Lake Iroquois Watershed Erosion Study

prepared for

Vermont Department of Water Resources
Montpelier, Vermont

by

Henry L. Barbaro
Winooski Conservation District

and

technical assistance provided by

Nicholas Ceto III
Resource Conservationist
Soil Conservation Service

June 14, 1984

Lake Iroquois Watershed Erosion Study

Introduction

This study involved a field survey of the Lake Iroquois watershed, located in the town of Hinesburg, Vermont, in which an erosion inventory of the area was developed. The field survey was comprised of recording erosion information on inventory worksheets; each sheet being numbered as an evaluation unit. Even though these worksheets are being submitted apart from this report, it will be necessary to refer to them for any detailed information not included in this report.

The field study was conducted in early May. In general, early spring is an excellent time of year to observe eroding areas because: 1) there is little vegetation which can obscure erosion inspection; 2) eroding areas are fresh from the large peak flows associated with spring runoff; and 3) road grading, which flattens out eroded gulleys, has usually not occurred yet.

There were three general types of erosion described: 1) sheet and rill; 2) streambank; and 3) gulley. Sheet and rill, and gulley erosion occurred on roads, driveways, bare lots, and other similar sites. Streambank erosion took place in flowing drainage ditches, streams, and lake shore areas.

Methods

To quantify sheet and rill erosion, the Universal Soil Loss Equation (USLE) was used. The USLE gives a predicted average annual soil loss in tons per acre per year by multiplying the values given to factors in the equation which affect soil loss. Even though the USLE was developed for farmland in the eastern U.S., it has been extensively used to estimate erosion from construction sites as well (Kimberlain and Moldehauer, 1977).

The USLE is described as:

$A = RKLSCP$ where:

- A = the average annual soil loss in tons/acre/year
- R = the rainfall factor
- K = the soil erodability factor
- L = the length of slope in feet
- S = the percent slope
- C = the crop management factor
- P = the conservation practice factor

R - the rainfall factor is a measure of rainfall intensity. R = 115 for Chittenden county.

K - the soil erodability factor is a measure of a soil's erodability. The range of K values used in this study was 0.20-0.40. These values were derived from the SCS Technical Guide - Section 1A (herein referred to as the Technical Guide), and from the nomograph for determining the K factor of U.S. mainland soils (Wischmeier, Johnson, and Cross, 1971). In all cases a K value was selected upon observing an eroding area's soil texture/structure and compaction.

L - the length of slope was measured in the field

S - the percent slope was measured in the field.

C - the crop management factor reflects the effects of vegetation growing on an eroding area. This value was estimated using the Technical Guide's C Factor Table. Exceptions were made for all dirt roads; these were given a C value of 0.20. According to the Technical Guide an area with 0% ground cover is given a C value of 0.45. But this applies to tilled farmland, in which soil particles are more readily dislodged from rainfall impact than they are on relatively compact road surfaces.

P - the conservation practice factor was set at 1.0 since there were no conservation practices being performed on any of the evaluation units.

The area of an eroding zone was also estimated in order to convert tons/acre/year into tons/year.

Streambank erosion was determined by measuring the length of the eroded segment and the eroded cross-section of the channel. Observing the depth of exposed roots and rocks was helpful in estimating the annual soil loss. After multiplying length times cross-section, this volume was then multiplied by the soil's density (see Appendix A) in order to obtain the tonnage of eroded sediment.

Gulley erosion was determined basically the same way. Road gulleys were relatively easy to describe. By knowing the frequency at which roads were graded (into a smooth, flat surface) the volume of material eroded annually could be estimated with more certainty than for an area that had been gulleying for an unknown length of time.

The volume of eroded sediment was subsequently multiplied by a delivery ratio (D.R.) for each site, which was estimated in the field. The D.R. is the percentage of eroded material reaching a receiving water body. Since the erosion process is selective (i.e. the fine fractions are transported more readily), the coarser particles will settle out of suspension on the way to the lake. Typically the D.R. decreases with increasing size of the watershed (Novotny and Chesters, 1981).

Approximating the D.R. was a somewhat subjective process considering that the most accurate D.R. estimations require information concerning drainage area sizes, relief/length ratios, source/texture analyses, ponding, rainfall, and other factors. Even if these parameters were measured there is still a rather wide band of possible D.R. values, as was reported by the SCS National Engineering Handbook, Section 3, Chapter 6. For example, this document gives a 64 acre watershed a range of D.R. values from 20-80%.

Visual observations which contributed to the D.R. approximations were vegetation (or obstruction) density and height, deposition depth and extent, slope, and length of land between the eroding area and the lake. The D.R. values were noted at the top of each inventory worksheet in which an eroding area was described.

Analysis

The area of the Lake Iroquois watershed which was inventoried is depicted in Figure 1. This area is comprised of 119 evaluation units, described individually on "inventory worksheets."

Upon completion of the field measurements and descriptions, estimates were made (using the methods previously described) of the sediment lost from each evaluation unit, in tons per year, to the lake. The sediment loading rates were reported at the top of the inventory worksheets.

