

GEORES No:
40P1-107

REPORT TO
GRAND RIVER CONSERVATION AUTHORITY

**PRELIMINARY ENGINEERING STUDY
GRAND RIVER VALLEY SLOPE FAILURE
COLBORNE STREET EAST
BRANTFORD, ONTARIO**

VOLUME II
DETAILED INFORMATION DOCUMENT

Golder Associates
Philips Planning + Engineering Limited
McCormick, Rankin & Associates Limited
Ecologistics Limited

July 1987

861-3257

VOLUME II

TABLE OF CONTENTS

INTRODUCTION

APPENDIX I	-	TERMS OF REFERENCE
II	-	GEOTECHNICAL CONSIDERATIONS
III	-	RIVER ENGINEERING
IV	-	TRANSPORTATION AND MUNICIPAL SERVICE CONSIDERATIONS
V	-	ENVIRONMENTAL ASPECTS
VI	-	PROPERTY
VII	-	ECONOMICS/BENEFIT VS COST ANALYSIS
VIII	-	LAND USE PLANNING
IX	-	PRELIMINARY DESIGN DRAWINGS

1. INTRODUCTION

This report details the results of our preliminary engineering study of various stabilization measures for the recent slope failure and adjacent area(s) along the Grand River Valley bank beside Colborne Street East in the City of Brantford, Ontario.

The report for this study is presented in two (2) volumes. Volume I is the summary document and Volume II provides more detailed supportive data.

1.1 General

The consulting Engineering Team responsible for carrying out this study consists of:

- Golder Associates
 - prime consultant role and geotechnical input
- Philips Planning + Engineering Limited
 - land use/property, benefit cost analyses and river engineering
- McCormick Rankin & Associates Limited
 - transportation and municipal engineering
- Ecologistics Limited
 - environmental and economics input

Their respective detailed reports form the various sections of Volume II, herein.

A Technical Coordinating Committee (TCC) was established to periodically meet with the Engineering Team to provide direction and review during the six month study period.

TCC COMPOSITION

- Grand River Conservation Authority
 - A.F. Smith, Director of Water Management
 - R. Moulton, Manager of Engineering
 - I. Kao, Assistant General Manager
- City of Brantford
 - A. Gretzinger, City Engineer
 - T. Spiers, Environmental Planning Engineer
 - J.P. Atcheson, Director of Planning
- Ministry of Natural Resources
 - Q. Alam, Construction Maintenance Engineer
- CP Rail
 - S.K. Chopra, Engineer - Bridges and Structures
 - M.J. Klassen, Design Engineer
- Ministry of Transportation and Communications
 - K. Selby, Chief Foundations Engineer
- Township of Brantford
 - J.F. Longley, Township Engineer

1.2 Background Information

On May 20, 1986, a major slope failure occurred along approximately 300 metres of the north valley wall of the Grand River between about MN 915 and 945 Colborne Street

East, in the City of Brantford, Ontario. The location of the failure (encompassing several houses and a railway line) is shown on Figure 1, together with the extent of the present study area.

The valley wall is about 30 metres in height, has an overall inclination of about 14 to 16½ degrees to the horizontal and is of irregular topography. The slope typically consists of a lower and upper portion separated by a narrow, horizontal bench. The Toronto, Hamilton and Buffalo Railway (now CP Rail) tracks extend along the bench. Beach Road is located below the tracks.

A preliminary geotechnical assessment carried out by Golder Associates immediately following the failure in June, 1986 concluded that the primary causes of the massive instability were:

- oversteepening of the slope as a result of ongoing erosion of the river bank
- high groundwater levels within the weak clayey soils which form the valley wall slope

The report concluded that unless adequate remedial work was undertaken, there remains a strong possibility of future slides of similar proportions. Several alternatives for slope stabilization measures were outlined and a scheme, consisting of cut and fill, was identified for conceptual design of remedial works.

Following the failure, an investigation was also carried out by CP Rail. In this regard, detailed post-slide topographical mapping of the study area was obtained and, in addition, an extensive geotechnical investigation and stability evaluation programme was performed (by Trow Geotechnical Ltd.), together with the installation of field instrumentation for a slope movement and groundwater level monitoring programme. This information was made available to the Study Team and was used in this current study.

Our review and evaluation of the CP Rail information confirms the earlier findings in the 1986 Golder overview as to the cause of failure. The mode of failure was regressive and deep seated with the lower portion of the slope failing first followed by the upper section of the slope.

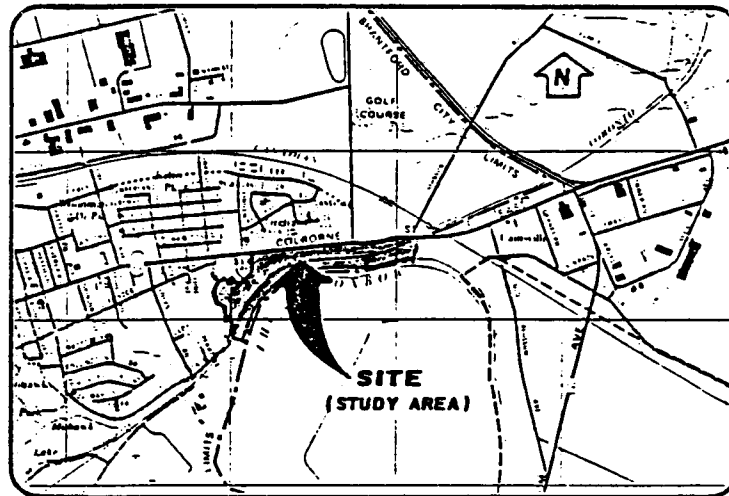
1.3 Terms of Reference

The present engineering study involves the examination of several alternative slope stabilization schemes with the objective that, at the end of the comparison process, a recommendation for the most appropriate alternative will evolve. The six (6) schemes to be considered include a "Do Nothing" approach, a full programme of slope stabilization and a major river diversion.

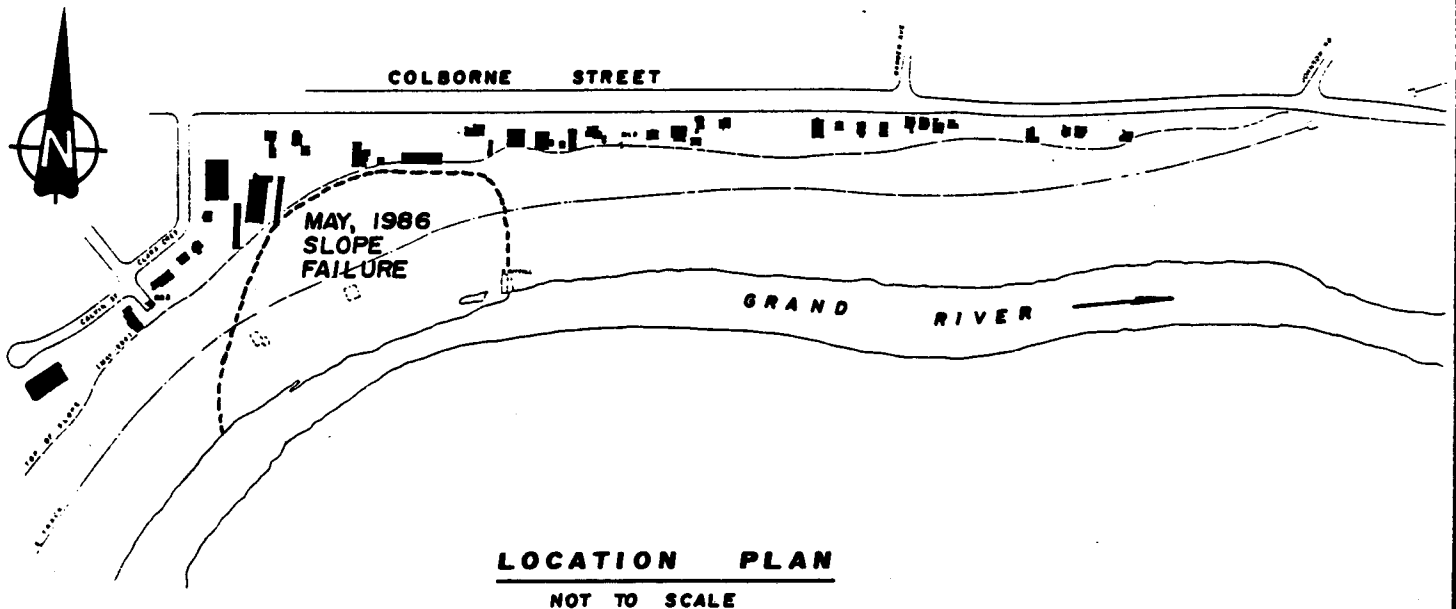
The complete Terms of Reference are included in Appendix I of this report.

PLAN

FIGURE 1.



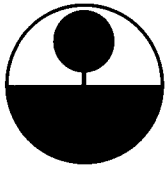
KEY PLAN



Date JULY, 1987
Project 861-3257

Golder Associates

Drawn C.M.S.
Chkd. *[Signature]*



Grand River Conservation Authority

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400 Clyde Road
Box 729 Cambridge Ontario
N1R 5W6
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**APPENDIX I
TERMS OF REFERENCE**

**PRELIMINARY ENGINEERING STUDY
GRAND RIVER VALLEY SLOPE FAILURE
COLBORNE STREET EAST
BRANTFORD, ONTARIO**

July 1987

August 11, 1986

Grand River Conservation Authority

Terms of Reference for Carrying out
a Preliminary Engineering Study of the
Colborne Street Slope Failure, Brantford, Ontario

Purpose of Study

- 1) Select the best method of stabilizing the slope within the study area;
- 2) Determine the best method of rechannelizing and/or protecting the Grand River banks;
- 3) Where necessary, develop a short term and long term property acquisition plan;
- 4) Within the study area, develop zoning and land use controls to reduce hazards to life and property posed by hazardous slopes.

