GEOGRAPHICAL PAPER No. 48

Roadside Erosion and Resource Implications in Prince Edward Island

Gail de Belle

POLICY RESEARCH and COORDINATION BRANCH

Department of Energy, Mines and Resources
Ottawa, Canada

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With special reference to western Prince County

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A report of a project forming part of a land use planning program supported by the Canada Land Inventory, Department of Regional Economic Expansion, and the Province of Prince Edward Island.

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Preface

In March 1969, the governments of Canada and Prince Edward Island signed a 15-year Development Plan for the province. In the preparation of the comprehensive development strategy for the Plan, the Economic Geography Section in what is now the Policy Research and Coordination Branch was requested to undertake a number of research studies. Miss de Belle's paper describes one such investigation, which was related to the program of highway improvement. The development plan provides for the expenditure of approximately $15 million on road construction, rebuilding and improvement. It had become apparent from previous highway improvement, however, that serious problems existed in regard to erosion, especially along the unseeded margins of new or rebuilt roads. Damage from erosion is a potential threat to road safety and is expensive to repair; the eroded material also has adverse effects on the water and other resources of the surrounding area. With the cooperation of the P.E.I. Department of Highways, Miss de Belle was able to make a sample study of the qualitative and quantitative effects of such erosion, which is likely to be of value to highway planning and construction in other parts of Canada.

Similar reports of individual research studies are being published in this series. Although none are likely to bear the name of Charles W. Raymond on the title page, each of the authors concerned wishes to recognize the debt owed to his vision and encouragement in the inception and completion of the research work. In a very real sense, he is the author of all the research investigations undertaken by the Economic Geography Section in the Maritime Provinces in recent years.

J.W. MacNeill
Director
Policy Research and Coordination Branch

Abstract

This study focuses attention on the seriousness of roadside erosion in Prince Edward Island. Until very recently, provincial highway construction and road improvement were not accompanied by practices to prevent roadside erosion. This has resulted in the development of an erosion problem of fairly widespread proportions.

Roadside erosion was classified and mapped along the entire paved road network in the western portion of the province, in order to demonstrate the magnitude of the problem in a specific area and to illustrate that the omission of control measures can have serious consequences. Not only is damage caused to the traffic pavement and the road shoulder, but sideslopes and backslopes are altered due to loss of surface material and gullying, and increased quantities of sediment lead to clogging of ditches and can have adverse effects on water and other resources. A high degree of road and roadside maintenance is required.

The final section of this report is concerned with the control of roadside erosion. Seeding of roadsides is emphasized, using operations in Nova Scotia as an example, and some other techniques are briefly introduced. It is shown that the cost of basic erosion control is minimal in comparison to total road construction costs.

Préface

Au mois de mars 1969, les gouvernements du Canada et de l'Île-du-Prince-Édouard ont signé une entente d'une durée de 15 ans pour la mise en oeuvre d'un programme d'expansion dans la province. Au cours de la phase initiale du programme, on a sollicité la Section de la géographie économique de la Direction de l'étude des politiques et de la coordination d'entreprendre une série d'études préparatoires à l'élaboration du plan. L'article de Mlle de Belle décrit un travail de recherches, relatif au programme d'amélioration du système routier. Le plan d'aménagement prévoit des dépenses de l'ordre de 15 millions de dollars pour la construction, la reconstruction et l'amélioration des routes. A la suite des améliorations précédentes de routes, il semblait cependant qu'il existait de sérieux problèmes d'érosions, particulièrement le long des bordures non gazonnées des nouvelles routes ou des routes reconstruites. Le dommage causé par l'érosion est une menace possible à la sécurité routière et coûte cher à réparer. Le matériel érodé exerce également des effets nocifs sur les eaux et les autres ressources avoisinantes. Avec la collaboration du ministère de la Voirie de l'Île-du-Prince-Édouard, Mlle de Belle a pu effectuer pour la première fois une étude des effets quantitatifs et qualitatifs d'une telle érosion; cette étude aura probablement une grande valeur dans la planification et la construction des routes ailleurs au Canada.

D'autres rapports semblables sur des recherches individuelles sont publiés dans la présente série. Bien que vraisemblablement aucun ne portera à la page frontispice le nom de Charles W. Raymond, chaque auteur reconnaît qu'il doit beaucoup à ses conseils et à ses encouragements dans l'élaboration et l'exécution de ce travail de recherches. Dans un sens, il est le véritable auteur des études entreprises par la Section de la géographie économique dans les provinces Maritimes ces dernières années.

J.W. MacNeill
Directeur
Direction de l'étude des
politiques et de la coordination

Résumé

Le but de la présente étude est d'attirer l'attention sur le sérieux problème de l'érosion des bordures de routes dans l'Île-du-Prince-Édouard. Jusqu'à tout récemment, la construction des routes provinciales et les travaux d'amélioration ne s'accompagnaient pratiquement d'aucune technique spéciale destinée à prévenir l'érosion des abords de routes. Le résultat de cette carence a été l'apparition d'un problème d'érosion aux proportions assez étendues.

L'auteur a classifié et cartographié le degré d'érosion des bordures de routes pour l'ensemble du réseau asphalté de la partie occidentale de la province, afin de montrer l'importance du problème dans une région déterminée et de démontrer les conséquences sérieuses que peut entraîner l'absence de mesures de contrôle appropriées.

Il ne s'agit pas seulement des détériorations causées à la chaussée et aux accotements, mais encore des modifications subies par les talus et les terrassements du fait de la perte des matériaux de surface et du ravinement, à quoi il faut ajouter un volume croissant de sédiments qui obstruent les fossés et peuvent avoir des effets défavorables sur les eaux et autres ressources. Un sérieux entretien des routes et de leurs abords demeure nécessaire.

La dernière partie du rapport traite du contrôle de l'érosion des bordures de routes. L'auteur insiste sur le gazonnement des accotements, citant en exemple certaines réalisations en Nouvelle-Écosse, et présente brièvement d'autres techniques. Le rapport suggère finalement que le coût du contrôle de l'érosion est minime en comparaison au coût total de la construction d'une route.

Acknowledgments

The author wishes to thank several individuals and agencies for assistance in various stages of the project: C. W. Raymond, former Head of the Atlantic Region Section, Planning Division of the Policy and Planning Branch, Department of Energy, Mines and Resources, for the proposal and direction of the study; R. Donnelly, engineer, Department of Regional Economic Expansion, for considerable assistance in survey and report planning stages and for literature; G. Dargie, soil scientist, P.E.I. Department of Development, for technical advice on soil erosion and control measures; G. White, Deputy Minister, and B. Scott, engineer, P.E.I. Department of Highways, for essential data on road construction and maintenance; N.S. Department of Highways for further information; R. Drinnan, Fisheries Research Board of Canada, Bedford Institute, N.S., for information on siltation; the Engineering Services of the Department of Regional Economic Expansion, Amherst, N.S., for valuable photo-mosaics; and Dr. C. I. Jackson, Head of the Economic Geography Section of the Department of Energy, Mines and Resources, for assistance in directing and editing the final report. To all of these, and others, the author expresses gratitude.

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with special reference to western Prince County

*Gail de Belle**

Introduction

A crucial problem of long standing in Prince Edward Island has been that of roadside erosion and its effects, since an erosion control policy has not traditionally formed part of the highways program. Various government departments and university officials within the province indicated concern over this situation in the past; however, no attempt was made to adequately document the problem, nor was a policy developed by the appropriate provincial authorities to deter roadside erosion.

The Government of Canada has become increasingly concerned with environmental quality and with the protection of natural resources in the country from pollution and other detrimental factors. Erosion is one of the problems to be considered. This led the Department of Energy, Mines and Resources to undertake a survey of roadside erosion in P.E.I. in 1969. The purpose was to investigate and demonstrate the magnitude of the erosion problem in the hope of influencing the implementation of an active program of roadside erosion control within the province. It should be mentioned that, subsequent to the completion of the survey, the P.E.I. Department of Highways purchased a hydroseeder and commenced roadside seeding operations in the summer of 1970.

The field survey in 1969 was limited to mapping and providing quantitative measures of the extent of erosion and deposition along the paved road network in the western portion of P.E.I. Although most of the accompanying photographs provide examples of conditions encountered in the west, others have been drawn from central and eastern areas to illustrate that the problem is indeed widespread.

Road construction and the erosion problem in Prince Edward Island

The Province of Prince Edward Island, approximately 2,200 square miles in area, has a very dense road network. There is no tradition of roadside seeding by the province, nor is there much evidence of the application of erosion-control design for structures and embankments. Furthermore, many slopes have not always been adequately compacted and finished. Hence, construction sites have normally been left unprotected and consequently remained open to erosion until a vegetation cover established itself by natural means. In many instances, indications suggest that five years may lapse before 50 per cent of the surface area is covered with vegetation, and that it may take up to ten years, or even longer, depending upon local conditions, before a complete cover develops. Thus, it was generally believed that a fairly severe roadside erosion problem existed in the province, particularly in view of the considerable amount of road improvement and paving carried out each year (Table 1).

Numerous factors influence the rate and extent of roadside erosion. These include soil type and susceptibility to erosion, amount and intensity of rainfall, amount and velocity of runoff, slope length and gradient, amount of vegetation present, and frequency and severity of freeze-thaw phenomena. Melting snow-

*Economic Geography Section, Policy Research and Coordination Branch, Department of Energy, Mines and Resources.

Table 1

Rural road improvement and road paving program in P.E.I.

Year	Total paved roads (Miles)	Increase of paved roads (Miles)	Total improved roads (Miles)	Total unimproved roads (Miles)	National park roads (Miles)	Total paved and unpaved roads (Miles)
1956	362.9		1406.1	1410.0	15.5	3194.5
1959	635.6	272.7	1656.8	904.9	15.5	3212.8
1961	860.4	224.8	1552.9	782.4	15.5	3211.2
1962	962.0	101.6	1483.3	750.4	15.5	3211.2
1963	1044.4	82.4	1442.1	711.3	15.5	3213.3
1964	1114.3	69.9	1396.2	688.4	15.5	3214.4
1965	1184.8	70.5	1352.1	665.0	15.5	3217.4
1966	1309.6	124.8	1245.5	646.8	15.5	3217.4
1967	1368.3	58.7	1195.6	638.0	15.5	3217.4
1968	1393.1	24.8	1183.7	629.0	21.6	3227.4
1969	1484.8	91.7	1096.5	624.5	21.6	3227.4

Source: **Department of Highways, Prince Edward Island.**

banks, piled up along the roadside, also contribute to high runoff in springtime. From a comparable area, the annual soil loss from exposed roadsides greatly exceeds that from forested and cultivated land.