The evaluation units were then categorized into groups according to their contribution of sediment to the lake. This breakdown is depicted in Table 1.

Table 1. Rate of Eroded Sediment to Lake Iroquois

Code #	Erosion Category	tons/yr.	units/category
0	none	0	36
1	very slight	<0.0099	13
2	slight	0.01-0.0999	37
3	moderate	0.10-0.9999	26
4	high	1.00-9.9999	6
5	very high	>10	1

The code number was written in red at the top right hand corner of each evaluation unit sheet.

In order to "identify those sites where it would be feasible and beneficial to implement sediment control practices," the evaluation units were grouped according to their erosion rate categories. Four factors were taken into account for the purpose of ruling out the "non-treatable" evaluation units. These factors are as follows:

1. sediment transport rate(e.g. an evaluation unit with "none" or "very slight" sediment yields)

2. time (e.g. a bare yard with dense grass (which would stabilize the area within a year) beginning to sprout)

3. accessibility (e.g. an eroding streambank in a fragile wooded area)

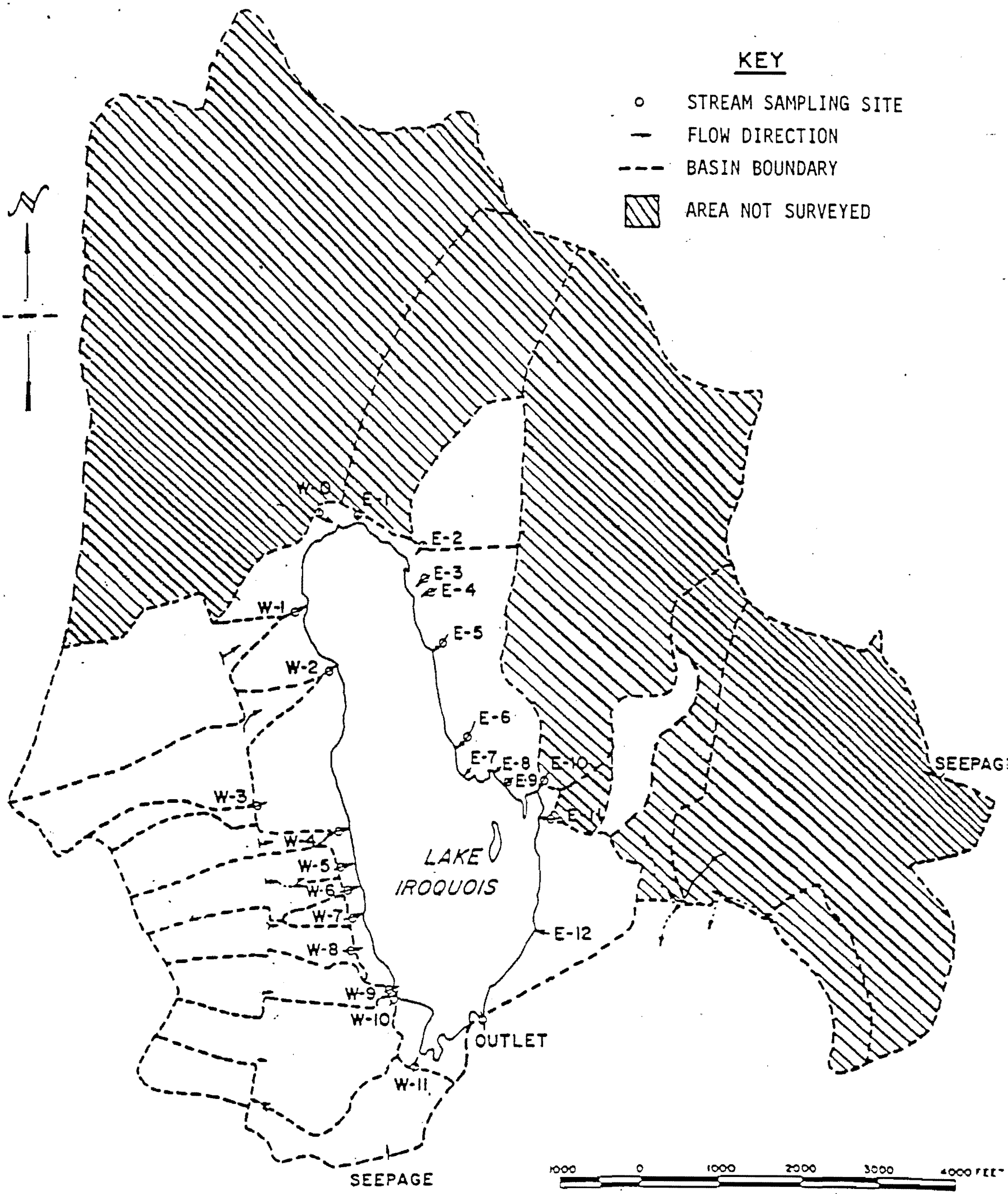
4. ownership (e.g. an eroding private boat launch)*

*It was deemed to be administratively impractical to implement sediment control practices on a small scale, case-by-case basis. Nonetheless, if there was an individually owned area experiencing significant erosion, it was not "ruled out."