Background

On the evening of May 20, 1986, a major slope failure occurred on the Grand River Valley slope adjacent to Colborne Street East in Brantford, Ontario. This massive movement directly affected 3 residences on Beach Road located on the valley floor, the C. P. Rail (T.H. & B.) tracks located at the toe of the slope, two commercial establishments and one residence located at the top of the valley slope on Colborne Street.

A preliminary engineering study by Golder Associates indicated that the primary causes of this failure are:

- 1) on-going erosion of the river bank by the Grand River leading to oversteeping of the lower slopes;
- 2) high groundwater levels within the slope.

If nothing is done, on-going erosion and valley wall instability will endanger additional residences and portions of Colborne St. The study briefly described three alternatives to stabilize the slope, the cost of which ranged from \$11 million to \$6 million.

A more detailed study is now required to provide a comprehensive plan of remedial works for implementation by the various affected private and public bodies.

The study will recommend a slope stabilization alternative, details of proposed river works and municipal services, incorporation of C. P. Rail/T. H. & B. Railway requirements and recommendations on acquisition or protection of various affected structures. The study area is indicated in the shaded area on the accompanying map.

Study Requirements

Tasks to be carried out by the Consultant are:

1. Geotechnical Review and Sampling

- a) Review all available geotechnical information to assess the need of additional field sampling and testing of samples;
- b) Subject to the approval of the Technical Co-ordinating Committee, carry out any additional soil sampling and testing that may be required to carry out pre-design studies.

2. Field Survey

Where required, carry out field survey and prepare profiles and cross-sections sufficient for pre-design purposes.

3. Inventory of Affected Structures

Within the study area, assess the damage and structural integrity of the residences and commercial properties affected by the May 20th failure.

4. Attend Meetings

- a) Meet with the Technical Co-ordinating Committee, C. P. Rail/T. H. & B. Railway and other appropriate representatives to obtain full information on existing and proposed municipal and utility services, roads and other structures within the study area. Review existing policies and zoning controls for study area.
- b) Meet with the Technical Co-ordinating Committee periodically during the course of study to inform the committee of progress and to receive direction and guidance from the Committee.

5. Comparison of Alternatives

Carry out a detailed comparison of alternative proposed remedial works. These alternatives should include:

- 1) Four alternatives listed in Golder's report;
- 2) Alternative including channelization across oxbow;
- 3) Do nothing alternative;
- 4) Relocation of Colborne Street with no other structural remedies carried out.

The comparison of alternatives should consider technical merits, costs, number of properties protected, properties required, social impacts and environmental impacts.

The alternatives should include the impact of the alternative on:

- a) Colborne Street;
- b) C. P. Rail (T.H. & B.) railway line (immediate impact);
- c) Railway relocation study (long range impact).
(Note in Part c, only existing studies would be used to assess the impact).

6. Selected Plan

For the selected alternative, indicate the following staging and costing:

- a) Immediate property required;
- b) Rechannelization;
- c) Slope stability;
- d) Long-term property acquisition;
- e) Appropriate official plan policies, zoning and other land use controls.

7. Costs and Benefits

As part of the comparison, carry out a cost-benefit analysis of the alternatives using the existing (1983) Ministry of Natural Resources Guidelines for Benefit/Cost Analysis, Erosion Control.

8. Pre-Design Drawings and Cost Estimates

In consultation with the Technical Committee, select a proposed alternative and develop detailed cost estimates and pre-design drawings describing the remedial measures. Cost estimates should include estimates of property costs (land and building).

9. Environmental Study

The study should contain sufficient information to be able to satisfy the Association of Conservation Authorities of Ontario Class Environmental Assessment for Water Management structures.

10. Cost of Study

The proposal submitted by the consultant to carry out the study should include a schedule of Consulting Services together with estimated fees and/or allowances for each phase of the study. The total of these fees and allowances shall be considered as an "upset limit".

The "upset limit" shall not include additional soil sampling and testing as stated in Section 1(b).

11. Engineering Agreement

The Terms of Reference together with the Consultant's proposal shall form part of the Engineering Agreement. The Standard form of agreement published by APEO is acceptable subject to changes on Pages 5 and 6 as shown on the attached copy.

12. Public Information

In order to publicize the findings of the study, the consultant will plan and organize:

- 1) an open house and public meeting when the alternatives are being compared and explained;
- 2) an open house and public meeting when an alternative is recommended. This will take place prior to producing the final report, but after producing a draft report on the final selection by the Technical Co-ordinating Committee.

The two open houses and two public meetings will take place on the same day with the open house being held in the afternoon and the public meeting being held in the evening.

The open house will take the form of a drop-in session with the consultant present to describe the study through the use of displays, etc.

The public meeting will take the form of a formal presentation followed by a question and answer period.

13. Reports

The study findings and recommendations should be summarized in a report. Fifty copies of the final report will be required. Ten copies of a draft final report should be submitted to the Technical Co-ordinating Committee for approval before producing the final report.

Technical Co-ordinating Committee

A Technical Co-ordinating Committee will be formed to review the Consultant's work. The team will consist of members from the City of Brantford, Grand River Conservation Authority and the Township of Brantford, Ministry of Natural Resources, Ministry of Transportation and Communications, C.P. Rail/T.H. & B. Railway.

Consultant Team

The prime consultant should identify in the proposal to carry out the study what consultants he would use to carry out:

- a) Hydraulic component;
- b) Land use component;
- c) Property acquisition plan;
- d) Cost-benefit studies.

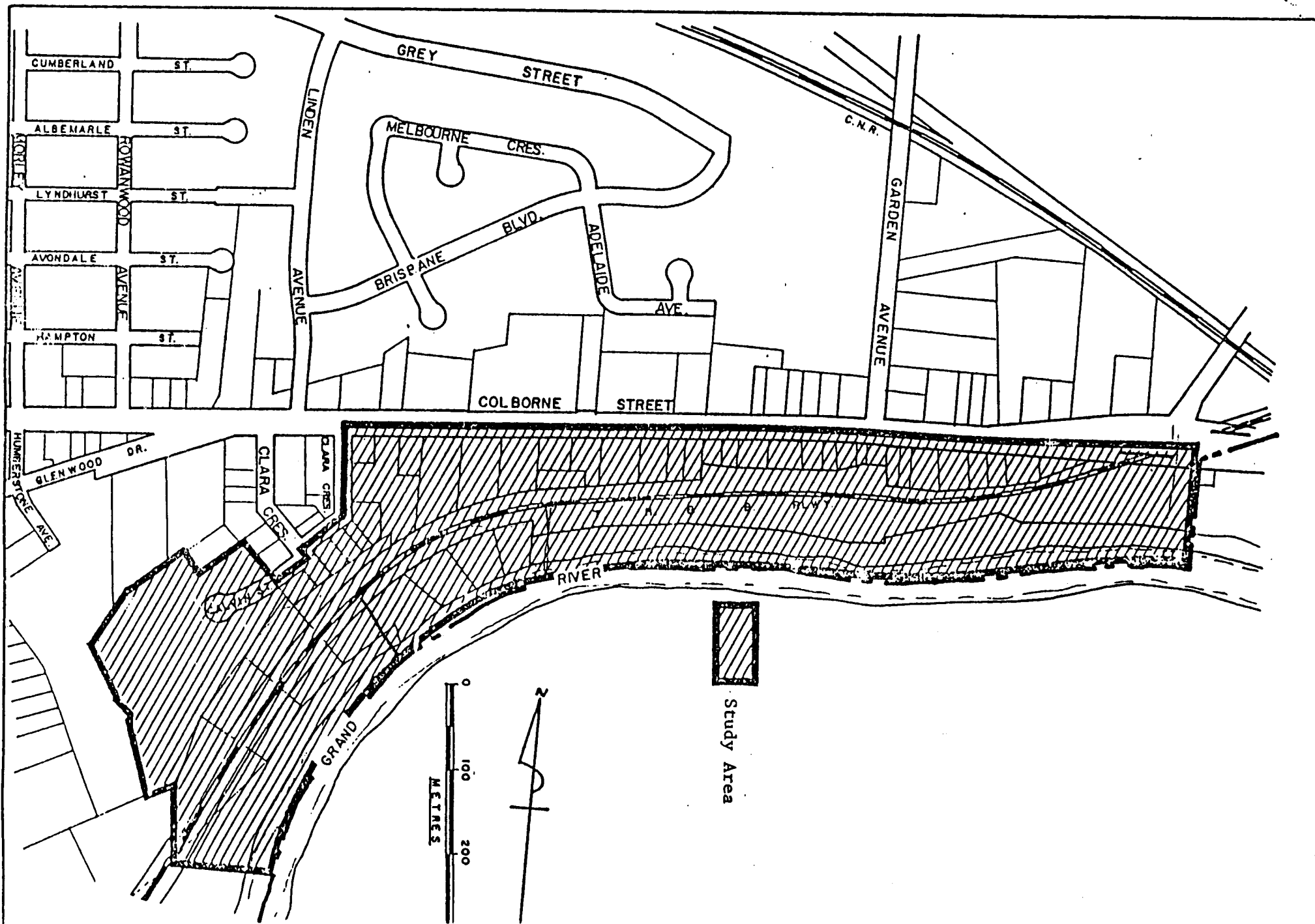
Available Data

- 1) Design flows are available from the GRCA for various flood frequencies.
- 2) Preliminary Geotechnical Assessment, Grand River Valley Wall, Colborne Street East, Brantford, Ontario, Golder Associates, June, 1986.
- 3) C. P. Rail/T. H. & B. soil stability study and field surveys/cross sections.