When road construction sites are left bare of vegetation, erosion develops within the right-of-way: on the road shoulders, the sideslopes (foreslopes) extending from the edge of the shoulder to the ditch, and on the backslopes (Figures 1, 4 and 14). Embankments at stream crossings are particularly critical sites for erosion. The width of the right-of-way in the province is 66 feet for standard two-lane roads, and 100 feet along arterial highways (such as the Trans-Canada and the Western Road), involving an average of 5 acres and 8 acres of bare roadside surface respectively per mile of road paving. Depending upon construction requirements and standards, road building and paving costs per mile in Prince Edward Island range roughly between $40,000–$84,000 for standard roads, and $96,000–$120,000 for arterial highways approaching all weather standards (1).

The bedrock from which P.E.I. soils have developed is mainly sedimentary sandstone, most of which is soft, friable and easily weathered. The fill commonly used in road construction consists largely of sandy-clay subsoil and soft broken sandstone, which is moderate to highly erodable.

In the absence of erosion control, much surface material is lost from unprotected roadsides, gullying develops, road surfaces and adjacent structures are affected, and excessive deposition occurs in ditches. Consequently, increased maintenance of roads and roadsides is required. Other results include the downgrading of the roadside landscape, increased sedimentation in streams, ponds and estuaries, and adverse effects on water flora and fauna. Equally serious is the development of highway conditions unsafe for motorists, such as low shoulders, pitted pavement margins, and shoulder gullies. Various examples are given in accompanying photographs.

The study area: western Prince County

The area surveyed in detail was western Prince County, that part of the province lying west of Summerside (Figure 5). The field study was undertaken in June and July 1969 along all paved roads, which totalled some 305 miles. Following completion of the survey, an additional 15 miles of loose surface roads were paved in the region in 1969.

The landscape of western Prince County is a mixture of forest and farmland. Topography is flat to gently undulating. While more spectacular erosion would be expected in the hilly central portion of the province, extensive roadside erosion also develops along roads passing through relatively flat terrain—in effect, wherever construction sites are left unprotected.

Summerside has a mean annual temperature of 42°F, and an average annual frost free period of about 150 days. Mean annual precipitation in western Prince County ranges between 38 and 40 inches. Runoff has been estimated to be from 23 to 25 inches per year (2). Erosion control assumes particular importance, in view of the high runoff coupled with local soil characteristics.

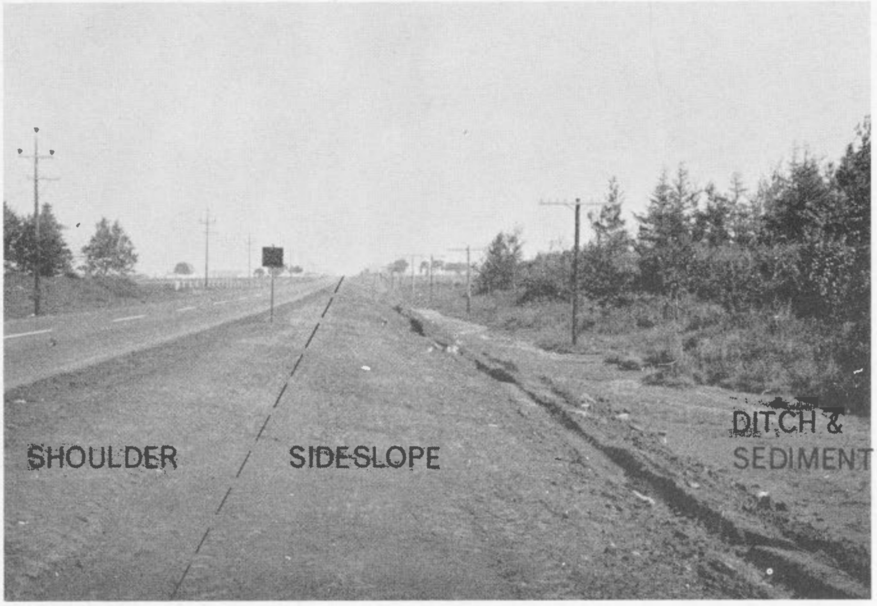

FIGURE 1. Western Road, western Prince County. Sheet erosion (Class 1) on the shoulder and sideslope. Note deposition in ditch at right. The sign reads: "Danger – Soft Shoulder".

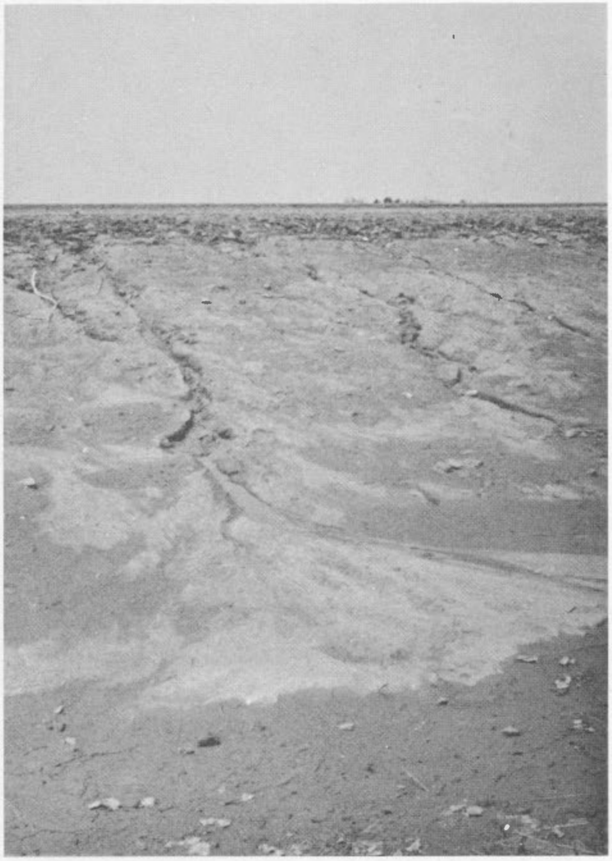

FIGURE 2. Western Road, western Prince County, near Elmsdale. Rill erosion (Class 2) on the sideslope. Note fan-shaped deposit.

FIGURE 3. Western Road, western Prince County. Initial gully erosion (Class 3) on sideslope. Gully 10" deep and 1'6"–2' across.

FIGURE 4. Western Road, western Prince County, near Carleton. Rill erosion (Class 2) on the backslope.

Methodology

Roadside erosion classification

A general classification was devised to identify and map the occurrence of erosion and to quantify the extent of the problem in western Prince County. The classification adopted is presented in Table 2. It is not intended to imply that all roadside erosion can be conveniently classified into these categories, nor that the categories are always clearly distinct from each other. A transition from one class to another occurs, and often a combination of characteristics of different classes may be found, although certain criteria are normally much more pronounced than others. This classification, however, based in part on simple measurements, suited the purpose of this particular survey, and provided a convenient, rapid and effective means to map and describe the relative severity of erosion.

Sheet erosion involves the detachment and removal of a thin layer of particles; occasionally a few minute, widely-spaced channels may be present (Figure 1). Rill erosion develops quickly, and is characterized by an organized runoff pattern consisting of a rill network, with individual channels measuring up to six inches in depth (Figures 2 and 4). Unless checked, this may progress to gully erosion (Figures 3, 6 and 13) although rill erosion is often present on the surface area between gullies. Sliding, slumping, or other forms of slope failure or mass movement may also contribute to the development of enlarged gullies or depressions (Figures 8, 10, 11 and 12).

Table 2

Roadside erosion classification

Erosion class	Definition
1	Sheet erosion. Minute rivulets occasionally present.
2	Rill erosion. Rill pattern present, with rills up to six inches deep.
3	Initial gully erosion. Presence of numerous small gullies between six inches and twelve inches deep.
4	Marked gully erosion. Presence of numerous gullies between one foot and two feet deep.
5	Advanced erosion. Presence of gullies or depressions over two feet deep.

Photo-mosaic mapping base

An excellent mapping base for a survey of this nature is a large-scale air-photo mosaic; a complete coverage at a scale of 1 inch equals 1,500 feet was provided for the study by the Engineering Services of the federal Department of Regional Economic Expansion, Amherst, Nova Scotia. The use of photo-mosaics facilitates orientation in the field and enables rapid and precise mapping. It also makes possible, in place of time-consuming field measurements, linear air-photo measurements of site distances. These, in conjunction with field data, provide quantitative measures on the extent of erosion and sediment accumulation in ditches, and are useful for estimating erosion prevention costs.