The evaluation units were then organized into "drainage groups" that had a common erosion control measure and outlet to the lake. For example,

FIGURE 1

LAKE IROQUOIS EROSION SURVEY STUDY AREA



evaluation units 17, 18, 20, 25, 27a, and 27b were eroding roads and driveways, all of which ultimately emptied into a drainage ditch leading to the lake.

These drainage groups were further classified into three types of erosion: road, streambank, and houselot. The erosion classes and drainage groups are depicted in Table 2 below:

Table 2. Erosion Class Grouping

Erosion Class	Evaluation Units of Each Drainage Group
Road	(7,8,9), (11), (17,18,20,25,27a,27b), (37,38,39), (41), (43,44,45), (47,48,49,52), (63a, 65), (92,93), (96,97), (99)*, (109)*, (110), (111), (113)
Streambank	(50,51,60), (61,95), (69), (84), (100)
House lot	(67a,67b,68)

*Describes 2 drainage groups

A set of erosion and/or sediment control practices (also termed Best Management Practices [BMPs]) was then assigned to each of these drainage groups based on cost, practicality, and effectiveness. The dimensions and location of the BMPs were sketched in orange on the back, and described on the front, of the erosion worksheets. The "Lake Iroquois Watershed Maps" also provide the location of the BMPs in relation to the lake. Using the "BMP Options" section (see Appendix B) a cost estimate of each BMP was then calculated. (Note: All of these BMP strategies require some sort of maintenance. Technical advice will be provided at no cost by the SCS if necessary.)

The sediment removal efficiency of the BMP was approximated (all but two BMP strategies had removal efficiencies approaching 100%), and the total sediment load reduction from each drainage group was determined and reported at the bottom left-hand corner of the group's first "erosion worksheet."

Next, enrichment ratios (E.R.) for "natural" and "road" sediments were selected. The E.R. refers to the ratio between the sorbed pollutant (TP) concentration in washload particles, and the soils from which the sediment originated (Novotny and Chesters, 1981). Upon inspection of preliminary data supplied by the State Of Vermont, the E.R. for sediment transported from a "natural" area, e.g. a stream bank, was estimated at 1.96 pounds TP per ton of sediment. In addition the E.R. for road-related sediment was averaged to be 1.48 pounds TP per ton of sediment. Thus the reduction of TP loading rates (in pounds/year) to Lake Iroquois was also reported at the bottom left-hand corner of the worksheets.

All of this information was compiled and tabularized in Table 3:

Table 3. Sediment and P Reduction, and BMP Cost for "Significant" Erosion Classes.

	House Site	Streambank	Roads
Gross Current (tons)	7.9	62.8*	14.9
Erosion w/BMP (tons)	<0.05	<0.05	<0.05
Net sediment change (tons)	-7.9	-62.8	-14.9
Net TP change (lbs.)	-15.5	-125.1	-22.1
Total BMP cost	$140.00	$3,900.00	$5,150.00
n of drainage groups	1	5	15

*sediment information for one stream site not available

A summary of the erosion classes described below (for a more detailed description, please refer to the erosion inventory worksheets):

1. House Site - there was one area (E,U, 67a, 67b, 68) which was recently regraded and left exposed. Seed/mulching with rip-rap for gulleys was recommended.

2. Streambank - rip-rapping eroding streambanks and constructing sediment traps were recommended for these sites. Of primary concern is E.U. 61, which represents 99 percent of the streambank erosion class total.

3. Roads - regrading and setting down crushed stone is generally the most practical means of reducing sediment transport from umpaved roads. This will also facilitate easier access during the wet seasons. The roads leading to year round residences in the western watershed were in greater need than those leading to summer camps in the eastern watershed. These latter roads are used much less and export only 6 percent of the total road-related sediment.

It should be noted that no benefit/cost type of analysis for BMP installation was performed. It would be appropriate for the State of Vermont to assess the cost effectiveness of sediment and TP loading reductions for each BMP site. Installation of all recommended BMPs has the potential to reduce TP loading from surface inflow by 163 pounds annually; this is 37 percent of the estimated total of TP from surface inflow in 1982. (A point of interest is that E.U. 61 was not eroding in 1982. If this site is deleted, the potential reduction from the recommended BMP installations is 39 pounds, which is a more typical fraction (9 percent) of the TP exported by 1982 surface inflow.)

Discussion/Recommendations

One of the primary motivating factors behind this study was to determine the cause for the overall "elevated" TP loading rates from the western subbasins. With the information developed from this study, two likely explanations for this observation have been formulated:

1. Intermittent streams and drainage courses are continually carving out relatively new channels and, in the process, transporting P-rich sediments to the lake;

2. These sediments tend to be more fertile, compared to those from eastern sub-basins, because in recent history the western sub-basins were extensively used for agricultural purposes; this land was subjected to timber harvesting, grazing, and fertilization. The sub-basin of E-2 is the only exception among the low TP-exporting eastern sub-basins but, consistently, this area was also grazed in recent history.