Time to Complete Study

This study should be completed as soon as possible.

A proposed time table should be submitted with the proposal.



Article IV – EXPENSES AND DISBURSEMENTS:

1. The Engineer shall be reimbursed for all expenses properly incurred by him in connection with the Project including, but not limited to, automobile mileage, reasonable travelling and living expenses, long distance telephone charges, teletype and telegraph charges, printing and reproductions, progress photography, advertising for tenders, special delivery and express charges, overtime premium payments, and the cost of providing and maintaining site offices, supplies, and equipments.
2. The Engineer shall also be reimbursed at cost plus a charge of 5 % of such cost as an administrative charge for approved special consultations such as sub-surface investigations, legal surveys and chemical and physical tests.

Article V – PAYMENT OF FEES AND EXPENSES:

1. Payment of fees and reimbursable expenses for services performed by the Engineer for which the fee is calculated on a Time Basis shall be made within 30 days after the Engineer has forwarded to the Client his statement of account, rendered monthly.
2. Payment of fees and reimbursable expenses for services performed by the Engineer for which the fee is calculated on a Percentage of Cost of the Work shall be made within 30 days after the Engineer has forwarded to the Client his statement of account. The monthly fee shall be based upon the Engineer's monthly progress estimate pro-rated on the basis of the amount of design work completed, applied against agreed estimated construction costs. If the design of any part of the Project has been completed but tenders for the work have not been called, the fee then due to the Engineer shall either be calculated on a time basis or on the Engineer's estimates of the Cost of the Work, at the option of the Engineer. If subsequently tenders are called and received, or the Cost of the Work is ascertained within one year of the completion of the design, then the Engineer's fee shall be adjusted accordingly.
- ~~3. Overdue accounts are subject to carrying charges at a rate of _____ % per month.~~

Article VI – GENERAL TERMS AND CONDITIONS:

1. Co-operation

- (a) The Client shall give due consideration to all designs, drawings, plans, specifications, reports, tenders, proposals, and other information provided by the Engineer, and shall make any decisions which he is required to make in connection therewith within a reasonable time so as not to delay the work of the Engineer.
- (b) The Client shall, at the request of the Engineer, provide the Engineer with the following information and documents relating thereto, except insofar as the Engineer is expressly required to furnish the same under the terms hereof:
 - (i) all pertinent information which may affect the work to be done, including a correct survey of the site and existing facilities and utilities;
 - (ii) accurate information, plans, and specifications regarding any other existing or proposed buildings or works which are involved, and insofar as such information is not available, the cost of obtaining the same shall be borne by the Client;
 - (iii) copies of all bids and contracts for the work for which the Engineer is responsible and copies of all quotations, certificates for payment, and final accounts in connection with work insofar as they do not originate in the Engineer's office.

2. Plans, Specifications and Designs

Any and all plans, specifications, drawings and designs furnished by the Engineer will be prepared on the assumption that all information supplied by the Client or on behalf of the Client by any person or persons other than the Engineer is correct, and the Engineer shall not be liable for any loss or damage arising from any inaccuracy in such information. The Client shall immediately notify the Engineer of any discrepancies or inaccuracies in such information as they become apparent. The Engineer shall be entitled to make any necessary change or changes in his plans, specifications, drawings, or designs at the Client's expense if any such information should be erroneous or inaccurate.

3. **Compensation for Extra Work and Changes**

If it shall become necessary for the Engineer to make any changes in any designs, drawings, plans or specifications for any part of the Project for reasons over which he has no control, or if the Engineer is put to any extra work, cost or expense by reason of any act or matter over which he has no control, the Client shall pay to the Engineer a fee for such changes or extra work calculated on a time basis; provided that prior to the commencement of such changes or extra work the Engineer shall notify the Client in writing of his intentions to make such changes or to carry out such extra work and that the Engineer shall keep separate costs records in respect to such changes or extra work. **No extra work shall be carried out without prior written approval from the Client.**

4. **Fee for Additional and Special Services**

The fee for Additional and Special Services provided by the Engineer, if any, shall be calculated on a time basis unless specifically provided for in the percentage fee for other services provided for herein. (Additional and Special Services, if any, and the corresponding fees payable, shall be clearly itemized under Article II and III respectively, heretofore).

5. **Abandonment or Suspension**

- (a) If the Project or any part thereof is abandoned at any stage prior to completion of the design, or if any stage of the Engineer's work is unduly delayed for reasons beyond his control, the Client shall pay to the Engineer a fee for his services from the inception of the work calculated on a time basis.
- (b) If the Project or any part thereof is abandoned at any stage subsequent to the completion of the design, or if any stage of the Engineer's work is unduly delayed for reasons beyond his control, the Client shall pay to the Engineer the fee for his services from inception of the work to the completion of design as provided in this Agreement, and shall pay to the Engineer a fee for his services subsequent to the completion of design calculated on a time basis.

6. **Ownership of Documents**

All plans, drawings, specifications, designs, construction data, and documents prepared by the Engineer shall ~~be and remain the property of the Engineer. The Client shall be entitled to a copy of such documents for record purposes only, and shall not use or permit the use thereof for the construction of any other project without the consent of the Engineer.~~ **become the property of the Client.**

7. **Constructional Emergencies**

In the event of any constructional emergency which in the opinion of the Engineer requires immediate action in the Client's interests, the Engineer shall have authority to issue such orders and to take such steps on behalf, and at the expense, of the Client as he shall deem necessary or expedient.

8. **Confidential Data**

The Engineer shall not divulge any confidential information communicated to or acquired by him in the course of carrying out the engineering services provided for herein. No such information shall be used by the Engineer on any other project without the approval of the Client.

9. **Arbitration**

- (a) All matters in difference between the parties hereto in relation to this Agreement ~~shall~~ ^{may} be referred to arbitration.
- (b) No person shall be appointed to act as arbitrator who is in any way interested, financially or otherwise, in the conduct of the work on the Project or in the business or other affairs of either the Client or the Engineer.
- (c) The award of the arbitrator shall be final and binding upon the parties.
- (d) the provisions of The Arbitrations Act, R.S.O., 1970, Chapter 25, shall apply to the arbitration.

Article VII – SUCCESSORS AND ASSIGNMENT

- 1. This Agreement shall enure to the benefit of, and be binding upon, the parties hereto, and except as hereinafter otherwise provided, the executors, administrators, successors and assigns.
- 2. If the Engineer is an individual and dies before his services hereunder have been completed, this Agreement shall automatically terminate as of the date of his death and the Client shall pay for the services rendered and disbursements made to the date of such termination.

**APPENDIX II
GEOTECHNICAL CONSIDERATIONS**

**PRELIMINARY ENGINEERING STUDY
GRAND RIVER VALLEY SLOPE FAILURE
COLBORNE STREET EAST
BRANTFORD, ONTARIO**

July 1987

861-3257

TABLE OF CONTENTS

	<u>Page</u>
1. INTRODUCTION	II-1
2. PROCEDURE	II-3
3. BACKGROUND	II-4
4. SITE DESCRIPTION	II-8
5. SITE GEOLOGY	II-11
6. EXISTING SLOPES	II-12
6.1 General	II-12
6.2 Zone A	II-12
6.3 Zone B	II-13
6.4 Zone C	II-15
6.5 Zone D	II-16
7. SUBSURFACE CONDITIONS	II-17
7.1 General	II-17
7.2 Soil Conditions	II-17
7.2.1 Valley Wall	II-17
7.2.2 Flood Plain	II-20
7.3 Groundwater Conditions	II-20
7.4 Rock Conditions	II-22
8. PRESENT STABILITY OF EXISTING SLOPES	II-23
8.1 General	II-23
9. EROSION CONSIDERATIONS	II-26
10. REMEDIAL SCHEMES	II-28
10.1 General	II-28
10.2 Do Nothing	II-29
10.3 Relocate Colborne Street	II-30
10.4 Fill Scheme	II-30
10.5 Cut and Fill Scheme	II-33
10.6 Cut Scheme	II-35
10.7 Oxbow Cutoff	II-37
10.8 Comments on Slope Stabilization Works	II-37

TABLE OF CONTENTS (Continued)

	<u>Page</u>
11. RIVER WORKS	II-40
12. COST ESTIMATES	II-42
13. PRELIMINARY DESIGN	II-43
13.1 Selection of Design Scheme	II-43
13.2 General	II-44
13.3 Erosion Protection	II-46
13.4 Regrading Requirements	II-47
13.5 Drainage Requirements	II-49
13.6 Implementation	II-50
13.6.1 General	II-50
13.6.2 Phasing	II-50
14. ADDITIONAL WORK	II-52
TABLE II-I - Summary of Effective Stress Slope Stability Analyses	
TABLE II-II - Cost Comparison of Slope Stabilization Schemes	
APPENDIX II-A - References	

1. INTRODUCTION

This report presents the results of the geotechnical engineering study carried out as part of the overall preliminary engineering study being undertaken to provide a recommended slope stabilization alternative for a section of the north valley wall of the Grand River in the Colborne Street East area of Brantford, Ontario. The study area is located as noted on the Key Plan, Figure II-1 and is outlined on the Location Plan, Figure II-2.