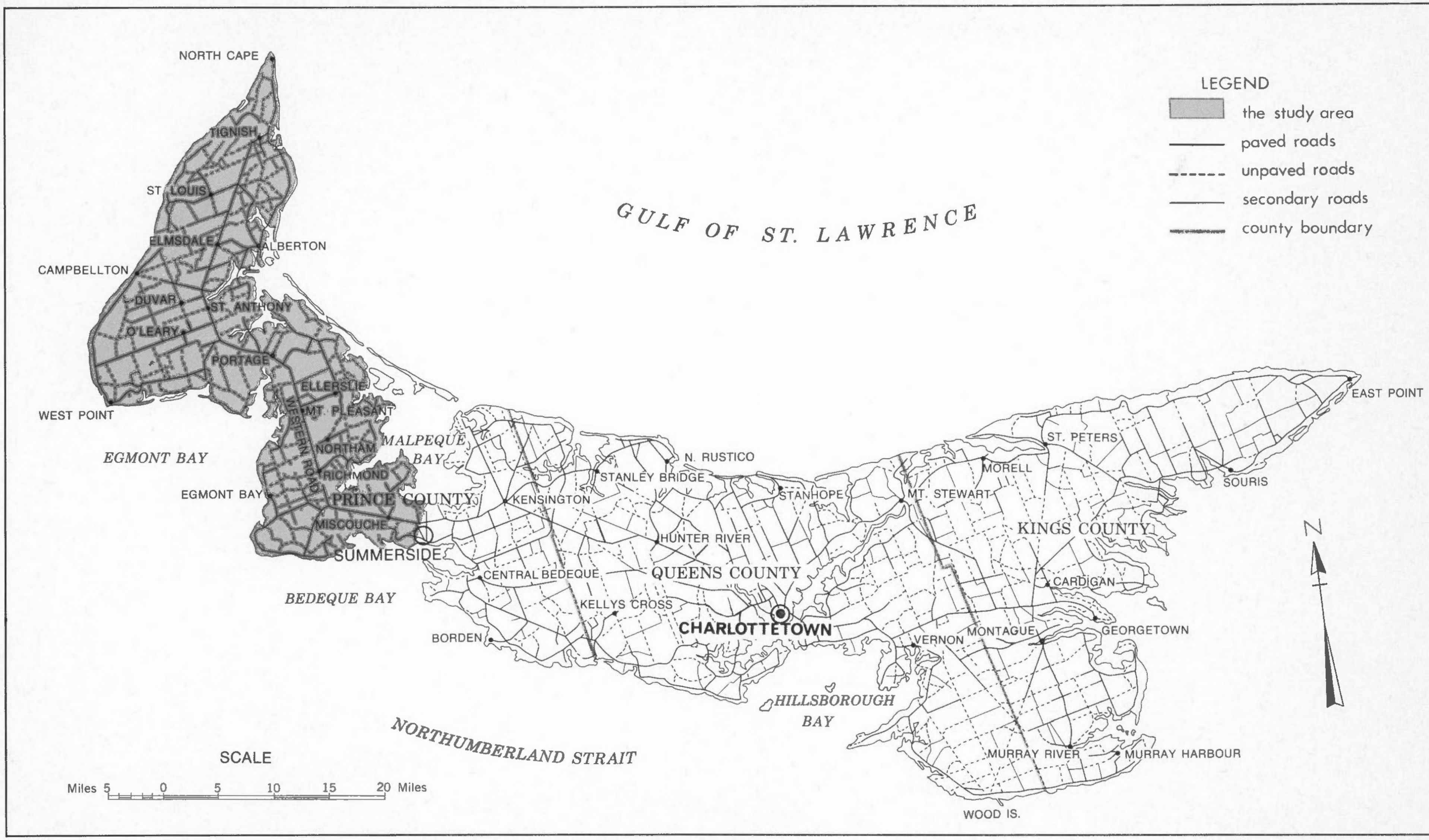

FIGURE 5. Location of study area, western Prince County, P.E.I.

Field code and mapping procedures

The code used for rapid mapping in the field is explained and illustrated for a sample area in Figure 9. In addition to identifying the class of erosion present, the code also indicates the location (shoulder, sideslope, or backslope, on one or both sides of the road), shoulder and slope measurements, amount of vegetation cover, slope ratio (horizontal to vertical), depth and surface extent of ditch sediment, and gully dimensions. A significant change in any one of these elements (and the corresponding code) was indicated accordingly on mosaics.

Field measurements were recorded on shoulder width, length of sideslope and backslope, gully size and sediment in ditches (depth and surface extent of deposit across the ditch). As indicated previously, the linear extent of erosion and ditch sediment along paved roads (i.e. site distances) was determined from air-photo measurements.

The notation 1E2E4/12/10′-20′/V0-0/4:1/S2′6″•5′/-G1′ 2″•1′8″ (the code shown on the lower right-hand corner of Figure 9) indicates the following: erosion is present on one side (the east side) of the highway; Class 2 (rill erosion) and Class 4 (marked gully erosion) are found on the shoulder and sideslope respectively; the former measures 10 feet from the edge of the pavement and the latter measures 20 feet downslope; vegetation is totally absent on both the shoulder and sideslope; a slope ratio of 4:1 exists; sediment in the ditch extends to a depth of 2 feet 6 inches to the base of the channel and averages 5 feet across in surface extent; the average dimensions of the Class 4 gullies present are 1 foot 2 inches in depth and 1 foot 8 inches in width.

The extent of roadside erosion in western Prince County

The extent of roadside erosion along the paved road network west of Summerside is illustrated on the accompanying fold-out map (Figure 14). Some 60 sites are indicated, and details on the extent of all classes of erosion at these sites are contained in the Appendix.

FIGURE 6. Northam Road, western Prince County. Initial gully erosion (Class 3) on sideslope. Small gullies 9″ in depth beginning to coalesce.

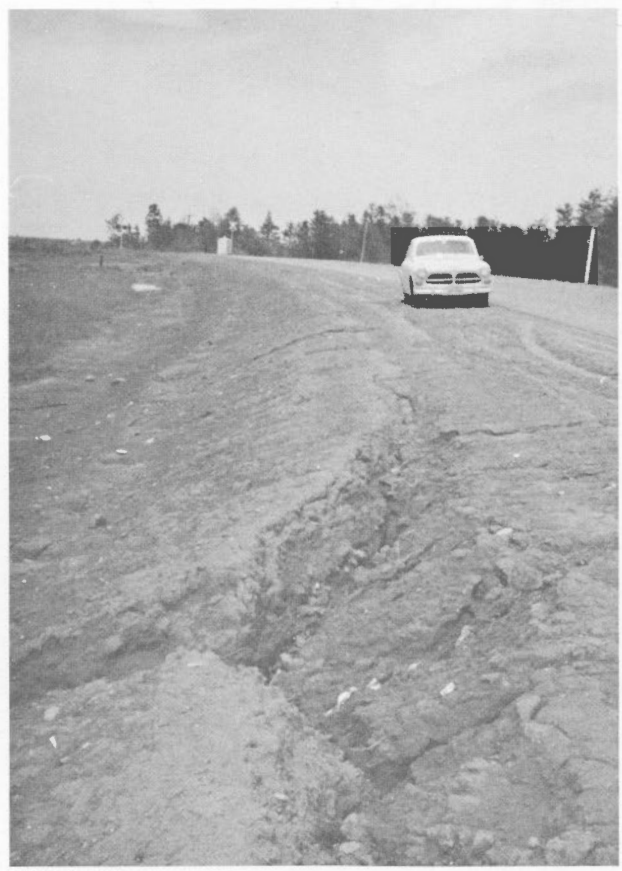

FIGURE 7. Western Prince County. Sideslope gully 3′ in depth beginning to eat into the shoulder of the road.

Most of these sites consist of a number of restricted sub-sites which were mapped in the field as individual road segments and which were later grouped together for summation purposes and to produce a single, simplified map of erosion. Sub-sites aggregated were normally contiguous strips. In a few cases, separate areas were grouped together due to similarities in the class or degree of erosion (e.g. sites 1 and 2).

The field survey revealed that fully 57 miles, i.e. 18.7%, of the 305 miles of paved roads in western Prince County were affected by some degree of erosion in June and July. By the late fall of 1969, an additional 15 miles of roads had been paved, and since seeding and other erosion-control practices were not carried out, it is a valid assumption that 22.5% of the total paved road mileage (i.e. 72 of 320 miles of paved roads) exhibited erosion. The surface area which was undergoing erosion in 1969 is presented in Table 3.

Table 3

Surface area (in acres) undergoing erosion along paved roads in western Prince County, P.E.I., 1969

Erosion class	Shoulder	Sideslope	Backslope	Total
1	93.7	39.0	1.0	133.7
2	25.5	95.8	.7	122.0
3	2.2	17.2	.2	19.6
4	.6	5.8	–	6.4
5	.3	1.4	–	1.7
June-July	122.3	159.2	1.9	283.4*
November				358.4**

* Total roadside acreage undergoing erosion, along 57 of the 305 miles of paved roads which existed in June and July.

** Estimate of total roadside acreage undergoing erosion, along 72 of the 320 miles of paved roads which existed in November.

Table 4

Location and gully dimensions of marked gully erosion (Class 4) in western Prince County, P.E.I.

Site number	Gully depth	Gully width
36	1'-1' 11"	1'-2'8"
52	1'1"	3'
56	1'1"	3'
26	1'2"-1'6"	1'6"-2'6"
22	1'3"	2'
23	1'3"-1'7"	2'-4'
47	1'5"	1'9"
20	1'6"	2'6"
31	1'8"	2'
21	1'8"	2'6"
13	1'8"	3'
25	1'11"	3'

Table 5

Location and gully/depression dimensions of advanced erosion (Class 5) in western Prince County, P.E.I.

Site number	Average gully/depression depth	Average gully/depression width
48	2'	4'
50	2'2"	5'
23	2'3"	3'
46	2'6"	4'
18	2'6"	4'
31	3'6"	5'
7	3'6"	6'6"
26	3'8"	7'
22	4'	7'
28	5'	6'
41	6'	19'

It is evident, from Table 3, that sheet and rill erosion are especially widespread on shoulders and sideslopes. The inclined foreslopes, in particular, are subject to noticeable rill and small gully erosion. Most of this erosion was found to occur along recently constructed roads, especially along the arterial Western Road.

While the total surface area of Classes 4 and 5 erosion is minimal in comparison to that of other classes, Tables 4 and 5 demonstrate that numerous (although restricted) sites are affected and that roadside gullies can reach surprising proportions. Marked gully erosion (Class 4) and advanced erosion (Class 5) were encountered at 12 and 11 sites respectively in western Prince County. Figure 15 pinpoints the occurrence of advanced erosion, Class 5, since the fold-out map (Figure 14) has been generalized and does not reveal the precise location of all the 11 areas.

In most cases, advanced erosion (Class 5) was found associated with stream crossings, where slopes tend to be long and steep, where culverts offer a focus for erosion, and where the flowing stream itself may also exert an erosive effect at slope bases by undermining banks. Large gullies are also found elsewhere in the province: one near Montague, in Kings County in eastern P.E.I. measured 10 feet deep and 13 feet across (Figure 12).