Hence, if everything remained constant around Lake Iroquois (e.g. no further development), these watercourses would continue to input elevated levels of sediment and TP to the lake until the channels eventually stabilized; at which time the export levels would be comparable to those on the watershed's east side.

However, it seems very unlikely that future residential development will not occur in the watershed. The areas in which this development is possible and/or likely was noted on the inventory worksheets and presented on the "Lake Iroquois Watershed Maps". The areas most likely to be developed are those adjacent to existing roads leading to the lake. Areas that are presently unlikely to be developed may be built upon in the future if road construction occurs, thereby increasing the overall housing density of the watershed. The primary area of future development, however, is probably the west side of the lake, particularly the northern half (sub-basins of W-1 and W-2).

Residential development in the surrounding sub-basins of Lake Iroquois is one of the most critical factors influencing the lake's future trophic state as well as its aesthetic and recreational values. This correlation relates to the lake watershed's drainage behavior. Upon surveying this area, it was clear that this land is rather sensitive to physical changes, especially the land on the west side because of its wet soils and steep slopes.

An important point to make here is that in managing the P loads to the lake, not ony should displaced sediment be reduced, but displaced water as well. Taken on the whole, channel erosion is a major contributor of particulate TP to Lake Iroquois. Increased channel flow due to an increase in impervious land areas, drainage ditch construction, and so on promote this type of erosion. In general, by reducing the infiltration capacity of the land surface, peak flows proportionately increase. To accomodate these increased flows, the draining channel will increase its carrying capacity by eroding its banks. Moreover, virtually all eroding channels were fed by water flowing through culverts, which act to concentrate surface flowing waters.

Thus, in preparing for the future development of areas within the Lake Iroquois watershed, thoughtful water management should be of prime concern. This water planning should emphasize the reduction and dispersal of flowing surface water from construction sites; along with the containment of sediment on site.

The time of year is important in reducing surface water flows. It is preferable to perform short-term construction during the growing season. Otherwise, precautions should be taken to disperse overland flow in accordance with the season. For example, in the spring, an excavated house site can establish grass which anchors the soil from erosion. However, in the fall bare soil is unlikely to "take seed," and silt fences and/or hay bales would be necessary to dissipate on-site overland flows and contain sediment. Other methods of water dispersal include the use of gutters and dry wells. Rather than allowing the concentrated roof flows to run along an eroded channel, this flow is effectively dispersed underground.

These and other possible erosion mitiagting BMPs for a typical construction site of this watershed are depicted in Figure 2 . The landowner's estimated average cost for installation of these erosion control practices is \$250-\$300. Requirements for erosion control and water management should be included in the building permits issued for any significant future construction.

To exhibit the importance of properly treating a typical construction site, a a comparison of erosion rates was made for treated vs. non-treated land. This comparison is shown in Figure 3 (using the USLE) and extended to Table 4 where tons of sediment and pounds of TP export was approximated for four different development scenarios.

Zoning and housing density is another important consideration in planning for the future impacts on the lake. As the housing density surrounding the lake increases, risk of water contamination and intensified peak flows increase also. It would be appropriate to conduct benefit/cost and risk analyses in order to better manage development in the Lake Iroquois watershed. This would further clarify the long-term objectives and desires of town government as well as the landowners and users of the lake.

Another possible management strategy would be to regulate construction in sensitive areas, e.g. sites that are especially wet, close to the lake, or on bedrock precluding adequate septic-leach field systems. Restrictions on building may be circumvented by using somewhat creative technology, such as composting toilets or septic holding tanks.

At present, even though residential development is an important factor, farming practices more markedly influence the trophic state of the lake. The northern sector of the Lake Iroquois watershed (sub-basin of W-0) is used extensively for agricultural purposes. The runoff from this area is relatively high in TP concentrations, most of which is in the form of dissolved phosphorus (P). Dissolved P is the P form which is most available for algae growth (Vollenweider, 1968). Therefore, the P transported in agricultural runoff will more effectively promote algae growth than the soil-associated P from roads and wooded, hayed, and residential lots. This sub-basin is undoubtedly a persistent source of significant amounts of available P to the lake.

Hence, it was determined if there were any further control measures which were feasible to reduce P yields from this agricultural section. This area consisted of two active dairy farms which drain from the north into Lake Iroquois. Both of these farms had runoff problems several years ago due to winter speading of manure and runoff from cropland. In 1979 the Soil Conservation Service entered into long-term contracts with these two farms to decrease runoff into the lake, and subsequently, the Laplatte River as part of a PL-566 project to protect water quality in Shelburne Bay.