The purpose of the geotechnical component of the preliminary engineering study was to:

- i) assemble, compile and review existing soil, rock, groundwater and topographical data
- ii) develop simplified slope topographic and stratigraphic profiles for analytical purposes
- iii) carry out slope stability analyses for the current (May 1986) conditions and for the potential remedial schemes
- iv) prepare conceptual design outlines for the various remedial schemes including a comparative evaluation of the schemes
- v) estimate slope related cost components
- and vi) prepare preliminary geotechnical design criteria for the remedial scheme selected, based on the overall study.

The preliminary results of the geotechnical study have been provided to the other members of the study team as the study evolved in order that the non-geotechnical aspects of the various schemes could be analyzed concurrently and combined within the present report as an all inclusive document.

2. PROCEDURE

The present study entailed carrying out a review and correlation of existing information to establish representative ground surface and stratigraphic profiles and geotechnical engineering design parameters for the study area. This data was to be utilized in assessing the present stability of the slope and developing and evaluating the various schemes to be considered.

The sources of information reviewed in conjunction with the preparation of this report are listed in the enclosed Appendix II-A.

3. BACKGROUND

The present course of the Grand River in the Brantford area is the result of the dynamic nature of the river hydraulics and related geological processes as well as the subsurface soil and groundwater conditions. In recent geological history, large meanders have formed as the river has eroded into the valley wall slopes on the outside of the bends. Concurrently, an accretion of deposited material has created a wide, flat flood plain on the inside of the meander. As shown on Figure 1, the study area is situated along the valley wall of one such meander typical of this section of the Grand River known locally as "The Oxbow".

Slope instability associated with the ongoing toe erosion and oversteepening of the valley wall slope along the outside of the meander has been reported previously in this section of the Grand River Valley. It is understood that landslides near Onondaga, downstream of the study area, necessitated the relocation of a section of Highway 54 several years ago. Evidence of similar deformations which have resulted in loss of property, ongoing maintenance or abandonment of facilities or structures have been noted in the Brantford area by others.

The valley wall topography in the study area generally comprises a broken back slope consisting of a relatively flat lower slope adjacent to the river, a gently sloping or horizontal bench and a relatively steep upper slope. The continual erosion along the toe of the lower slope has resulted in some ongoing deformation of both the upper and lower slopes.

Prior to May, 1986, however, the observed deformations were generally manifested in localized slope failures initiating at the toe and with a gradual regression of successive shallow failures up the valley wall slope. However, the results of an air photo analysis of the valley regime have indicated previous large scale failures of the slopes outside of the current study area.

Although the Toronto, Hamilton & Buffalo Railway which ascends the valley wall through the study area has experienced some distress due to ongoing slope deformations, the serviceability of the line has been maintained by periodic adjustments to the line and grade since its construction in 1895. The regression at the top of the slope has resulted in some property loss but, previously, structures had generally not been affected and the response of land owners was often to attempt to reclaim lost lands by placing fill. It was apparent that the oldest of the three dwellings located south of Beach Road had experienced some distress which could probably have been attributed to movements in the slope; however, the structure was still occupied prior to the May 1986 event.

In early May 1986, deformation of the upper portion of the slope east of the main failure was reported. This deformation, typically in areas of the slope where significant amounts of fill had been placed at the top of the slope, was observed in the form of tension cracks opening and localized sliding of the fill material downslope. In addition, a large slope failure occurred in the west valley wall of the Grand River some 2.6 kilometres downstream of the study area. The river valley

walls and banks at this latter location are about 22 metres high with an overall inclination, as measured from the 1963 topographic mapping, of about 24 degrees to the horizontal.

On May 20, 1986, the residents of MN 929 Colborne Street East which is located within the area of this study noted that a scarp about 0.6 metres high had developed at the top of the slope behind their house. Cracking in Beach Road which is located in the lower portion of the slope was also noted on that day. In the evening of May 20, large movements of the slope occurred affecting the three houses south of Beach Road, the Toronto, Hamilton & Buffalo Railway as well as structures at the top of the slope. In addition, the river channel was partially blocked. The approximate limits of this main failure are outlined on Figure II-2. Subsequently, additional movements were observed in the upper slope for a distance of some 300 metres east of the main failure. It is significant to note that the May 1986 failure contrasted sharply from the recent historical trends described above in that movements of a catastrophic magnitude occurred.

The slope failure has been the subject of a preliminary engineering report by Golder Associates for the City of Brantford and a detailed geotechnical investigation by Trow Geotechnical Ltd. on behalf of CP Rail. Subsequently, the Grand River Conservation Authority has commissioned the present study to assess potential alternatives and to prepare preliminary design drawings for the selected alternative for slope stabilization within the study area.

In the interim, there has been continued movement within the slopes in the study area. Some periods of accelerated movement have been indicated which appear to correspond to variations in the climatic conditions, groundwater levels and river water levels. Surface deformations in the slope are being monitored by the City of Brantford forces in the interest of public safety and awareness. Instrumentation designed to monitor groundwater levels and subsurface deformations in the slope is being monitored by the Conservation Authority and Golder Associates to provide geotechnical data for design purposes and to supplement the City's monitoring programme. The results of this additional monitoring are being reviewed and reported on a regular basis and the results to mid-March 1987 were discussed in Golder Associates' March 1987 interim condition report.

4. SITE DESCRIPTION

The site is located along the outside bend of a large meander in the Grand River and near the east limit of the City of Brantford and just west of Cainsville, as shown on the Key Plan, Figure II-1. The limits of the study area are shown on Figure II-2 and extend along the north side of the Grand River from a point adjacent to the Toronto, Hamilton & Buffalo Railroad subway under Colborne Street upstream a distance of some 1.3 kilometres generally paralleling Colborne Street East.

In the study area, the north valley wall is about 30 metres in height with a typical top of slope elevation of 220 metres. The surface topography of the slope is irregular and typically consists of a broken back slope with an overall inclination of from about 14 to 16½ degrees from the horizontal, or from 4 horizontal to 1 vertical to 3.4 horizontal to 1 vertical, based on the topographical mapping. The valley wall generally consists of an upper and a lower slope separated by a relatively level bench located about halfway up the total slope. The slopes are generally well vegetated with trees except in the area of the May 1986 failure scarp and in the area between MN 937 Colborne Street East and the storm sewer outfall from Colborne Street to the Grand River.

The Toronto, Hamilton & Buffalo Railway tracks extend along the bench within the western 600 metres of the study area rising towards the east at a grade of about 0.5 per cent before climbing to the subway structure at Colborne Street at a grade of about 1.5 per cent. The railway

embankments on the slope are up to 15 metres in height on the downslope side of the tracks. Nominal 1 to 2 metre high cuts exist locally on the upslope side of the tracks.

Numerous structures are located close to the top of the valley wall throughout the study area. Three houses are situated near the top of the lower slope below the railway. Access to these structures is via Beach Road which runs immediately south of the railway in the western portion of the site.

Filling with miscellaneous materials has taken place at the top of the slope at some locations to the east of the May 1986 failure area. This filling has generally extended down over the upper portion of the slope.

The massive slope failure which occurred on May 20, 1986, extended over approximately 365 metres of the western portion of the study area. The approximate outline of this failure is shown on Figure II-2 and was delineated by a vertical scarp which was as much as 12 metres in height. Several structures have been undermined as a result of the failure and subsequent regression of the scarp. Additional buildings are situated immediately adjacent to the present (March 1987) location of the scarp.

In this report, the study area has been divided into four characteristic zones, primarily on the basis of slope geometry, for analytical purposes. The four zones, designated as A, B, C and D, are outlined on the Plan, Figure II-2 and typical simplified slope geometries for

each zone are shown on Figures II-3 to II-6, respectively. Zone A comprises the area of the large movements which occurred during the May 1986 failure. Zones B and C consist of lands within the study area which experienced some deformations during and subsequent to the May 1986 event; however, the magnitude of these movements has been substantially smaller than in zone A. The distinction between zones B and C is primarily based on minor differences in slope geometry. Zone D comprises the remainder of the study area and consists of the area on which the May 1986 slide had little effect. Zone D is generally characterized by a somewhat flatter overall slope inclination as compared to zones B and C.

5. SITE GEOLOGY

The study area is located within the physiographic region of Southwestern Ontario known as the Haldimand Clay Plain. Published geologic information indicates that the north valley wall in the study area is comprised of glaciolacustrine deep water sediments of glacial Lake Warren laid down during the Late Wisconsin age. These sediments typically consist of laminated to varved silts and clays and contain minor amounts of sand.

Bedrock at the site is considered to be dolomite and mudstone belonging to the Salina formation of Upper Silurian age.

6. EXISTING SLOPES

6.1 General

The condition of the valley wall slopes in the study area following the May 1986 failure has been described in the previous section. As noted, however, deformation of the slopes has been ongoing since the failure. The following paragraphs present a brief description of the present condition of the slopes in each of the four zones identified for the study area.

6.2 Zone A

In zone A, the existing ground surface profile consists of a wide, gently sloping lower slope and an oversteepened upper slope, as outlined on Figure II-3. The overall inclination of the lower slope is about 7.5 horizontal to 1 vertical. This lower slope comprises disturbed soil including a large volume of slide debris. Numerous post-failure scarps generally paralleling the river are present and much of the area, particularly between the present alignment of the railway and the upper slope scarp, contains ponded water from ground surface runoff and groundwater seepage.

Three dwellings were located in the lower slope south of Beach Road. One of these is presently unoccupied and one of the structures has been demolished. It is understood that unsuccessful attempts have been made to reinstate the integrity of the foundation of the easterly remaining dwelling.

