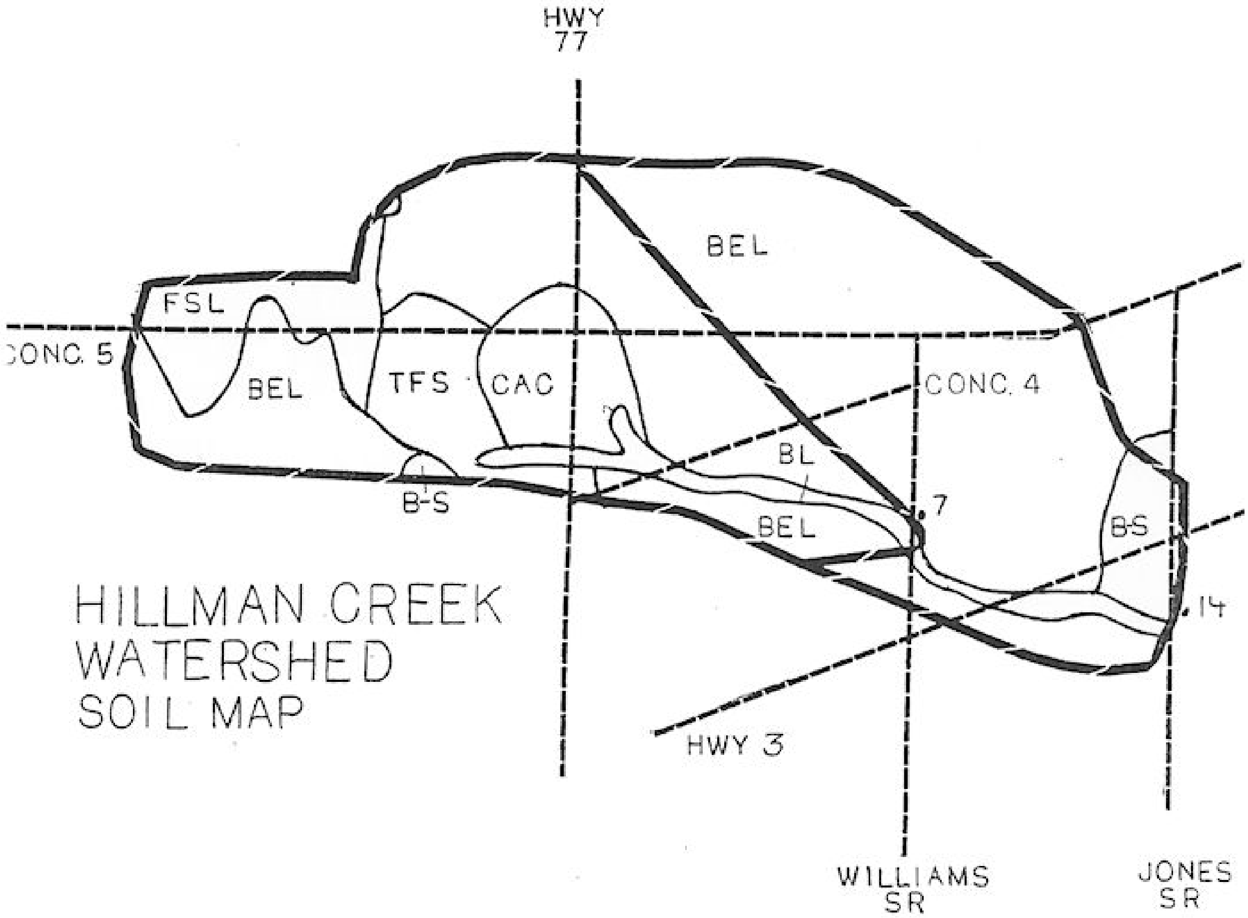
B S
B-S
CONC
CTY RD 37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BEL
FSL
CONC. 5
BEL
TFS
CAC
CONC. 4
BL
.7
BEL
B-S
B-S
.14
HILLMAN CREEK
WATERSHED
SOIL MAP
HWY 3
WILLIAMS SR
JONES SR

APPENDIX E:

Assorted Tabulated Data

Station Averages September 1987 - May 1988

Station	TP Loads (mg/s/km^2)	SS Loads (mg/s/km^2)	TP/SS Ratio	TP Conc. (mg/L)	SS Conc. (mg/L)
Ruscom 1	4.2252	1049.18	0.0040271	0.1456	56.152
Ruscom 2	4.1	1167.1	0.0035129	0.16225	63.7201
Ruscom 3	17.85	3439.36	0.0051899	0.2324	50.72125
Ruscom 4	1.3	438.15	0.0032967	0.0708	28.1635
Ruscom 5	2.6	773	0.0033635	0.19155	51.2938
Ruscom 6	- - - -	- - - -	- - - -	- - - -	- - - -
Hillman 7	7.28	1432	0.00508	0.316415	44.3
Big Creek8	13.905	6230.84	0.0022316	0.3008	78.2425
Big Creek9	16.2215	3568.75	0.0045454	0.3128	39.854
Big Creek10	5.915	1011.75	0.0058463	0.312	49.6172
Ruscom 11	6.65	2451.54	0.0027125	0.224	123.167
Ruscom 12	2.365	284.95	0.0082997	0.2531	24.0955
Ruscom 13	5.0855	1865.6	0.0027259	0.17475	73.444
Hillman 14	12.15	880.68	0.0137961	0.30175	54.773

Station Averages May 1985 - May 1986

Station	TP Loads ($mg/s/km^2$)	SS Loads ($mg/s/km^2$)	TP/SS Ratio	TP Conc. (mg/L)	SS Conc. (mg/L)
Ruscom 1	42.8355	22697.041	0.0035	0.2846	135.481
Ruscom 2	41.764	14050.173	0.0045	0.2152	84.029
Ruscom 3	44.461	27853.225	0.0065	0.34106	51.691
Ruscom 4	10.0435	3552.486	0.0035	0.0903	39.0053
Ruscom 5	10.2185	3086.3665	0.007	0.1826	40.1803
Ruscom 6	11.708	4764.1175	0.086	0.1828	57.5829
Hillman 7	34.438	13361.201	0.2155	0.5437	119.6664
Big Creek8	22.2925	7948.5585	0.0055	0.52967	322.6283
Big Creek9	68.088	20361.089	0.0435	0.6856	46.200
Big Creek10	24.0105	6557.086	0.0065	0.3484	90.30
Ruscom 11	42.7205	12681.16	0.0075	0.3661	197.983
Ruscom 12	10.641	1780.4445	0.058	0.25911	17.42