Both farmers were very cooperative in participating in the voluntary project. Mr. Degree installed a Manure Storage Structure, diversions. and cropping systems intended to reduce runoff from his farm. Mr. Isham

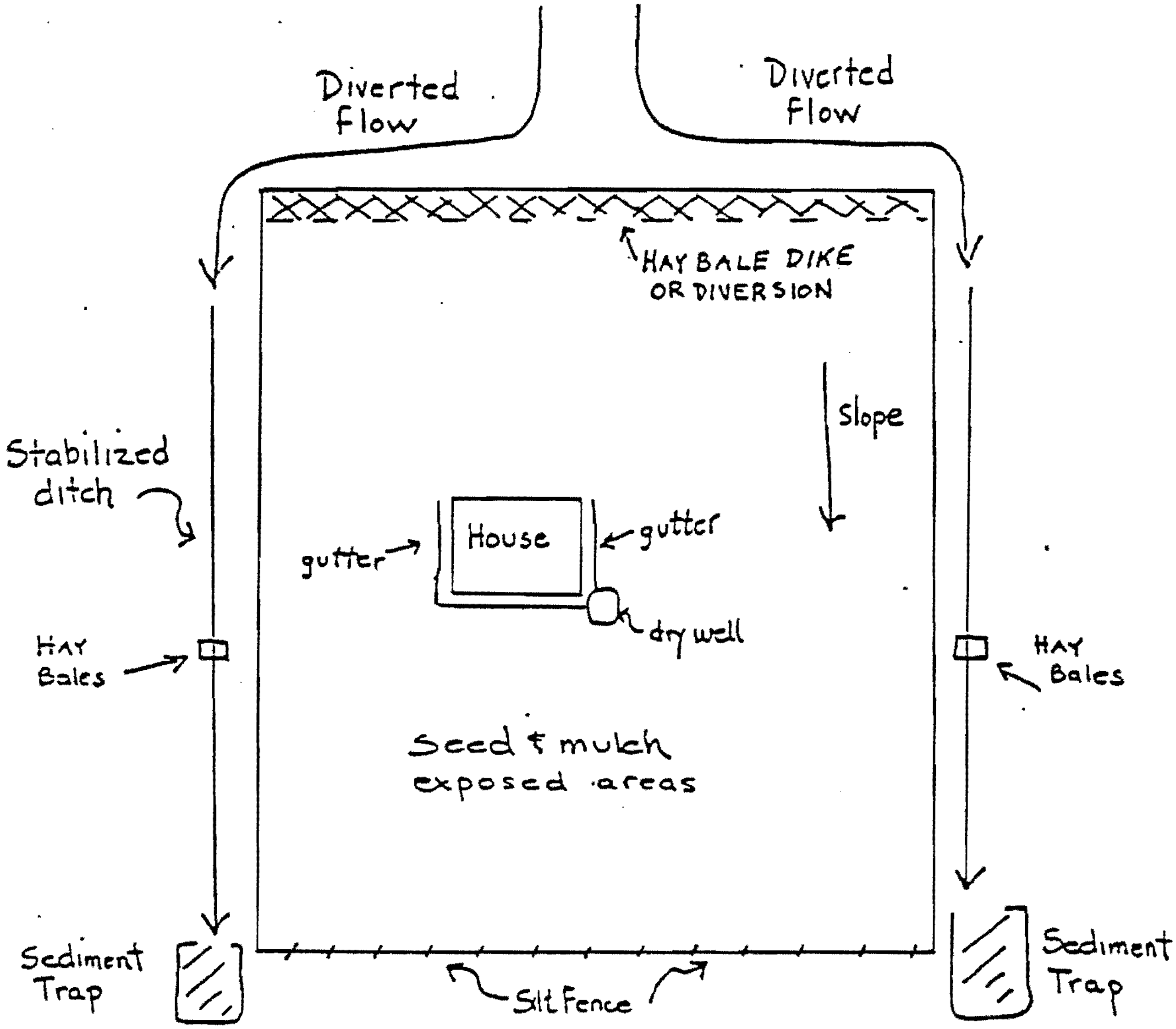


Figure 2 - Typical Erosion Control Plan
For House Site

TYPICAL HOUSE CONSTRUCTION SITE

Assumptions:	disturbed area	1 acre
	slope %	7%
	slope length	200'
	soil erodability (K)	.24
	C factor	.45

A = R*K*LS*C*P

A = 115 * .24 * 1.2 * .45 * 1.0 = 14.9 T/AC/YR

Typically a site would be disturbed for 3 of 9 erosive months/year, therefore, 5 tons could be expected to erode at this site.

If 20%* of the 5 tons produced is delivered then 1 ton of sediment with 2 pounds of TP would be expected to reach the lake.

*This will be highly variable depending on the site.

FIGURE 3 House Site Erosion/TP Potential

Table 4. Sediment/TP Transport From House Construction Sites

	Development Rate	Erosion Control?	-Estimated- tons sediment/yr	lbs of TP/yr
Case 1	3 houses/yr	NO	3	6
Case 2	3 houses/yr	YES	insignificant	insignificant
Case 3	9 houses/yr	NO	9	18
Case 4	9 houses/yr	YES	insignificant	insignificant

also installed a Manure Storage Facility; in addition, he worked on decreasing runoff from his barnyard, seeded steep fields, and adopted a cropping system that minimized erosion. Over the past several years, runoff from these two farms has been reduced considerably.