Following the May 20, 1986 failure, the upper slope consisted of a nearly vertical scarp with a height of some 12 metres. Since May of 1986, the top of slope has continued to regress, gradually reducing the height of scarp and the severity of the inclination. At present, the scarp height is about 3 metres. This regression has resulted in a substantial loss of property along the top of the slope since May 1986. In particular, the car wash building was taken out of service and was eventually demolished. The top of the slope in this area has subsequently regressed. At the rear of MN 929 Colborne Street, the focal point of the May 1986 slide, the slope has regressed to within a few metres of the house. Further west, at the Clubine Lumber Yard, the slope has regressed into the yard. However, to date only one building has been significantly affected. Sympathetic movements involving large soil masses have also occurred primarily on lands east of and adjacent to the main failure area. This has necessitated regular inspection of the slope to assess the safety of certain dwellings.

A typical cross section of the valley wall slope in zone A is shown on Figure II-3. Both the pre-failure and post-failure geometries, are shown illustrating the changes in profile since the failure.

6.3 Zone B

While the valley wall slope topography is somewhat irregular within zone B areas, the following generalized comments can be applied to develop a typical geometry for analytical purposes. The overall inclination of the lower slope

is typically about 4 horizontal to 1 vertical with localized zones as steep as 2.5 horizontal to 1 vertical. The height of the lower slope varies from about 6 to 9 metres above normal river water level. A gently sloping bench separates the lower and upper slopes. The width of the bench in this section ranges from about 18 to 21 metres. In zone B, the railway is typically located on an embankment. The height of the railway embankment side slopes in zone B varies from about 3 to 12 metres with side slope inclinations of about 2 horizontal to 1 vertical. The height of the upper slope ranges from about 11 to 15 metres depending primarily on the elevation of the railroad. The inclination of the upper slopes vary between about 1.7 horizontal to 1 vertical to 3.3 horizontal to 1 vertical with an average overall inclination of about 2 horizontal to 1 vertical being considered representative.

The deformations which were observed in zone B areas immediately following the 1986 failure were significant but of substantially smaller magnitude than those in zone A. Although there was some distress noted in patios, out buildings and the like, no residences were vacated. While there was some disturbance of the Toronto, Hamilton & Buffalo rails, these movements were of a smaller magnitude than the movements within zone A.

Since May 1986, additional deformation of significant magnitude has occurred within the zone B slopes. Localized disturbance of railway tracks has been observed as recently as March 1987 and movements along former failure scarps

at the top of the slope have been observed. In some instances, the deformation is perceived to reflect the movement of fill along the former slope surfaces or movements along former failure scarps.

A cross section typical to zone B is shown on Figure II-4.

6.4 Zone C

The overall inclination of slopes in zone C are slightly flatter than those in zone B. The overall inclination of the lower slopes generally ranges from about 3.5 horizontal to 1 vertical to 5.0 horizontal to 1 vertical with an average overall inclination of about 4.3 horizontal to 1 vertical. The height of the lower slopes ranges from about 7 to 22 metres with an average height of about 16 metres. The inclination of the upper slope ranges from about 1.8 horizontal to 1 vertical to 3.0 horizontal to 1 vertical with an average overall inclination of about 2.3 horizontal to 1 vertical. The corresponding average upper slope height is about 11 metres with a range of some 8 to 14 metres. Railway embankment fills with side slope heights of up to about 10 metres and inclinations of about 2 horizontal to 1 vertical exist between the upper and lower slopes in the easterly section of this zone.

It is considered that some deformation of the slopes in zone C occurred during and subsequent to the May 1986 slide. However, the deformation is much less evident than in zone B. Recently, during March 1987, some distortion of the railroad tracks through this zone has

been observed. In addition, some movements in the upper slope have been noted. The nature of these deformations infer movement of fill along former slope surfaces and former scarps.

A cross section considered typical of the slope geometry in zone C is shown on Figure II-5.

6.5 Zone D

Zone D comprises approximately the westerly 200 metres of the study area. The valley wall slopes in zone D are similar in geometry to zone C but have a somewhat flatter overall inclination. The lower slope has a typical overall inclination of about 4 horizontal to 1 vertical with a corresponding slope height of about 15 metres. The upper portion of the slope has an overall inclination of about 2.5 horizontal to 1 vertical and a slope height of about 17 metres. The bench separating the upper and lower slopes is some 16 metres wide. Both the portion of Beach Road and the railway tracks located on this bench are essentially at the prevailing grade.

Since existing development is generally somewhat removed from the top of the slope in zone D, little attention has been given with regard to monitoring slopes in this portion of the study area. There has been no indication of any recent slope movements within this zone. A typical cross section of the slope in zone D is shown on Figure II-6.

7. SUBSURFACE CONDITIONS

7.1 General

In addition to previous investigations carried out in the area of the site, the subsurface conditions within the study area have been identified by a site specific detailed geotechnical investigation carried out by Trow Geotechnical Limited for CP Rail. This document has been used as the primary source of data regarding the detailed subsurface conditions at the site. The results of previous investigations by others in the general vicinity of the site have also been used as background data. Reference should be made to the above documents as listed in Appendix II-A for detailed descriptions of the actual subsurface conditions encountered. The following paragraphs are intended as an interpretive summary of the predominant subsurface conditions for the purposes of conceptual and preliminary geotechnical design only.

7.2 Soil Conditions

7.2.1 Valley Wall

The results of a review of all of the subsurface data compiled from the sources noted in Appendix II-A for the study area has been used to develop a general stratigraphic section for the valley wall. Variations from the general pattern occur predominantly in boreholes drilled in the highly disturbed area previously designated as zone A.

The results of the deeper boreholes drilled in and adjacent to the study area indicate that the overburden extends to a depth of about 40 metres below the table land or to about elevation 180 metres. The overburden materials encountered in the valley wall slope generally comprise glaciolacustrine sediments which are typically described as a complex and irregular interlayering of clayey silt, silt and silty clay. A thin stratum of silty sand was encountered at about mid-depth between the table land and the bedrock surface or at about elevation 200 metres. Deposits of fill were encountered at the top of the slope in some areas and in the railway embankments.

Summary plots of N values, as determined from standard penetration tests, natural water contents and Atterberg limits are presented on Figure II-7 along with the inferred soil stratigraphy. Similar data for the boreholes drilled in zone A, the disturbed area, have been considered separately on similar plots on Figure II-8. Envelopes of grain size distribution curves for the cohesive materials sampled above and below the sand layer are shown on Figure II-9.

The degree of scatter in the data shown is indicative of the highly layered structure of the soils. The range in plasticity indicated by the Atterberg limit determinations is indicative of the relatively low plasticity of the silt layers and the intermediate plasticity of the silty clay materials.

Based on our interpretation of the data presented, and for the purposes of numerical modeling of the valley wall and conceptual and preliminary geotechnical design only, the soil stratigraphy has been characterized as two discrete layers comprising

- i) the upper silty clay consisting of the layered cohesive material above the sand layer at about elevation 200 metres

and ii) the lower silty clay consisting of the layered clayey soils between the sand layer and the bedrock surface.

Although not incorporated as a discrete layer for analytical purposes, the presence of the sand has been accounted for in the numerical modeling not only as a separation between the upper and lower clayey strata but also by assessing and defining the piezometric levels at the corresponding elevations in the slope.

To determine appropriate effective stress parameters for modeling the upper and lower silty clay the results of isotropically consolidated drained triaxial compression tests previously reported by Trow have been summarized and reviewed. Figures II-10 and II-11 present summaries of the results of the triaxial testing on effective stress diagrams for the upper and lower silty clay strata, respectively.

Based on our interpretation of the data presented, and for the purposes of numerical modeling of the valley wall and conceptual and preliminary geotechnical design only, the soil stratigraphy has been characterized as two discrete layers comprising

- i) the upper silty clay consisting of the layered cohesive material above the sand layer at about elevation 200 metres
- and ii) the lower silty clay consisting of the layered clayey soils between the sand layer and the bedrock surface.

Although not incorporated as a discrete layer for analytical purposes, the presence of the sand has been accounted for in the numerical modeling not only as a separation between the upper and lower clayey strata but also by assessing and defining the piezometric levels at the corresponding elevations in the slope.

To determine appropriate effective stress parameters for modeling the upper and lower clayey silt, the results of isotropically consolidated drained triaxial compression tests previously reported by Trow have been summarized and reviewed. Figures II-10 and II-11 present summaries of the results of the triaxial testing on effective stress diagrams for the upper and lower silty clay strata, respectively.

Based on the data presented and using a line of best fit assuming a zero cohesion intercept, angles of effective shearing resistance, ϕ' , for the upper and lower silty clay strata of 28 and 25 degrees, respectively, have been determined. It should be noted that test results for samples which had anomalously low plasticity and predictably higher strengths (inferring a higher percentage of silt sizes), have been deleted from the analysis of the data. The summarized soil conditions are presented graphically on Figure II-12.

7.2.2 Flood Plain

The results of the geotechnical investigation carried out in the flood plain south of the present river course by Golder Associates indicate that the predominant soil conditions in the flood plain consist of topsoil overlying some 5 to 7 metres of fine grained sands and silts. The loose granular deposits comprise materials recently deposited on the inside of the meander. The surficial strata are underlain by clayey silt and silty clay. The results of the investigation indicated a probable bedrock surface at about elevation 180 metres which is consistent with other information for the area.

7.3 Groundwater Conditions

Instrumentation for groundwater level determination has been installed in the boreholes drilled in the study area. Monitoring of the instrumentation has been carried out on a regular basis by Conservation Authority forces. Based on this data and for analytical purposes, the

stabilized groundwater conditions in the study area have been simplified, as shown on Figure II-12. As shown on this figure, three groundwater profiles have been considered to approximate the complex groundwater regime in the valley wall. Included in the figure are a phreatic surface, a piezometric profile based on pressures measured at the rock surface and an intermediate level groundwater profile.