The effects of roadside erosion

Sediment production and deposition

Rates of sediment production were not examined in the Prince Edward Island survey, largely due to time constraints, but also because a number of research studies on this subject have already been undertaken elsewhere. These investigations have shown that the quantity of sediment which may be derived on a unit

FIGURE 8. St. Anthony-Mill Road, western Prince County. Severe erosion (Class 5) on a long side-slope at a stream crossing. Note road guard rail above.

basis each year from exposed construction sites, such as urban development and roadside areas, greatly exceeds that originating from wooded watersheds and forested rural or agricultural land. The total source area composed of such construction sites, however, is really quite limited in comparison to that of agricultural land. Wadleigh (3) cites a study of the Potomac River area by Wark and Keller which indicates that sediment contribution from watersheds in forested regions was only between 20-100 tons/mi.^{2} /yr. A survey undertaken by Wolman and Schick (4) revealed that sediment yields from urban and suburban construction sites range from 1,000 to roughly 100,000 tons/mi.^{2}/yr., in comparison with 500 tons/mi.^{2}/yr. from Piedmont farming areas of Maryland. In one case construction site data extrapolated to a square mile gave a yield estimate as high as 140,000 tons/mi.^{2}/yr. The maximum soil loss tolerance rates from agricultural land in the United States range from 1-5 tons/acre/yr., i.e. 640-3,200 tons/mi.^{2}/yr., depending upon topography, soil properties, and prior erosion (5). Research by Diseker and Richardson (6) on roadside erosion and sediment production in Georgia has shown results comparable to those of Wolman and Schick, a material loss in the order of 50,000-150,000 tons/mi.^{2}/yr.

It was possible in the P.E.I. survey to rapidly obtain data on the extent of deposition immediately adjacent to sideslopes; general observations were also made of deposition in water bodies (Figures 18 to 21). The measurements of deposition in ditches in western Prince County emphasize the enormity of the problem of roadside erosion and sediment production. The most extensive deposition was encountered along the Western Road, including those sections which traverse relatively flat, forested countryside (this clearly points to the road construction site itself as the predominant source of sediment throughout much of the region). The maximum concentration of eroded material in ditches, found near Portage along the Western Road, measured 3 feet 2 inches in depth (at the centre of the ditch channel) and between 15 and 20 feet across the ditch (Figure 18). The road section from Miscouche to Carleton, which had been recently improved and was still under construction in parts, was selected to determine the total volume of eroded material accumulated in ditches at the time of the survey (Table 6). Deposits were present along 23.7 miles of road, almost the total distance from Miscouche to Carleton.

Table 6

Quantity of sediment accumulated in ditches, Miscouche to Carleton, Western Road, western Prince County, P.E.I.

Site number	Quantity (cu. ft.)
28	97,876
30	146,688
34	5,180
35	67,229
36	84,835
16	251,862
37	26,424
38	1,256
39	7,737
41	23
Total	689,110 cu. ft. = 25,523 cu. yds.

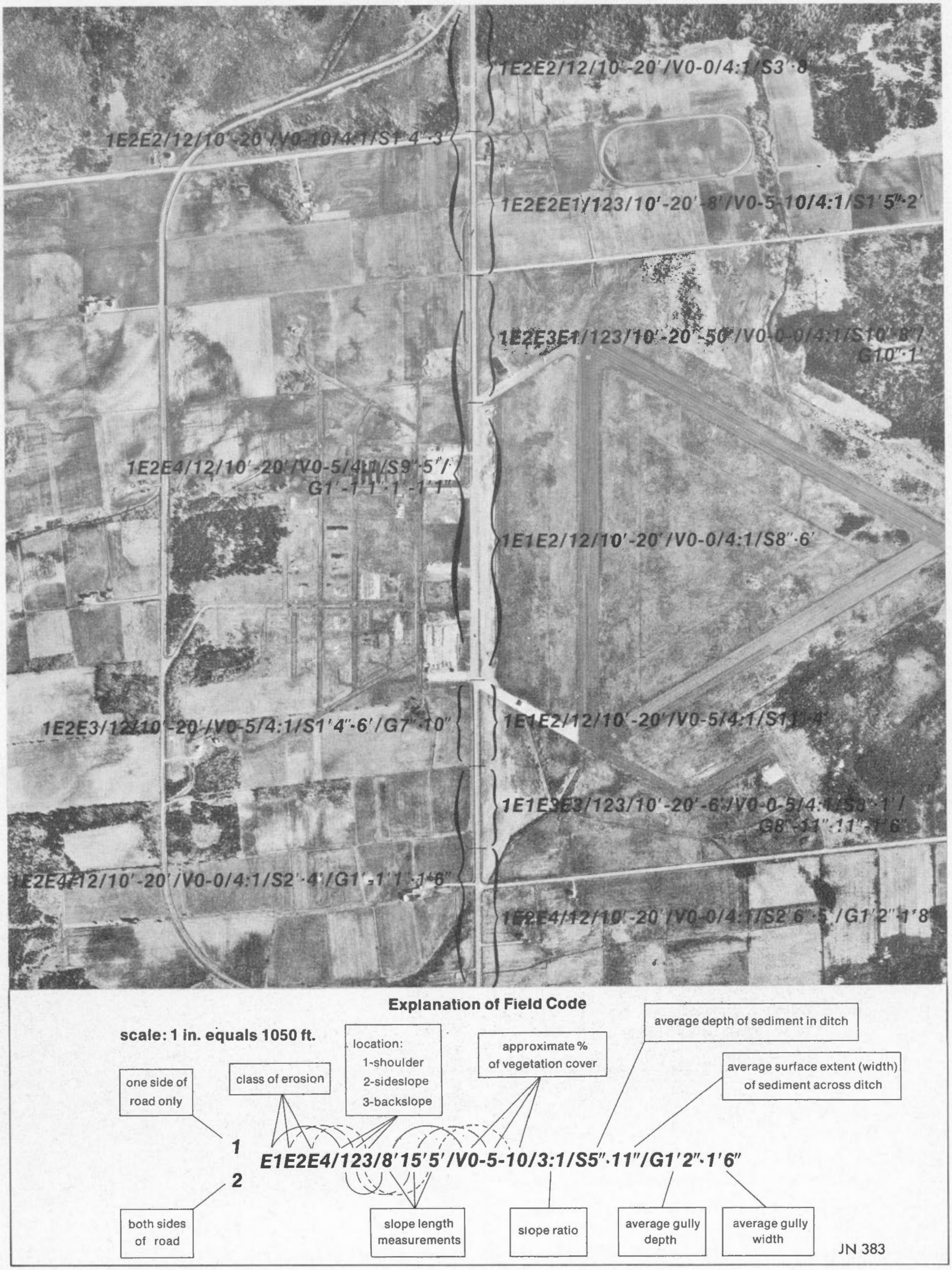

FIGURE 9. Field code and mapping sample-section of the Western Road (Mt. Pleasant area), western Prince County, P.E.I.

In order to estimate the volume of sediment, it was assumed that the shape or cross-sectional area of the ditch approaches that of a parabolic curve. Therefore, the volume of sediment present in ditches was calculated using the parabolic cross-sectional area equation, as follows.

$$V = \frac{2ab}{3} \times D$$

where, V = Volume (cu. ft.)
a = average extent of sediment across the channel (ft.)
b = average depth of sediment at the centre of the channel (ft.)
D = distance along highway (ft.)

If we take 115 pounds as the unit weight of 1 cu. ft. of typical eroded material in its natural state, i.e. *in situ* (7), then 1 cu. yd. of sediment equals 3,105 pounds, or approximately 1.6 tons. In other words, there were roughly 40,000 tons of sediment present along this 23.7 miles section of the Western Road, an average of 1,670 tons per mile of paved road. The maximum concentration on an overall site basis was encountered at site No. 16, amounting to 3,218 tons per mile (averaged over the total site distance of 4.5 miles along the highway). This visible on-site accumulation, however, is only part of the picture, since vast quantities of sediment have been and are constantly being transported from these sites.

Impacts on water resources and aquatic life

Much of the sediment eroded from roadside surfaces is delivered to water bodies (Figures 11 and 20). Many roadbanks, in fact, drain directly into streams and ponds, and this results in many water bodies, both natural and artificial, becoming rapidly filled with silt. That this situation is indeed serious and widespread is borne out by a recent stream survey of western Prince County, sponsored by the provincial Department of Fisheries, which indicates that a high percentage of streams are already so heavily silted that trout production could be significantly suppressed (8).

Increased siltation induces various changes in the physical characteristics of water bodies and changes in their plant and animal communities. Among the important physical controls of aquatic habitats are chemical and physical qualities of water, the temperature, depth and movement of water, light penetration, and the character of the bottom. Large quantities of sediment influence the erosion process as well as the deposition and overflow patterns of streams. Heavy loads reduce light penetration upon which photosynthesis is dependent. Gravel beds used for spawning may be blanketed and eliminated by sediment. Deposition sometimes buries individual organisms or even communities, and may lead to an increase in water temperature due to a decrease in water depth. Alterations generated in the primary stages of the food chain, namely aquatic plant communities and invertebrate populations, affect fish, fur bearers and waterfowl species which rely upon the primary sources for food and cover. Thus, siltation can lead to a loss or change in recreation resources.

Siltation has had and continues to have a noticeable effect on the Island's oyster industry. A marked decrease in both quantity and quality of oyster production in many areas has been associated with increase of silt deposits. Considerable research on siltation, from both the physical and biological viewpoints, has been carried out under the auspices of the Bedford Institute of Oceanography and the Fisheries Research Board of Canada at the Biological Station at Ellerslie, P.E.I. Thomas (9) has demonstrated the changes of fauna associated with change in bottom type in a six-year study of Bideford River, and his results suggest that over the past 100 to 200 years the estuary has changed from being virtually entirely a hard-bottom oyster bed community to one in which only three per cent can be so designated at present. Sedimentological studies by Buckley (10) involving analyses of core samples suggest average deposition rates of one half to one and a half inches per year, and it appears that the rate of deposition has been increasing. Drinnan (11) has further observed that:

FIGURE 10. St. Anthony-Mill Road, western Prince County. Advanced erosion (Class 5) at stream crossing. Note stream at bottom right-hand corner.