In spite of the work done on these two farms, there is still some remaining runoff that the State of Vermont has identified as being a potential phosphorus load to Lake Iroquois. In view of this, the farms were visited in May of 1984 to explore the possibility of further reducing runoff from the farms.

Upon visiting the Isham farm, it was determined that there still existed a runoff problem associated with the barnyard, though it is much diminished from previous levels. Barnyard runoff is entering directly into a tributary stream of Lake Iroquois. Regular scraping of the barnyard into the manure pit is practiced but runoff still occurs if rain falls while manure is on the concrete area. Because of the location of the barnyard with respect to the stream, any runoff from the yard easily reaches the stream. The Manure Storage Facility is another possible source of polluted runoff, though volumes are relatively small. Leaks in the perimeter of the storage facility may allow some manure to leak into the stream downslope of the storage facility.

To address the barnyard runoff problem on the Isham farm, it is recommended that more curb and concrete slab for scraping be installed to make scraping the yard more efficient. This would allow more manure to be scraped into the facility and consequently less would be available to runoff into the adjacent brook. In addition, the installation of more curb would eliminate the direct runoff of manure to the brook as it would be trapped at the low point in the curb where there currently exists no impediment to direct runoff. In conjunction with modifications to the barnyard itself, the current intermittent stream channel could be piped underground in low flows and a rock channel could be constructed above to handle peak flows. This would allow a grass filter strip to be constructed to treat water that will inevitably flow over the curb during major storm events.

This recommended work is estimated to decrease runoff from the Isham farm by at least 60% at a cost of about $8,000. The Soil Conservation Service would provide a detailed design at no cost if this work were to be done.

The seepage from the Manure Storage Facility at the Isham farm will be resolved in the summer of 1984 by sealing the storage facility from the inside. This has been done with several other storages with considerable success. Mr. Isham expects to incur this expense himself; estimated cost is $600.

Runoff problems from the Degree farm are primarily limited to polluted runoff from a curtain and underdrain associated with the Manure Storage Facility. It is recommended that this runoff be treated in a filter trench and grass filter field. Similar practices have been installed on other farms with good success.

The cost of the recommended practices would be about $1,700. The Soil Conservation Service would provide technical assistance for the installation at no cost. Installation of the proposed practice should decrease runoff from the drain by 80%.

Discussions with Mr. Isham and Mr. Degree indicated a willingness on their parts to install the practices mentioned in this report if the cost to them was minimal.

Another important source of TP to the lake is from many of the watershed's house lots. Taken individually, existing residential sites tended to have relatively insignificant erosion rates. Nonetheless, when these individually eroding areas were aggregated as a whole, their effect was significant. For example, 44 house sites described as having some sort of lakeshore erosion (mostly bare boat launches) were exporting a total of 1.95 tons of sediment and 3.8 pounds TP to the lake each year. Furthermore, the 21 house sites portrayed as having eroding driveways and other miscellaneous areas were exporting an annual total of 1.04 tons of sediment and 2.0 pounds TP.

The dynamics of this situation is common among areas of environmental degradation, i.e. although an individual's actions are insiginificant in and of themselves, the aggregate effect of many individual actions is significant. In this circumstance, public awareness of the problems created by excessive P inputs to the lake is probably the best means of managing these diffuse sediment-P sources. Although somewhat optimistic, perhaps more homeowners would take responsibility to stabilize their yards, driveways, and/or boat launches if they knew that these actions would improve the water quality and longevity of their lake.

It should be emphasized that this report stems from information gathered during a 1-2 week period of field observations. There is an excellent chance that there have been changes to the watershed since the time of this inventory. The south end of evaluation unit #84 is a prime example of this. Upon a subsequent visit in early June this area had been seriosly altered with the use of a bulldozer. Apparently no sediment control measures of any kind were being used, at the time, as flowing gulleys transported their load of P-laden sediment directly to the adjacent stream, 300 feet upstream from the lake.

In conclusion, it is the aggregation of these kinds of imprudent actions which pose a significant threat to the lake. During the field survey two other areas were described where individuals had taken action to change the landscape (E.U. # (67a,67b,68) and #(61)) and created areas which exported considerable amounts of sediment and TP to the lake. Although the individual significance of these actions may be argued, it must be recognized that (since the lake has a finite volume) it is necessary to mitigate the cumulative effects of human alterations whenever possible. Again, increased public awareness (of landowners and construction crews) and a constant vigilance over this sensitive watershed will be an important part of enhancing the water quality of Lake Iroquois.