The phreatic surface generally parallels the ground surface sloping upward from the river typically within about one metre of the ground surface in the lower slope. In the upper slope, the phreatic surface reaches a level generally about 3 metres below the tableland surface. The piezometric level associated with the bedrock surface slopes upward from about elevation 192 metres in the flood plain on the south side of the river to about elevation 195 metres in the area of the lower slope and to about 205 metres below the crest of the slope. This results in artesian conditions in the area of the lower slope and beneath the riverbed. The intermediate piezometric profile approximately coincides with the phreatic surface at the toe of the slope and rises to about elevation 210 metres towards the top of the slope. The water level in the section of the Grand River is at about elevation 189.5 metres at normal stage.

It should be noted that the groundwater levels measured in boreholes located in the highly disturbed area (zone A) shortly following the May 1986 failure were, and remain, somewhat elevated from the stabilized levels indicated from instrumentation in zones B and C.

7.4 Rock Conditions

Although rock was not proven by coring in the boreholes drilled in the study area, the information generally indicates auger refusal and a probable bedrock surface consistently at about elevation 180 metres. This is in general agreement with bedrock surface mapping for the area which has been compiled from water and gas well records by the Ontario Department of Mines and Northern Affairs. Based on the tricone cuttings, the rock encountered in the boreholes has been described as dolomite. Bedrock in the vicinity of the site is known to consist of dolomite and mudstone of the Salina formation of Upper Silurian Age.

8. PRESENT STABILITY OF EXISTING SLOPES

8.1 General

Previous sections of this report have noted the complexity of the soil and groundwater conditions at the site. The ongoing erosion of the toe of the lower slope, combined with high piezometric levels and low strength soils resulting in deep seated rotational failures in the lower slope, followed by a rapid progression of successive rotational failure(s) in the upper slope, has been recognized as the likely mechanism of the May 1986 failure.

Regardless of the remedial scheme considered, be it a "do nothing" approach or a full scale rehabilitation and restoration project, appropriate recognition must be given to the severe geotechnical constraints in the study area. In order to assess the consequences of the former approach and the potential scope of the latter work and to examine the geotechnical aspects of the potential alternatives, a complete assessment of present slope conditions and erosion potential is required.

To this end, effective stress slope stability analyses have been carried out for typical conditions existing for the four characteristic zones previously identified for the study area. The representative valley wall geometries for the four zones as outlined on Figures II-3 to II-6 along with the simplified soil stratigraphy and groundwater conditions shown on Figure II-12 and a river water level of 190 metres have been assumed for analytical purposes. A computer programme based on a limiting

equilibrium technique has been used in the analysis in addition to conventional manual methods. In addition, a series of undrained analyses were carried out for the various slope sections using the undrained shear strength data noted previously for comparative purposes. The results of these analyses, which represent only short term conditions, indicate factors of safety against failure of substantially greater than unity even for the area of the recent failure and are therefore not considered to be relevant or appropriate for the analysis of the valley wall stability. Therefore, only the results of the effective stress analyses have been utilized for the purposes of this study. These analyses were carried out utilizing both circular failure surfaces and curvilinear surfaces. The results of the analyses are summarized in Table I and on Figures II-3, II-4, II-5 and II-6. The factors of safety shown for the upper, lower and overall slopes are generally for the critical circular failure surfaces.

The results of the analyses have indicated that the condition of the slopes in zones B, C and D are not markedly dissimilar with those computed for the pre-1986 slide geometry for zone A. It should be noted that the analytical model used does not account for the potentially lower frictional resistance along former failure surfaces. This is of particular significance in interpreting the high apparent factor of safety against an overall slope failure indicated for the post-failure geometry in zone A, especially since the results of inclinometer monitoring in zone A indicate post-failure movements along a deep seated composite failure surface located very close to

the rock surface. These deep seated movements are considered to be the result of regressive failures combining to result in an on going creep type of movement at depth.

Similarly, although factors of safety of 1.1 and 1.2 are indicated for the upper slopes in zones B and C, surficial movement has been measured on these slopes, probably along former failure scarps or slope surfaces and within fill materials.

Factors of safety of less than unity have been indicated for the upper and lower slopes in zone A for the post-failure geometry. In the case of the upper slope, this reflects the presence of the oversteepened scarp resulting from the failure and the subsequent regression of the top of the slope presently being experienced. In the case of the lower slope, the low factor of safety is indicative of the elevated piezometric pressures which have been indicated for zone A with respect to the stabilized piezometric levels generally indicated for the other zones.

9. EROSION CONSIDERATIONS

Estimates have been made to quantify the rate of erosion of the north river bank by comparing various topographical mapping dated 1913, 1955, 1964, and pre-failure 1986. The erosion rates determined on this basis are somewhat qualitative since a comparison of the mapping infers both inward and outward movement of the river bank. This might be attributed to fluctuating river water levels, the effects of deformation of the lower slope and the accuracy of the mapping. However, the results of the analysis indicate that during the 73 years spanned by the mapping, the north river bank has shifted to the north by as much as 24 metres within the limits of the study area. Little or no apparent movement is indicated in the upstream and downstream sections of the study area with the maximum erosion occurring within zone A. Further, some 10 metres of apparent erosion in zone A is indicated over a 23 year period between 1963 and 1986 corresponding to an average rate of about 0.4 metres per year. Some 14 metres of erosion is inferred for the same section over a 50 year period between 1913 and 1963, corresponding to an average rate of about 0.3 metres per year.

For the area immediately downstream of zone A, substantial erosion is indicated for the period between 1913 and 1955 with an average rate approaching 0.5 metres per year being estimated. Since that time, some 8 metres of apparent accretion or outward movement of the river bank is indicated.

The continued, and apparently recently increasing, rate of erosion indicated for zone A relative to other zones has been identified as a primary cause of the 1986 failure. Further, it is considered that the encroachment of the recent failure debris into the river channel in zone A has resulted in an increased river flow velocity and variations in stream flow vectors. The disturbed nature of the slide debris combined with the increased velocity, particularly during high flow periods, is likely to result in localized increases in the apparent erosion rate. Relatively rapid erosion of the slide debris is anticipated, increasing the potential for continual and accelerated creep of the lower slope in zone A. In addition, the erosion exposure of the other zones may have been increased as a result of the changes to the river flow characteristics caused by the May 1986 failure and subsequent deformations.

Based on the above, any scheme in which toe erosion remains unchecked must allow an appropriate erosion component in establishing the limit of slope regression anticipated within a specified design period. Based on a review of data noted above, an average erosion rate of at least 0.4 metres per year for the 50 year design period is recommended for the study area.

10. REMEDIAL SCHEMES

10.1 General

In accordance with the Terms of Reference for the preliminary engineering study, six conceptual design schemes have been considered to address the hazardous conditions which presently exist in the study area. These schemes, which will be discussed in some detail below, are designated as follows:

<u>Scheme</u>	<u>Description</u>
1	Do nothing
2	Relocate Colborne Street only
3	Stabilize slopes by filling only
4	Stabilize slopes by cutting and filling
5	Stabilize slopes by cutting only
6	Divert river isolating the oxbow

The first two schemes represent a passive approach in which erosion is unchecked and the slope is allowed to regress unimpeded. In the second scheme, major public works would be relocated away from the hazard area. In the next three approaches, major civil engineering works would be carried out to arrest toe erosion and stabilize the slopes. Rechannelization works, erosion control works and slope regrading are common to these three schemes. The final scheme considers constructing a major river diversion which would cut off the large meander and remove the erosion potential in this reach of the river.

10.2 Do Nothing

In a "Do Nothing" scheme, no remedial work, whatsoever, would be carried out and the natural process of erosion and slope failure regression would carry on unimpeded. The consequences of this scheme are that no protection is provided for the lands and buildings on the south side of Colborne Street and abandonment will be necessary. Further, it is unlikely that the railway line could be restored to service with an acceptable degree of risk against catastrophic failure, even in the short term. The top of slope including the regression estimated for a 50 year period and the pertinent slope stability component is shown on the Plan, Figure II-13.

For the purposes of preliminary planning and considering a 50 year design period, the fill/building line for this scheme may be established by the criteria noted below and outlined on Figures II-14, II-15 and II-16 for zones A, B and C, respectively.

<u>ZONE</u>	<u>EROSION COMPONENT</u> (m)	<u>STABILITY COMPONENT</u> (m)	<u>BUFFER</u> (m)	<u>TOTAL SETBACK FROM MAY 1986 TOP OF SLOPE</u> (m)
A	20	40	6	66
B	20	30	6	56
C	20	20	6	46

The erosion component is based on the average rate of erosion noted in Section 9. The stability component represents the horizontal distance required to obtain

a stable slope inclination and the buffer is an arbitrary set back to any proposed construction such as buildings or areas of fill placement.

10.3 Relocate Colborne Street

This scheme is similar in most respects to the above scheme except that the serviceability of the section of Colborne Street and associated utilities in the study area would be ensured for the design period by relocation to the north, away from the hazard area, as outlined on Figure II-13.

10.4 Fill Scheme

In a total fill scheme, the present (May 1986) location of the top of the slope is maintained with the exception of some minor trimming of the scarp in zone A. The slope would be regraded to a stable inclination primarily by filling at the toe and, where required, on the upper slopes. The provision of suitable erosion protection at the toe of the filled slope will be required to preserve the stability of the lower slope which is vital to maintaining the stability of the upper slope and the overall stability of the entire valley wall slope in the long term.