Apart from the obvious gross effects on the estuarine communities there are other phenomena which play an important role in the productivity of commercial molluscs. Silt in suspension affects the feeding of oysters, and its deposition on surfaces settled by young oysters is an important factor in their mortality. Deposition of silt by fall rains or spring run-off may adversely affect the normal regeneration of inorganic nutrients from bottom deposits and hence overall estuarine productivity. The records of forty years observation at Ellerslie show a progressive decline in the fatness of oysters and a decrease in the reliability of successful oyster recruitment, which may be associated with such phenomena.

Road construction sites and borrow pits are, of course, only one source of sediment. About 80 per cent of the watershed immediately surrounding the Bideford drainage system consists of cultivated land and pasture (12), and large quantities of sediment are derived from these surfaces. Farmland extends to the banks of the Bideford River. The remainder of the watershed consists of a peat marsh and timbered areas.

Road and roadside deterioration and maintenance

Allowing erosive processes to operate unchecked may result in serious deterioration in the condition of road shoulders and sideslopes, damage to guide post and guard rail bases, fence lines and bridge structures, and sometimes the road base and asphalt surface itself. Not infrequently, safety hazards are created. Numerous examples of these conditions are provided in photographic illustrations. Reshaping of roadsides and other repairs and special maintenance become necessary, and all too often these are costly and only temporary remedies in a repetitive, erosion-repair-erosion cycle.

Damage resulting from erosion and the continual road maintenance required must clearly cost the province tens of thousands of dollars each year. It is unfortunate that this aspect cannot be inspected in detail and examined as part of a cost-benefit analysis, but the P.E.I. Department of Highways was unable to provide the necessary data, since precise records of these particular activities and related expenditures are apparently not kept. Nonetheless, some indication of scale may be gained from a description of the manpower and equipment involved in coping with the problems derived from erosion throughout the province. The number of road crews operating each year varies slightly, depending upon requirements, but mainly in response to budget provisions.

In 1969 twelve general maintenance crews were employed for about 26 weeks, from May until November, for various kinds of road work across the province. Each of these crews was composed of three workmen, a truck and driver, and a foreman on a part-time basis. Salaries amounted to $292.00 per week per crew in 1969 and totalled $91,104.00 for the 12 crews over the period of 26 weeks. It has been estimated that roughly half the time of the maintenance crews, and thus half the preceding expenditure, i.e. $45,552.00, is spent on tasks induced by erosion and deposition (13). These include filling in spring washouts and other gullies, fixing and replacing guide posts and guard rails of roads and bridges, and cleaning or replacing culverts of roads and driveways, as well as a limited amount of ditch maintenance and fencing. In addition, there are substantial material costs (e.g. fill, culverts) and equipment costs (e.g. graders, trucks).

Repairing large gullies and washouts is expensive, averaging $2.50 per cu. yd. for fill and for compacting and finishing the surface (14). Thus, a massive gully approximately 200 cu. yds. in area, similar to but larger than that shown in Figure 8*, engenders a repair bill of about $500.00.

Besides the general maintenance crews, there are from two to five special highway crews which are largely concerned with restoring damaged asphalt surfaces and with other repairs related to the pavement and roadside. Only part of this work is due to the results of erosion. Two supervisors are in charge of these crews, and each crew consists of labourers, one to two trucks, and drivers. Finally, two ditch maintenance teams are employed to remove sediment and excess vegetation from ditches and to clean or replace culverts. Each of these teams involves a foreman, one equipment operator and two truck drivers, and requires two trucks and ditch excavation equipment (15).

Landscape aesthetics and tourism considerations

The absence of a good cover of vegetation and the existence of eroding roadsides has a downgrading effect on the appearance of the landscape. A striking example of this is the Western Road, which is an arterial highway with a 100 foot right-of-way. It is the major corridor of the region, the westward extension of the Trans-Canada Highway, channeling tourist movement into the western section of the province. Yet, mile after mile the wide stretch of roadside is a dull continuum of bare or almost bare, eroding earth surface (Figure 1). Equally unsightly are the borrow pits, located close to highways, sometimes three or four per mile, resulting in a pockmarked countryside (Figure 26). Many of these pits are two to

*The gully shown in Figure 8 is an exceptionally large one; most gullies present at this particular site averaged less than 4 ft. in depth and 7 ft. in width.

FIGURE 11. Montague Road, at junction of Routes 23 and 206, eastern P.E.I. Advanced erosion (Class 5) at a stream crossing. Depression measures 3′ in depth and 19′ across. Note deposition in stream.

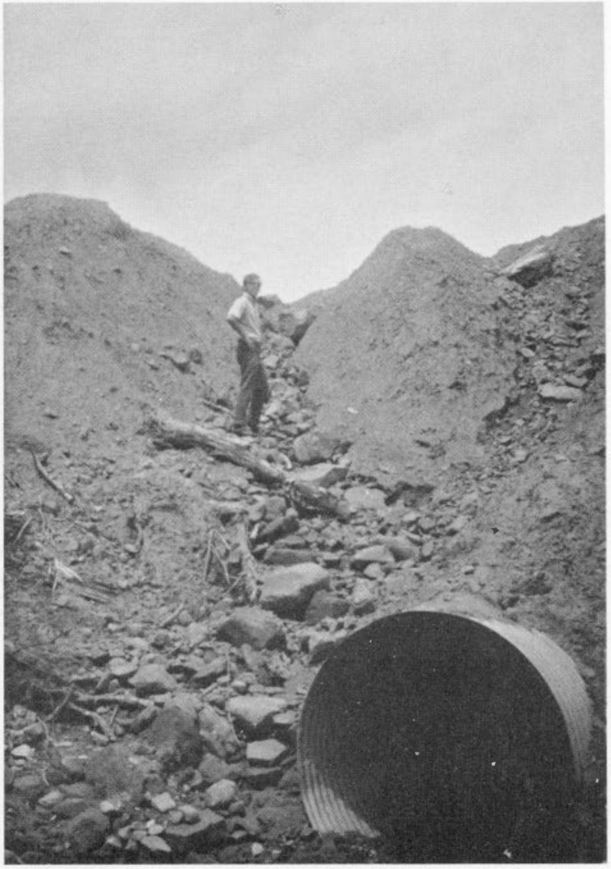

FIGURE 12. Near Montague, eastern P.E.I. Enormous roadside gully which has developed at a stream crossing. The gully measures 10′ in depth and 13′ in width.

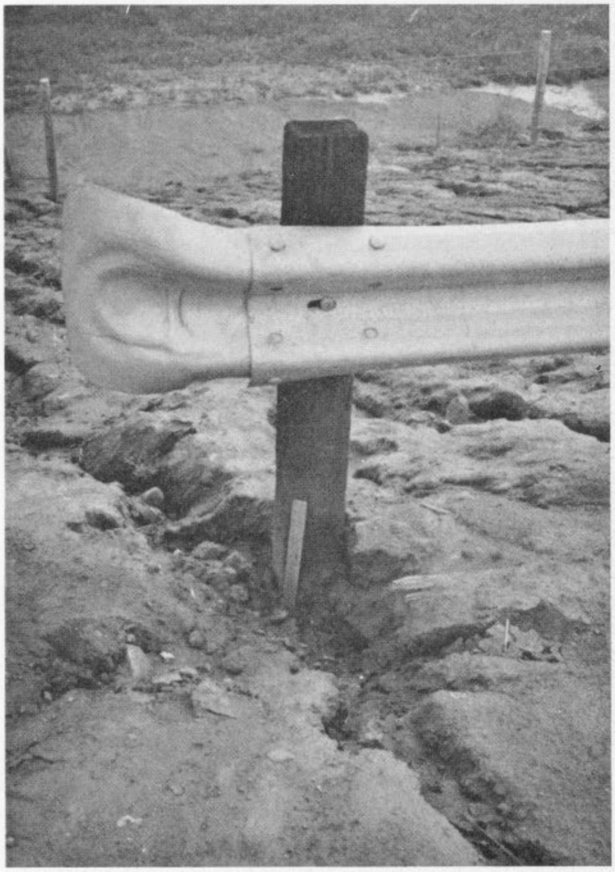

FIGURE 13. Western Road, western Prince County, near the junction with Route 125. Gully erosion (Class 3) occurring at the base of a guard rail post. The gullies on the shoulder and sideslope are 10″ deep and 14″ wide.