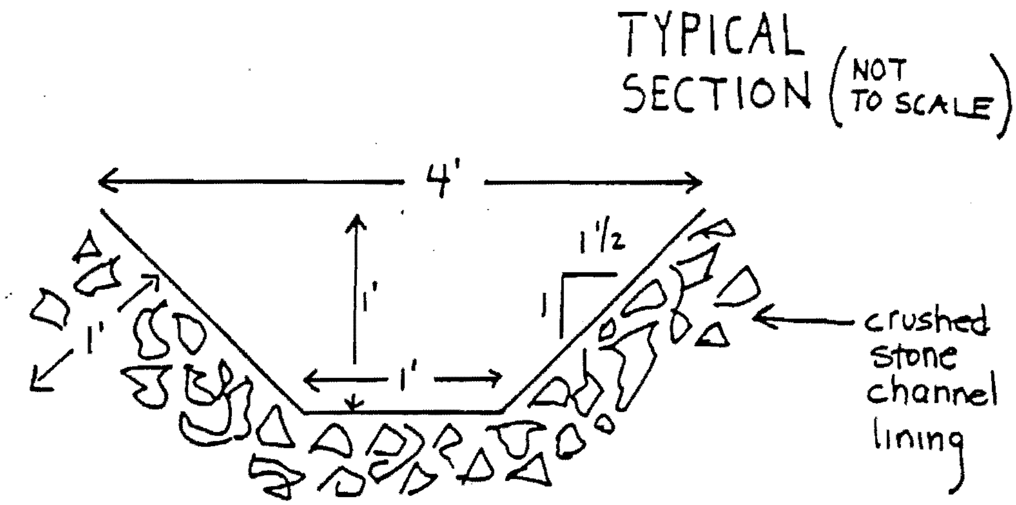
Appendix A. Soil Densities

Volume Wt. (#/ft^3) of Vermont Soils (Ap Horison) (exclusive of particles 2mm or larger)

[B.D. x 62.4 = #/ft^3]

Adams	72 lbs/ft^3	Hadley	84 lbs/ft^3	Peacham	
Agawam	72 "	Hartland	81 "	Peru	72 "
Amenia	94 "	Hinesburg	84 "	Podunk	80 "
Au Gres	69 "	Kendaia	78 "	Pomfret	66 "
Belgrade	66 "	*Kingsbury	90 "	Raynham	84 "
Berkshire	70 "	Lansing	84 "	Rumney	76 "
Binghamville	84 "	Leicester	70 "	St. Albans	70 "
Buxton	66 "	Limerick	81 "	Scantic	71 "
Cabot	56 "	Livingston	84 "	Stetson	72 "
Colrain	70 "	Lordston	78 "	Stockbridge	70 "
Colton	78 "	Lyman	61 "	Stowe	53 "
*Covington	84 "	Macomber	78 "	Sudbury	78 "
Deerfield	69 "	Mansfield	70 "	Swanton	72 "
Dover	78 "	Marlow	72 "	Tunbridge	62 "
Duxbury	69 "	Massena	78 "	Unadilla	84 "
Eldridge	84 "	Melrose	72 "	*Vergennes	87 "
Elmwood	73 "	Middlebury	80 "	Vershire	70 "
Enfield	70 "	Missisquoi	69 "	Westbury	66 "
Enosburg	84 "	Munson	81 "	Whately	41 "
Farmington	78 "	Nellis	90 "	Windsor	69 "
Georgia	70 "	Ondawa	80 "	Winooski	78 "
Glover	43 "	*Panton	53 "	Woodstock	44 "
Groton	70 "				

Stream Stabilization



1.8' + 1.8' + 1.0' = 4.6' x 1' thick x 1' length segment
= 4.6 ft^3/linear foot
= .17 yd^3/ft (linear)

Cost: per 100 feet

Stone	100' x .17yd/ft^3 = 17 yd^3	@ $8.00	$136
Gravel	100' x .08yd/ft^3 = 8 yd^3	@ $3.50	28
Excavation	100' x .20yd/ft^3 = 20 yd^3	@ $3.50	70
			$234
+labor (hand)	5hrs	@ $8/hr	40
	cost per 100'		$274

$2.74/foot

SEDIMENT BASINS

67 yd^3/drainage area acre

10 acre drainage area example:

10 x 67 = 670 yds^3 670 x 27 = 18,090 ft^3
18,090 ft^3 ÷ 5' depth = 3,618 ft^2
= 60' x 60' x 5'

excavation cost:

800 yds^3 @ $1.50	$1,200
rock protection	
50 yds @ $8.00	400
pipe spillway	400
	$2,000
fencing	500
	$2,500