For conceptual design purposes, it was considered that the lower slopes in zones B and C should be regraded to an overall inclination not greater than 4 horizontal to 1 vertical with the upper slopes being regraded to an overall inclination not steeper than 2.5 horizontal to 1 vertical. Under this scheme, the overall inclination of the lower slope in zone A would remain at its present slope which is about the same or somewhat flatter than the above criteria. While only minimal filling would

be required to flatten the upper slopes in zones B and C, more substantial filling would be required to stabilize the upper slopes in zone A. The geometry required to achieve the regrading for zones A, B and C is shown on Figures II-18, II-19 and II-20. A broken back slope is recommended consisting of a protected lower slope with an inclination of 3 horizontal to 1 vertical, a horizontal bench and an upper slope inclined at 2.5 horizontal to 1 vertical. Railway embankments, also with 3 horizontal to 1 vertical side slopes, could be incorporated into the scheme as an intermediate bench.

Consistent with the above criteria, and in order to provide a uniform transition along the river bank through the study area, the toe of the lower slope would encroach some 9 to 25 metres into the present river channel as shown on the Plan, Figure II-17. Consequently, major widening or relocation of the river would be required. Based on the results of the slope stability analyses carried out for this scheme, the long term factor of safety of the lower slopes would be improved to 1.1 in the worst case with a typical factor of safety of 1.3 for the upper slopes. In conjunction with the fill scheme, it is considered that drainage works should be incorporated into the final design. While the effects of such drainage works have not been considered in the analyses, the effects would be beneficial to the long term stability of the slopes.

With a full programme of erosion protection and slope regrading, erosion and stability components need not be considered in establishing the limits of the hazard zone

for the completed works. Such a zone would be established by a 6 metre setback from the top of the regraded slope. This would result in a minimum of property at the top of the slope being located within the hazard zone upon completion of the work. This does not, however, preclude the loss of property which could occur prior to implementation and completion of a project of this magnitude.

A full fill scheme would allow for the restoration of the railway line to a serviceable condition. Periodic maintenance and routine monitoring of the restored rail line would be required. Under this scheme, all of the dwellings located along Beach Road would be removed and the entire slope would be deemed as a hazard zone with future development being prohibited.

It has been estimated that some 300,000 cubic metres of earth fill will be required for the stabilization of the approximately one kilometre of valley wall slope to be addressed (comprising study zones A, B and C). In addition to the earth fill, other key construction elements include tree removal, grubbing and stripping, and surface restoration as well as widening and/or relocation of the river channel. The total costs of the slope stabilization and restoration work exclusive of any channel widening and property acquisition costs is \$6 million. A summary of the various cost components for this alternative is presented in Table II-II.

10.5 Cut and Fill Scheme

Regrading of the slope to achieve a stable geometry could also be achieved by a cut and fill scheme. This scheme would result in less encroachment into the existing river channel but would require some loss of table land at the top of the slope. The hazard zone would be established in a similar manner as outlined for the full fill scheme; however, the top of the slope would be cut back further north to achieve the required geometry in effect moving the hazard zone to the north. As with the previous scheme, some rechannelization works would also be required. Reinstatement of the railroad with the regraded, stabilized slopes would be considered geotechnically feasible.

It is considered that the present inclination of the lower slope in zone A is somewhat flatter than that theoretically required to achieve a stable inclination. While some cutting of the lower slope in zone A would reduce the extent of the fill which would be required to provide the composite geometry required for both slope and river channel works, such a scheme is not considered geotechnically desirable due to the disturbed nature of the soils in the lower slopes in zone A. Consequently, any fill savings over the full fill scheme are not as large as might be anticipated with this type of scheme in zone A.

A broken back geometry similar to that described above for the fill scheme and as shown schematically on Figures II-22, II-23 and II-24 is recommended for the cut and fill scheme in zones A, B and C, respectively. Consistent

with the total fill scheme, the lower slope would be regraded primarily by filling to achieve an overall inclination of not steeper than 4 horizontal to 1 vertical with localized slopes of 3 horizontal to 1 vertical or flatter. The upper slopes would be flattened to an inclination of 2.5 horizontal to 1 vertical or flatter by cutting. This would result in only sufficient filling to place erosion protection in zone A with substantial fills in zones B and C. Typically, the toe of the lower slope would extend 15 to 25 metres into the present river channel as shown on Figure II-21. The extent of this fill will vary, to some degree, with the condition of the upper slope at the time of construction. Presently, only minimal cutting would be required in zone C with more substantial cuts being required in zones A and B. Typically, the top of slope would be shifted some 10 to 15 metres to the north from its present location in zones A and B. The results of stability analyses indicate that the net effect of this scheme is generally the same as for the total fill scheme. The incorporation of appropriate drainage works into the scheme would have a positive effect on the long term stability of the valley wall slope.

Based on conceptual design criteria, some 33,000 cubic metres of earth excavation and some 230,000 cubic metres of earth fill would be required. A breakdown of the costs for slope stabilization work required under this scheme is summarized in Table II-II. These costs total \$4.7 million for the slope related works.

10.6 Cut Scheme

In the cut scheme, the existing toe of slope (pre-May 1986 failure) would remain fixed and a stable inclination achieved by cutting. No major river rechannelization works would then be required; however, the cut required to achieve the broken back geometry recommended would result in substantial encroachment on lands at the top of the slope. The regraded geometry would result in a top of slope some 18 to 30 metres north of the present location, as shown on Figure II-25 which would necessitate the relocation of Colborne Street. As with previous schemes, a 6 metre setback from the regraded top of slope would be used to establish the limits of the hazard zone. Schematic details of this scheme are shown on Figures II-26, II-27 and II-28.

Although no rechannelization work would be required, adequate erosion protection would be a major element of this scheme as with the previous two schemes. Reinstatement of the railway line would also be considered geotechnically feasible with this scheme.

To achieve the broken back geometry recommended for the regraded slope, as outlined previously, the net cut required on the lower slopes in zones B and C would be relatively small. Work at the river bank would essentially be confined to providing erosion protection. In zone A, substantial excavation would be required to remove the present slide debris from the channel and to provide continuity with the adjacent zones. It is considered that this operation would be extremely difficult to perform. Notwithstanding

the results of conventional analyses, it is anticipated that any excavation within the lower slope in zone A may precipitate a large outward movement of the disturbed overburden in that area. Therefore, careful planning and sequencing of the work prior to and during construction would be required to minimize the potential for such a failure during construction. The scheduling of any such work will have to be carefully programmed in clear recognition of the inherent risks.

For the slope geometry developed for conceptual design, factors of safety of 1.1 and 1.2 have been indicated for critical slip circles in the lower and upper slopes, respectively. In contrast to the two previous schemes, while surficial drainage works should be incorporated into the works, their effect is not substantial with this scheme. Considerable groundwater seepage is likely to be encountered and extensive drainage works may be required to facilitate the construction. While drainage works would also be required for the long term stability of the slopes, the effect of these works will likely be of less benefit than for the two previous schemes due to the severity of the groundwater conditions anticipated and the resultant overall slope geometry.

It has been estimated that a total of some 570,000 cubic metres of earth excavation would be required with this scheme at a cost of about 5.2 million dollars for the slope related works as noted in Table II-II.

10.7 Oxbow Cutoff

Consideration has also been given to a scheme which would isolate the large meander on which the site is located and which is known locally as "The Oxbow". This would entail construction of a major river channel diversion across the neck of the meander as shown schematically on Figure II-29. While such a scheme would essentially eliminate the erosion potential, a hazard would still exist due to the unstable slopes and, to be fully effective, this scheme would have to be combined with one of the regrading schemes outlined above to address the stability of the slopes.

The cutoff would entail construction of an approximately 500 metre long section of channel. Cuts varying in depth from about 3 to 20 metres below the existing ground surface would be required. Based on the anticipated soil and groundwater conditions, it would probably be necessary to cut the side slopes of the channel to an overall inclination of 3 horizontal to 1 vertical or flatter for long term stability. The erosion exposure in the channel will be severe requiring major erosion control and energy dissipation works.

10.8 Comments on Slope Stabilization Works

Of the three remedial schemes involving slope regrading and restoration works, the cut scheme is least preferred from geotechnical considerations. It is considered that this scheme is the least effective and the computed factors of safety are significantly influenced by even relatively

minor fluctuations in the high groundwater conditions which exist in the slope. In this regard, both the fill and cut and fill schemes are less sensitive to minor groundwater fluctuations and can readily incorporate drainage works into the restored slope which would be of significant benefit in maintaining the long term stability of the slope. Such drainage works would include the use of full face drainage blankets, perforated subdrains and the like.

A cut and fill scheme has the advantage that less imported fill would be required and some savings in cost might be realized by using the excavated material as fill.

The slope geometries developed for conceptual design purposes will result in the slopes being restored to a long term stable inclination based on the effective stress stability analyses. The conceptual designs are based on the premise that the slide debris would remain in place. Consequently, and irrespective of the factor of safety indicated, post-construction deformations of the slope should be anticipated due to the disturbed condition of some of the soil to remain in place. The nature of the deformations will probably resemble creep type movements. Complete removal and replacement of the slide debris is not considered feasible.

In the case of alternatives 1 and 2, which do not stabilize the slope, the existing storm sewer outlet should be relocated outside of the area of instability. Further, consistent with the above, if the storm sewer outlet is reconstructed in a stabilized slope, some post-construction

deformations should be anticipated which may require ongoing maintenance of the sewer. It would therefore be prudent to investigate any other potential outlet for the sewer which would not involve construction of works in the valley wall slope.