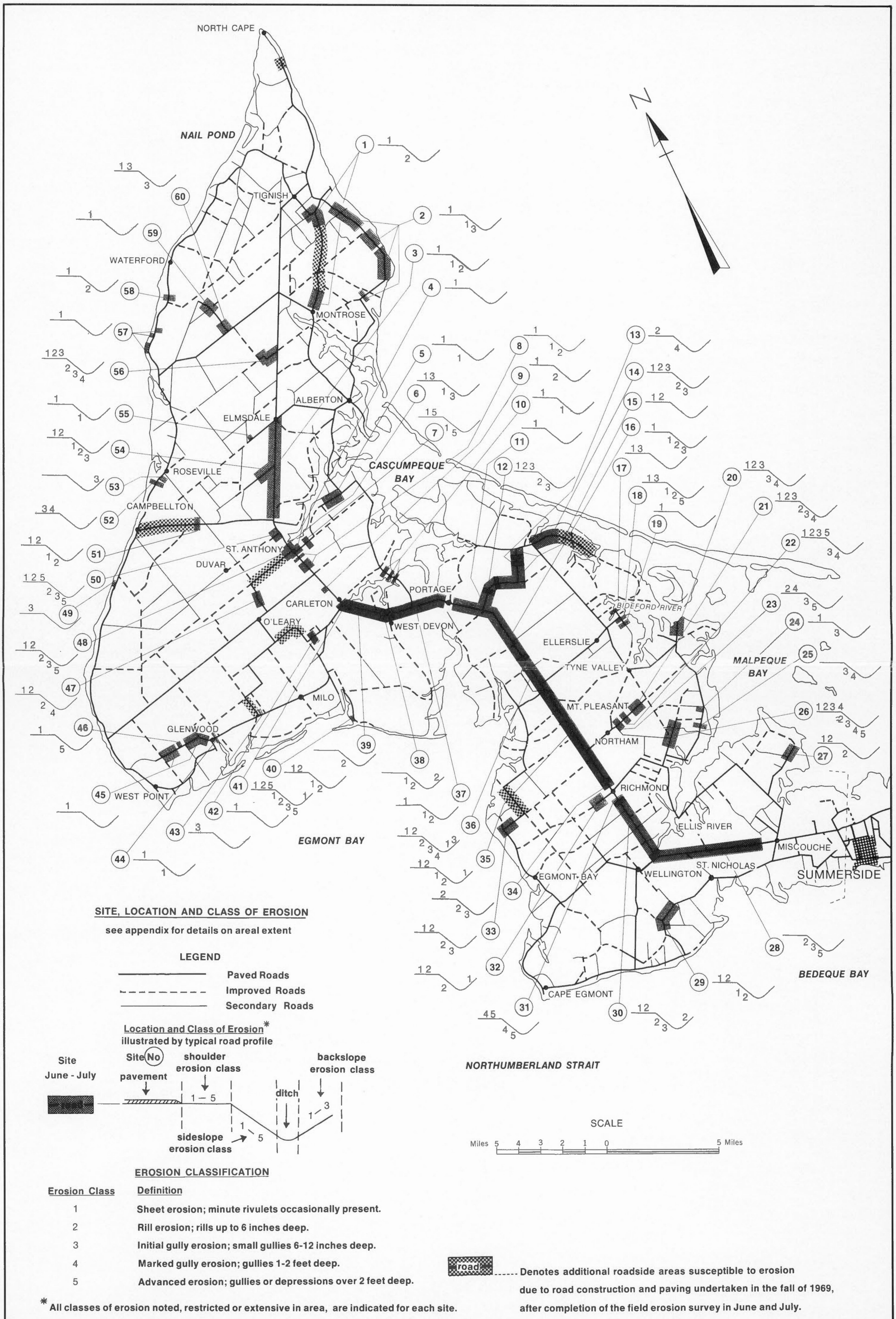

FIGURE 14. Extent of erosion along paved roads, western Prince County, 1969.

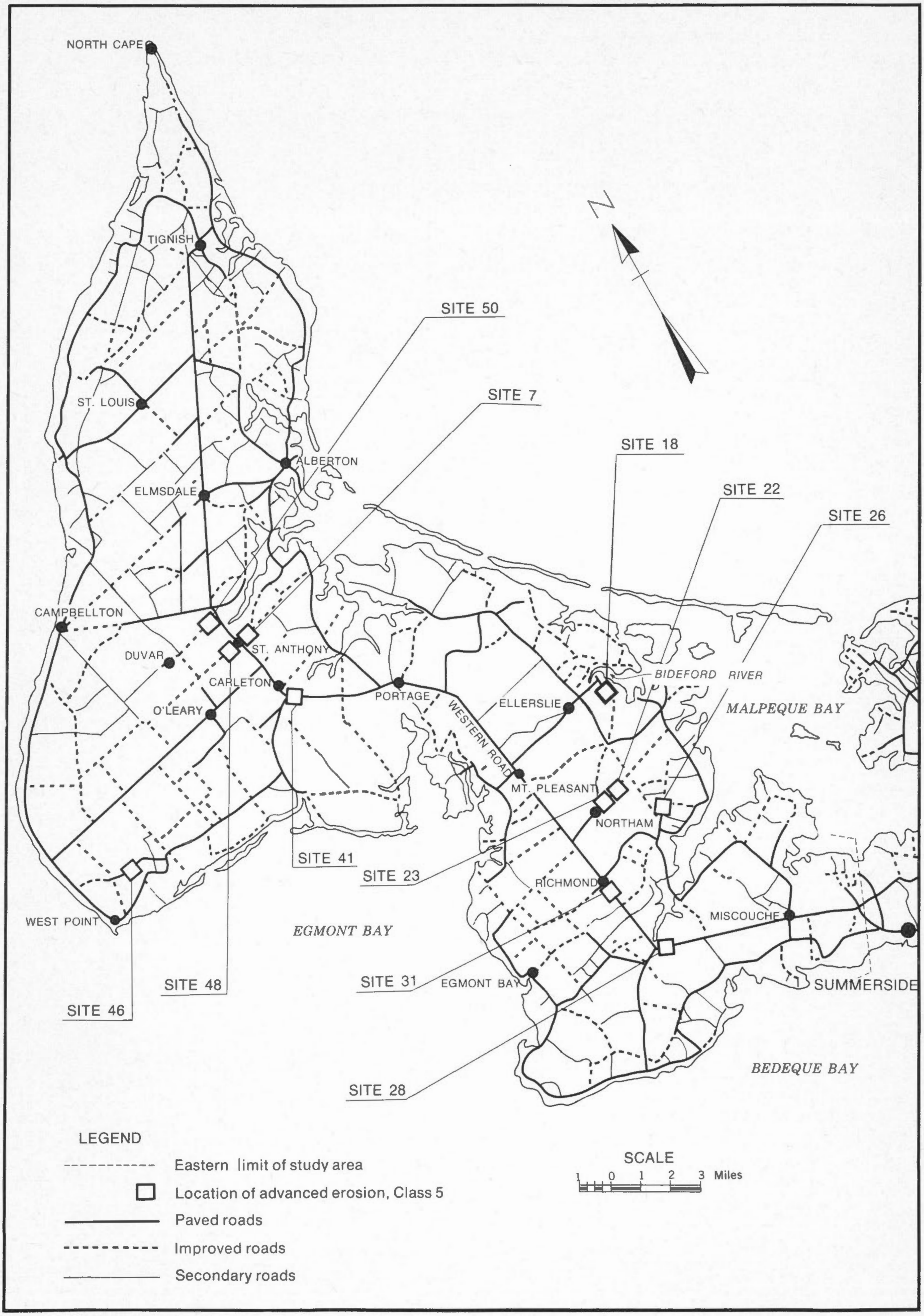

FIGURE 15. Location of advanced erosion (Class 5) in western Prince County, June-July 1969.

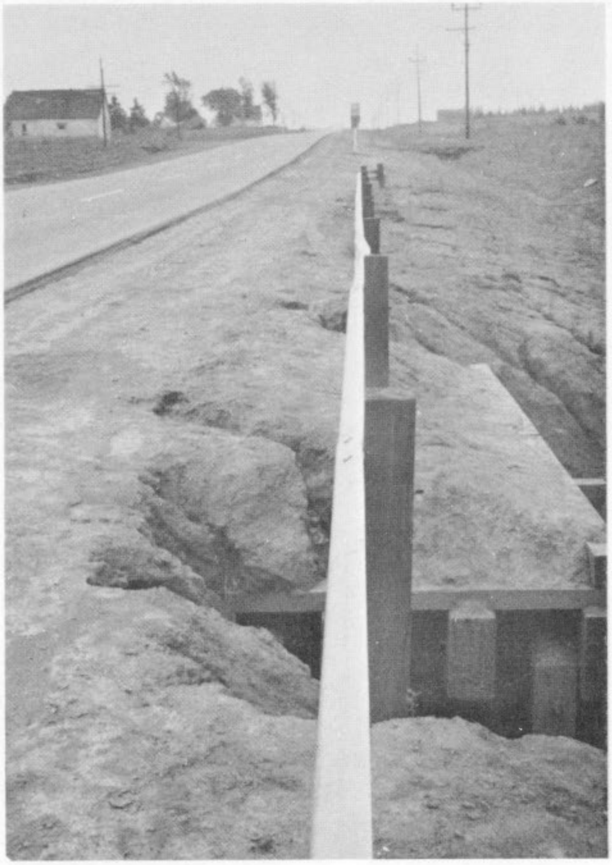

FIGURE 16. Western Road, western Prince County, near Richmond. Advanced erosion (Class 5) encountered at bridge structure. Note the extension of gullies inside the guard rail. One gully measures 3′6″ in depth and 5′ in width.

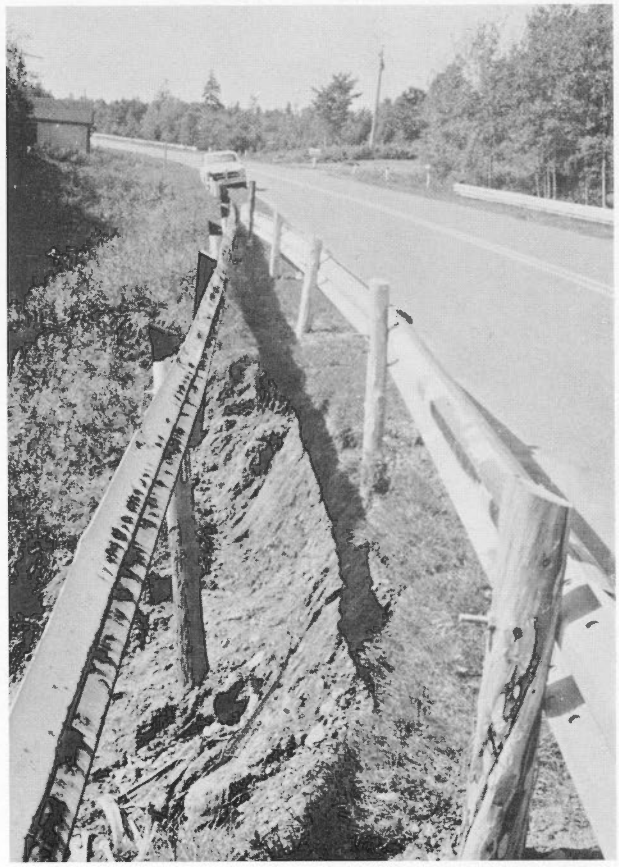

FIGURE 17. East Point Road, Route 16, eastern P.E.I. An example of very severe erosion on a steep roadside slope. Note the old guard rail on the left and the new rail on the right, demonstrating the extent to which the embankment has been eroded. Note also that the new guard rail is beginning to be affected.

three acres in surface area, and although they are normally levelled, the tendency has been to abandon them after road construction without any attempt at seeding.

Roadside landscaping would greatly improve the attractiveness of the environment for tourists as well as for Island residents. The tourist industry is an important consideration: in 1965 some 247,000 visitors entered P.E.I., a figure more than twice the province's total population in that year (16). Since then, there has been a dramatic increase in tourist numbers.