ROAD SURFACE STABILIZATION

14' wide
4" crushed rock (gravel)
100' long segment

14 ÷ 3 x 100 ÷ 27 = 17 yds^3/100 feet segment

17 yds^3 @ $8.00/yd^3 =	$102.00
machine time 1 hr @ 35	35.00
	$137.00

$1.37/foot

SEEDING AND MULCHING

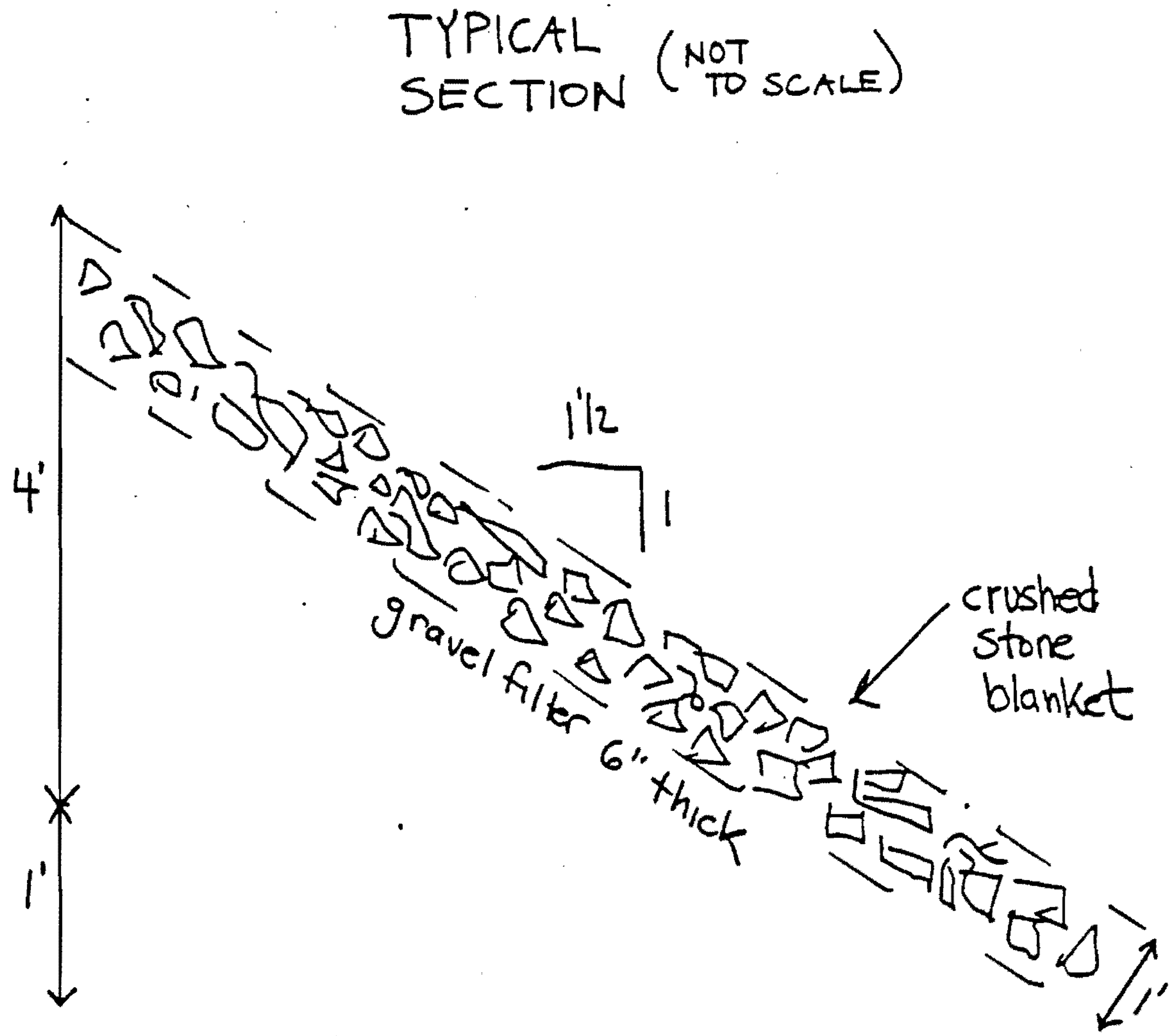
- $ from SCS experience-

$225/acre for small jobs
i.e. less than 3 acres

$200/acre for large jobs + cost of grading & shaping if needed

SILT FENCE AND HAY BALES

Hay Bales	$2.00 each for material
stakes	$2.00/bale
labor	$1.00/bale
	$5.00/bale



9' of rock @ 1' thick @ 100' section

9' x 1' x 100' = 50 yds^3

50 yds^3 stone @ \$8.00/yd^3	\$400
16 yds gravel @ \$3.50/yd^3	56
5 hrs machine time @ \$40	200
	\$656

\$656/100' = \$6.56/foot for 4' above bottom

BIBLIOGRAPHY

Kimberlin, L. and Moldenhauer, W. "Predicting Soil Erosion" in Proceedings of the National Symposium on Soil Erosion and Sedimentation by Water, Michigan: American Socity of Agricultural Engineers, 1977.

Novotny, V. and Chesters, G. Handbook of Nonpoint Pollution, Sources and Management. New York: Van Nostrand Reinhold, Co., 1981.

SCS National Engineering Handbook, (no date)

SCS Technical Guide, 1978

Vollenweider, R. A. "Scientific Fundamentals of Eutrophication of Lakes and Flowing Waters with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication" Report DAS/CSI/68.27. Paris: Organization for Economic Cooperation and Development.

Wischmeier, W. H., Johnson, C. B., and Cross, B. V. "A Soil Erodability Monograph for Farmland and Construction Sites" J. Soil Water Conservation. 26(5): 189-194, 1971.