Erosion control

It is not intended here to give a detailed account of roadside erosion control procedures, since an extensive literature already exists on this subject. Comments are confined primarily to basic erosion control by permanent seeding and fertilizing in order to establish a vegetation cover. This practice is common elsewhere in North America and should be given full consideration as part of a standard highway improvement and highway construction policy in Prince Edward Island.

Reference to operations in Nova Scotia provides some planning guidelines for P.E.I. The Nova Scotia Department of Highways, which initiated seeding and fertilizing about 1965, operates hydroseeders and a mulcher. Seeding is carried out between May 1 and June 15 and from September 1 to late October; during the summer the same crews are employed in spraying and brush control. The lime, fertilizer and seed formulas in use in Nova Scotia are detailed in Tables 7 and 8. The infertile and acid nature of road fill and subsoil exposed in road cuts necessitates a heavy application of lime and fertilizer.

FIGURE 18. Western Road, western Prince County, near Portage. Rill erosion (Class 2) is found on the road side-slope at right. Note the absence of vegetation. An outstanding example of extensive deposition in ditches. The deposit present at this site measured 3'2" in depth and 15'-20' in surface width across the ditch.

FIGURE 19. Duvar Road, western Prince County. An example of sediment, accumulated in a ditch, which is beginning to block a culvert.

FIGURE 20. Kellys Cross, central P.E.I. A typical example of a small pond silting up with eroded material. Note the recent bar deposits in the pond.

Table 7

Roadside lime and fertilizer formula, N.S.

Content	Quantity (lbs. per acre)
Urea	150
Triple superphosphate	200
Potash	50
Ground limestone	2,000
Total	2,400

Source: Department of Highways, Nova Scotia.

Table 8

Roadside seeding formula, N.S.

Common name	Scientific name	Quantity (lbs. per acre)
Creeping red fescue	*Festuca rubra*	27.5
Red top	*Agrostis alba*	5.0
Timothy	*Phleum pratense*	5.0
Kentucky bluegrass	*Poa pratensis*	5.0
Canada bluegrass	*Poa compressa*	2.5
Perennial rye grass	*Lolium perenne*	2.5
Alsike clover	*Trifolium hybridum*	2.5
	Total	50.0

Source: Department of Highways, Nova Scotia.

In Nova Scotia, a total of 1,495 acres and 1,618 acres of roadside was seeded and fertilized in 1967 and 1968 respectively. The average cost per acre amounted to $82.81. Total expenditures incurred in 1967 and a cost breakdown on a percentage basis are given in Table 9.

The P.E.I. Department of Highways initiated a seeding program in June 1970, with a small hydroseeder mounted on a trailer and hauled by tractor. Other equipment included trucks to transport water, seed, fertilizer and lime. The Nova Scotia lime and fertilizer formula was adopted, and the same seeding formula was put into use, except that wild white clover was substituted for alsike clover. The department also began trials on the use of oats in the formula. A total of 100 acres of newly-constructed roadside was seeded in June and September in Prince, Queens and Kings counties. The average cost per acre was $100.00. Reports by the engineer in charge of this new provincial seeding program have expressed considerable satisfaction with the results (17).

A cost estimate may now be made for seeding and fertilizing along paved roads in western Prince County. If we take $100.00 as the average cost per acre, and an estimate of 358 acres as requiring seeding in November 1969 along 72 of the 320 miles of paved roads in the region (including the limited area with more than a 20-25% cover of vegetation), this would represent a total expenditure of $35,800.00. The real figure, however,

Table 9

Cost of roadside seeding and fertilizing, N.S., 1967

Item	Cost	Per cent of total cost
Lime, fertilizer and seed	$ 69,813.73	56.3
Machinery rentals, depreciation and overhead costs	23,187.75	18.8
Truck hauls	5,231.25	4.2
Wages, board and miscellaneous	25,564.29	20.7
Total	$123,797.02	100.0
Cost per acre	$ 82.81	

Source: Department of Highways, Nova Scotia.

would be closer to $30,000.00, in view of the limited acreage already partially vegetated. Further costs are involved for seeding borrow pits. For immediate and future planning purposes the Department of Highways could make fairly good cost projections for the whole province by applying operational and material costs to estimates of the roadside acreage (based on the width of the right-of-way) exposed to erosion following recent road work and that anticipated in upcoming construction and paving programs.

Special treatment should be accorded critical sites where seeding and fertilizing alone are not wholly effective. Mulching is a procedure for anchoring seed and fertilizer in place, and is particularly recommended for steep slopes. However, the additional cost of mulching, about $90.00 to $130.00 per acre, has meant that this practice has not yet received serious consideration in P.E.I. Attention should also be given to specific design criteria which have been determined for special structural problems, such as those encountered at many stream crossings. Check dams and flumes may be required to improve drainage and to prevent erosion on long steep slopes.

Conclusion

This survey of roadside erosion along the paved road network of western Prince County has demonstrated that, in the absence of control practices, the erosion problem can reach extensive proportions. Evidence of this includes the amount of paved road mileage exhibiting erosion (22.5% in November, 1969), the total roadside area undergoing erosion (358.4 acres in November, 1969), the extensive deposition of eroded material in ditches, and the incidence of sites showing marked gully erosion (12 sites) and severe roadside erosion (11 sites). This situation is repeated across the province, in particular wherever road construction and paving have been undertaken in recent years.

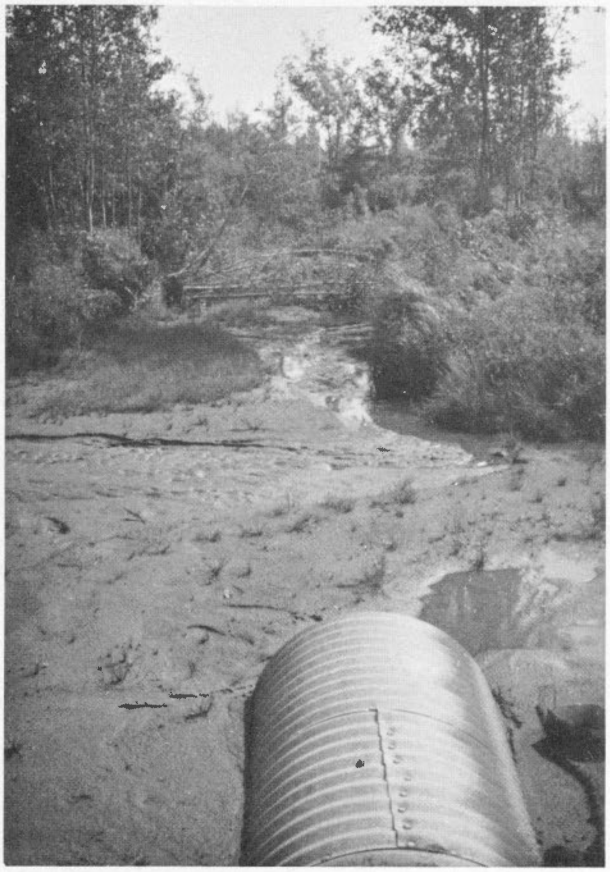

FIGURE 21. Western Road, western Prince County. Extensive accumulation of sediment at intersection with stream. Note degree to which road culvert has become embedded.

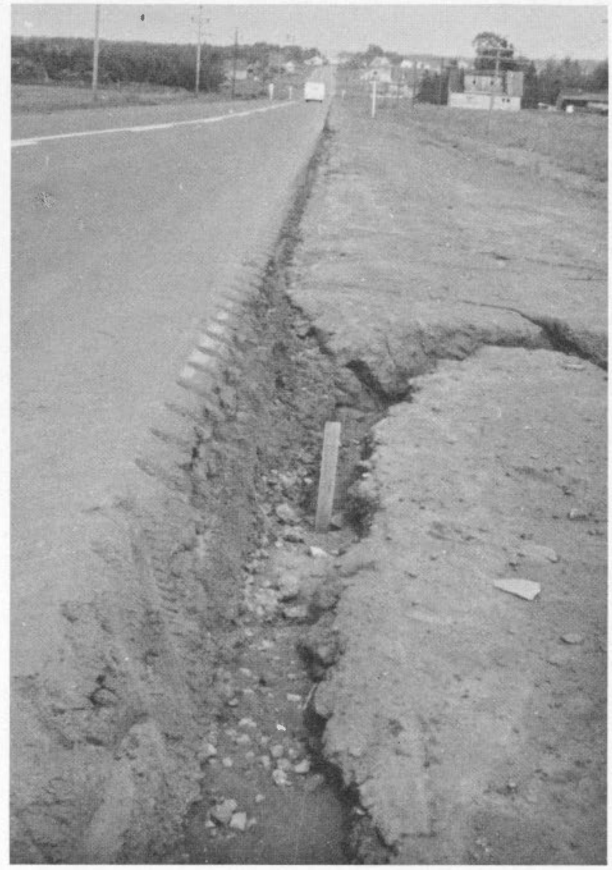

FIGURE 22. Western Road, western Prince County, near Richmond. The development of unsafe motoring conditions due to gullying parallel to the edge of the pavement.

FIGURE 23. Trans-Canada Highway, near Vernon, eastern P.E.I. Notable deterioration of the paved highway shoulder and the roadside area. This gully is 11″ deep and 3′ wide.

FIGURE 24. Duvar Road, western Prince County. The exposure and undermining of the road base as a result of roadside erosion. Note the absence of vegetation along the roadside. The gully is 1′6″ deep.

FIGURE 25. Trans-Canada Highway, near Vernon, eastern P.E.I. Numerous sections of pavement, over a very short distance, are deteriorating as a result of roadside erosion. These conditions are also safety hazards. The closely-spaced gullies average 10″-11″ in depth.

FIGURE 26. Western Road, western Prince County. A typical example of a borrow pit located close to the highway. These are normally abandoned without any attempt to seed the surface.

Among the results of such erosion are damage to the road surface and adjacent structures (bridges, guard rails), deterioration of roadside areas, and excessive deposition of sediment in ditches. In some instances, unsafe motoring conditions develop. Consequently, a high degree of road repair and roadside maintenance is required. Road construction sites and unseeded roadsides are also a principal source of sediment contributing to increased siltation in water bodies, which can prove detrimental to water flora, fish populations, oyster production and wildlife. Furthermore, bare and eroding roadsides are unattractive in comparison with vegetation-covered and landscaped surfaces which could be created.

Basic erosion control by seeding and fertilizing can be achieved at very small cost. Although it is not possible to compare this cost with that incurred by not seeding, due to the lack of data on the activities and expenditures of the Department of Highways, it can be related to the total road construction-paving expenditure per mile. The latter, depending upon construction requirements and road standards desired, ranges roughly between $40,000-$84,000 for standard two-lane roads and $96,000-$120,000 for arterial highways. In the former case, an average of 5 acres of roadside per mile require seeding and fertilizing; at $100.00 per acre, this represents a total of $500.00 per mile. In the latter case, an average of 8 acres per mile require similar treatment, amounting to $800.00. Even with attention to borrow pits and with mulching on more difficult sites where seeding alone is not sufficient, the cost entailed does not appear to be excessive when viewed against the overall per mile expenditure. The emphasis on maintenance would then be shifted from repairing damage brought about by erosion to preserving vegetated roadside areas in an optimum and attractive state. There are also other considerations, which do not lend themselves to a monetary evaluation, such as the assurance of safer conditions for vehicular traffic, a more attractive roadside environment, and a reduction in the amount of roadside sediment contributed to the drainage system.

It should also be recognized that the most pressing paving requirements of the province have been satisfied within the past decade. At the present time, nearly half the road network of the Island is paved, and it seems appropriate now to give special attention to seeding, mulching and other erosion control measures. It is logical that priority in the seeding program should be accorded to arterial highways, which have a wide right-of-way, and which carry a high traffic volume of Islanders and tourists. Immediate repairs and special erosion control should also be instituted at critical sites, such as steep embankments and bridge structures at stream crossings. By these means, a definite contribution can be made to improving and conserving environmental quality in the province.

Appendix

Sites and extent of roadside erosion along paved roads in western Prince County, Prince Edward Island, (June-July 1969)

		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Distance along road, mi.		1.6	4.0	4.2	.3	.8	.5	.2	.8
SHOULDER EROSION % Vegetation cover		0-20	0-40	0	20	2-20	5-40	10-15	10-30
-area-	E1	170,000	420,500	583,000	40,800	115,050	37,000	18,000	49,200
sq.	E2								
ft.	E3						2,400		
	E4								
	E5							5,600	
Total		170,000	420,500	583,000	40,800	115,050	39,400	23,600	49,200
SIDESLOPE EROSION % Vegetation cover		5-60	10-50	0-5		25	15-20	10-20	10-25
	E1		102,600	256,050		92,650	41,800	12,000	18,000
-area-	E2	136,000		562,450					11,200
sq.	E3		19,000				3,300		
ft.	E4								
	E5							17,200	
Total		136,000	121,600	818,500		92,650	45,100	29,200	29,200
BACKSLOPE EROSION % Vegetation cover									
-area-	E1								
sq.	E2								
ft.	E3								
Total									
TOTAL, acres		7.02	12.44	32.17	.94	4.77	1.94	1.21	1.80

		Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16
Distance along road, mi.		.2	.3	.9	.6	.07	1.1	2.1	4.5
SHOULDER EROSION % Vegetation cover		10	0-40	20-40	0-40	10	0-15	5-10	0
-area-	E1	8,000	17,800	68,000	30,200		74,000	20,000	481,200
sq.	E2				4,200	6,000	38,000	154,400	
ft.	E3				7,600		7,500		
	E4								
	E5								
Total		8,000	17,800	68,000	42,000	6,000	119,500	174,400	481,200
SIDESLOPE EROSION % Vegetation cover		5	0-10		5-20	15	5-20		0
	E1		18,600						129,000
-area-	E2	14,000			7,200		74,475		452,000
sq.	E3				13,300		26,625		320,000
ft.	E4					12,750			
	E5								
Total		14,000	18,600		20,500	12,750	101,100		901,000
BACKSLOPE EROSION % Vegetation cover									
-area-	E1								
sq.	E2								
ft.	E3								
Total									
TOTAL, acres		.50	.84	1.56	1.43	.43	5.06	4.00	31.74

		Sites 17-19	Site 20	Sites 21-23	Site 24	Site 25	Site 26	Site 27	Site 28
Distance along road, mi.		.3	1.1	.9	.02	.1	1.1	.7	4.8
SHOULDER EROSION % Vegetation cover		10-30	0-20	5-60	10		5-45	5-25	
-area-	E1	24,600	64,500	12,750	800		44,600	45,680	
sq.	E2		33,250	53,500			35,150	14,000	
ft.	E3	6,725	14,250	8,450			24,375		
	E4			2,400			12,000		
	E5			1,200					
Total		31,325	112,000	78,300	800		116,125	59,680	
SIDESLOPE EROSION % Vegetation cover		10-20	15-20	10-70	10	10-80	5-60	50-75	0-40
	E1	2,375							
-area-	E2	8,075		18,500			30,000	40,800	1,207,400
sq.	E3		18,600	38,900	1,200	4,400	24,000		1,500
ft.	E4		17,100	5,800		4,400	20,750		
	E5	10,800		1,000			9,625		3,000
Total		21,250	35,700	64,200	1,200	8,800	84,375	40,800	1,211,900
BACKSLOPE EROSION % Vegetation cover									
-area-	E1								
sq.	E2								
ft.	E3								
Total									
TOTAL, acres		1.21	3.39	3.27	.05	.20	4.60	2.31	27.82

		Site 29	Site 30	Site 31	Site 32	Site 33	Site 34	Site 35	Site 36
Distance along road, mi.		1.2	3.0	.04	.9	.7	.2	4.5	1.8
SHOULDER EROSION % Vegetation cover		15-30	0	0	5	25-60	10	0	0
-area-	E1	26,400	246,600		45,000	13,500		480,200	32,750
sq.	E2	61,400	131,400		52,500	60,000	3,000	25,000	151,750
ft.	E3								
	E4			2,400					
	E5			2,400					
Total		87,800	378,000	4,800	97,500	73,500	3,000	505,200	184,500
SIDESLOPE EROSION % Vegetation cover		20-45	5-30	10	20	35	5-20	0	0-10
	E1	33,000						809,200	
-area-	E2	70,600	340,725		44,250	13,500	6,600	50,000	126,000
sq.	E3		17,375			30,000	11,750		77,500
ft.	E4			2,400					165,500
	E5			4,000					
Total		103,600	358,100	6,400	44,250	43,500	18,350	859,200	369,000
BACKSLOPE EROSION % Vegetation cover			0-5		5-10			0	0-10
-area-	E1				19,200			6,300	10,500
sq.	E2		8,550						
ft.	E3								3,750
Total			8,550		19,200			6,300	14,250
TOTAL, acres		4.39	17.0	.26	3.69	2.69	.49	31.47	13.03

		Site 37	Site 38	Site 39	Site 40	Site 41	Site 42	Site 43	Site 44
Distance along road, mi.		2.5	.5	1.5	.06	.2	.4	.02	.1
SHOULDER EROSION % Vegetation cover		0			0	5-20	20	20	0
-area-	E1	336,600			3,000	6,000	43,000		7,000
sq.	E2				3,000	3,750			
ft.	E3							700	
	E4								
	E5					2,000			
Total		336,600			6,000	11,750	43,000	700	7,000
SIDESLOPE EROSION % Vegetation cover		0	20-50	20	5-10	5-20			5
	E1	106,000	29,400		4,500	7,200			7,000
-area-	E2	185,600	71,400	318,150	4,500	11,250			
sq.	E3					11,250			
ft.	E4								
	E5					3,600			
Total		291,600	100,800	318,150	9,000	33,300			7,000
BACKSLOPE EROSION % Vegetation cover			0-5			0-5			
-area-	E1					6,450			
sq.	E2		22,000						
ft.	E3								
Total			22,000			6,450			
TOTAL, acres		14.42	2.82	7.30	.34	1.18	.99	.02	.32

		Site 45	Site 46	Site 47	Site 48	Site 49	Site 50	Site 51	Site 52
Distance along road, mi.		2.3	.03	.9	.4	.01	.4	.3	.04
SHOULDER EROSION % Vegetation cover		0-10	5	0-2	0	5	2-5	10	15
-area- sq. ft.	E1	213,200	1,225	46,500	18,900		14,400	10,800	
	E2			46,500	22,500		31,900	26,400	
	E3					595			9,000
	E4								9,000
	E5						1,800		
Total		213,200	1,225	93,000	41,400	595	48,100	37,200	18,000
SIDESLOPE EROSION % Vegetation cover			5	0-2	5		20-65	10	
-area- sq. ft.	E1							9,000	
	E2			65,400	21,000		35,400	22,000	
	E3				21,000		17,000		
	E4			15,000					
	E5		2,450		8,000		2,250		
Total			2,450	80,400	50,000		54,650	31,000	
BACKSLOPE EROSION % Vegetation cover									
-area- sq. ft.	E1								
	E2								
	E3								
Total									
TOTAL, acres		4.89	.08	3.98	2.10	.01	2.36	1.57	.41

		Site 53	Site 54	Site 55	Site 56	Site 57	Site 58	Site 59	Site 60
Distance along road, mi.		.04	.8	.1	.9	.5	.08	.6	.4
SHOULDER EROSION % Vegetation cover			0-5	10	0-15	10-20	0	25	10-25
-area- sq. ft.	E1		26,000	4,800	42,825	24,900	8,000	64,000	38,750
	E2		80,000		71,775				
	E3				6,000				8,750
	E4								
	E5								
Total			106,000	4,800	120,600	24,900	8,000	64,000	47,500
SIDESLOPE EROSION % Vegetation cover			5-10	10	5-70		20		30
-area- sq. ft.	E1		16,000	4,800					
	E2		108,000		84,550		32,000		
	E3		36,000		44,325				14,000
	E4				7,500				
	E5								
Total			160,000	4,800	136,375		32,000		14,000
BACKSLOPE EROSION % Vegetation cover		5							
-area- sq. ft.	E1								
	E2								
	E3	3,000							
Total		3,000							
TOTAL, acres		.07	6.11	.22	5.90	.57	.92	1.47	1.41

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