Consideration has been given to the use of retaining structures to preserve specific localized areas of the tableland in combination with schemes 3, 4 or 5. The height and extent of any such walls would be very limited to preclude oversteepening of the overall slopes and the walls are not considered to be cost-effective. Specific areas which might benefit from such walls would be identified during the final design phase of the work.

11. RIVER WORKS

River works will be required in conjunction with any of the slope stabilization schemes. The scope of the work required varies considerably between schemes. Typically, either a complete diversion of the river or a river widening would be required for the fill or cut and fill schemes. The cut scheme will only entail the removal of a portion of the recent slide debris from the north side of the river in zone A and no widening on the south side of the river is anticipated.

In the case of a complete diversion, it is anticipated that construction of the channel will require excavations of typically 6 to 7 metres below the existing ground surface. Based on the results of a recent investigation, the materials to be encountered are anticipated to consist predominantly of topsoil, silty sand, silt and sandy silt with lesser amounts of sand and gravel and silty clay. In general, these materials are expected to be wet and relatively loose or soft.

Based on the results of the investigation carried out for the area of the proposed channel alignment, it is considered that, with proper handling and stockpiling, the topsoil and fine grained soils would be suitable for use as cover in dressing the regraded slopes. Further, unless significant drying of most of the excavated material is carried out, no substantial amounts of general borrow material will be available for the fill schemes from either of the channel realignment schemes.

For the case of complete channel relocation or for widening on the south side of the existing river channel, overall river bank side slopes of 2.5 horizontal to 1 vertical are recommended for the preliminary design of channel cut slopes. Suitable erosion protection is essential for the north bank of the river but may be optional for the south bank provided that some localized instability can be tolerated.

Should it be deemed desirable to fill the existing channel in conjunction with the construction of a new channel, it is considered that the general excavated material from the new channel can be used to fill the former channel provided that care is taken to excavate, handle and place the material in a manner which effectively reduces the water content. Further, the material should only be placed in the dry and the surface graded to prevent surface water ponding. Due to the nature of the fill materials, provision should be included to regrade selected areas following construction.

12. COST ESTIMATES

A cost comparison of the various components of the three slope stabilization schemes is presented in Table II-II. The costs have been determined on the basis of unit rates which have been provided by Philips Planning and Engineering Limited and are understood to be representative of rates presently (January 1987) prevailing in the construction industry in the Brantford area.

The costs of engineering fees associated with the design and construction of the works have been estimated at 10 per cent of the construction costs and are included in the amounts shown in Table II-II.

13. PRELIMINARY DESIGN

13.1 Selection of Design Scheme

The six alternatives have been evaluated by the engineering study team and the Technical Coordinating Committee. The results of these assessments have indicated that the fill and cut and fill schemes are highly favoured with an overall preference being given to the fill scheme which had the highest benefit cost ratio and scored highest in the various rating schemes. However, in light of recent developments, an assessment of the properties presently at risk has been sought for the intent of prioritizing land acquisition based on the degree of risk to individual properties. It has been pointed out that, presently, the technology does not exist to confidently predict when, where and to what extent future failures will occur under the existing conditions. For this reason, residences and other buildings at the top of the valley wall slope have been perceived to be at risk and will continue to be at risk until the slope stabilization works are complete. It has been considered that, in order to provide a virtually no risk safeguard against potential injury or loss of life due to slope instability, the occupants of all properties on the south side of Colborne Street should be evacuated.

In consideration of the above, it is understood that the Conservation Authority is proceeding to acquire all of the properties considered to be at risk. On this basis, the constraint imposed by attempting to maximize the amount of tableland preserved and to minimize the impact of

remedial work on private properties is significantly reduced. Further, when the various alternatives were reassessed by considering the necessity to stage construction to accomodate funding and cash flow constraints, it was determined that the cut and fill scheme, in conjunction with the realigned channel, evolved as the most appropriate remedial scheme. The geotechnical aspects of the preliminary design of the construction are outlined in the following sections.

13.2 General

It is considered that the completed remedial work should be of sufficient scope to provide a factor of safety of at least 1.2 against slope failure using effective stress analyses. As discussed previously, the analyses do not entirely address the potential for movements along former slip planes especially within zone A and, therefore, some post-construction deformations must be anticipated in this and other areas irrespective of the factor of safety indicated.

The preliminary design of the regrading scheme assumes that a 6 metre set back from the completed top of slope would be used as a criteria for establishing a hazard zone for any future filling or building construction. It is considered that some post-construction deformations would be tolerable within the hazard zone since the affected properties would be acquired and structures and settlement sensitive utilities within the hazard zone would be removed. This premise represents a substantial cost savings in that the slide debris and disturbed soils, with which ongoing creep movements are associated, need not be excavated and replaced. Notwithstanding the feasibility

of such removals, it is considered that the costs of schemes designed to stringent deformation tolerances and thereby necessitating removal and replacement of such materials, would be several times the cost estimate for the present design.

Conceptually, the cut and fill scheme will consist of protecting and stabilizing the lower slope by filling, restoring and maintaining the central bench containing the railway embankment at the approximate pre-failure location and elevation and stabilizing the upper slope by cutting. The recommended limits of the work are shown on Figure II-30 and include all of zones A, B and C. While Figure II-30 shows the river channel relocation option, the extent of the slope works is the same for the channel widening scheme. In addition, the limits of the work have been extended downstream of the study area and upstream some 100 metres into zone D to provide an effective transition to the portion of the study area in which no overall remedial works are proposed and to enhance the stability of the portions of valley wall slopes in the transition areas.

The proposed toe of slope and top of slope locations are shown on Figure II-30. The extent of cuts and fills required will vary considerably between the zones, as illustrated schematically on Figures II-31, II-32 and II-33. In zone A, the present inclination of the lower slope is relatively flat. Consequently, most of the fill in zone A is required to provide a base to establish sufficient erosion protection and to restore the mid-slope berm. Further encroachment into the river will therefore be minimized in this section. There will, however, be a substantial cut at the top of the slope to flatten the oversteepened slope to the recommended inclination. Greater

fills will be required for the lower slopes in zones B and C to achieve the criteria outlined above and to provide a smooth transition along the river bank between adjacent zones. The cut quantities in zones B and C will be rather minimal to achieve the 2.5 horizontal to 1 vertical inclinations recommended for the upper slope.

The work in zone D will probably consist of extending the toe protection from the adjacent downstream section and localized filling to provide a smooth river bank transition from the regraded slopes to the natural topography on the remainder of the slope.

13.3 Erosion Protection

Ongoing toe erosion has been identified as a primary initiating mechanism of slope deformation and failure in the study area and the reinstatement and preservation of the toe of the slopes are therefore key elements in the design of remedial works. As discussed in previous sections of this report, a complete river diversion had been selected for preliminary design of the cut and fill scheme.

Although the use of other erosion protection systems may be feasible, the use of flexible systems such as rip rap, armor stone or gabions is preferred for the preliminary design of works in the study area. Since post-construction deformations are anticipated, the protection must be flexible and readily maintainable. Properly constructed gabion mattresses, rip rap or rock protection can readily tolerate minor movements and settlement without being

adversely affected. Upgrading or restoration of the protection, required as a result of deformation or damage due to ice during high flow, can be readily carried out.

The protection should be designed based on the inclination of the lower slope and the appropriate hydraulic criteria. A separation geotextile will be required between the protection works and the regraded slopes.

13.4 Regrading Requirements

Based on the results of the stability analyses, it is considered that the regrading scheme must be sufficient to achieve an overall slope inclination of 4 horizontal to 1 vertical or flatter. A series of benches would be incorporated into the proposed geometry to assist in slope stabilization, to provide access for maintenance to the erosion protection, to facilitate the construction and maintenance of the drainage systems and to accommodate other facilities such as the railroad. With the use of such benches, maximum allowable side slopes of 3.0 horizontal to 1 vertical and 2.5 horizontal to 1 vertical have been set for the lower and upper slopes, respectively.

The regrading schemes for the typical zone A, B and C slopes meeting the above requirements are shown on Figures II-31, II-32 and II-33, respectively, and have been used for preliminary design consideration and costing purposes. While Figures II-31, II-32 and II-33 show the river channel relocation option, the extent of the slope stabilization works is the same for the channel widening scheme.

Typically, construction would entail placement of a berm of compacted granular material at the toe of the slope having a finished grade of about 197.5 metres, which corresponds to the river water level at a flood stage of about 850 cubic metres (30,000 cubic feet) per second. This berm should be designed with side slopes inclined at 3 horizontal to 1 vertical or flatter and provided with erosion protection as discussed in previous sections in this report.

In conjunction with this scheme, the railway embankments may be restored essentially following the grade and alignment existing prior to the 1986 slide. Improvements to the embankment relative to the preslide conditions may be included in the works presently envisaged. This may require a somewhat modified construction of the embankment in some areas such as zone A.

If placed in the wet, the granular fill below water level should consist of well graded, angular rock fill or clean, coarse graded Granular "B" material. Above water level, the fill material could consist of MTC granular borrow material. Materials meeting the gradation requirements of MTC Granular "C" will generally be suitable for fills above water level and for the railway embankments. Selective reuse of cut material may also be feasible. However, it is anticipated that materials excavated for the river widening will not be suitable for reuse unless the water contents of these materials are reduced by drying.

13.5 Drainage Requirements.

It is anticipated that much of the slope face, particularly cut areas of the upper slope and the area of the lower slope face, will be wet with groundwater flows being encountered during construction. Further, accumulations of surface water are anticipated. It is therefore considered essential that an adequate drainage system be constructed both to facilitate construction and to provide long term groundwater control thereby enhancing the long term stability of the regraded slopes. To this end, the full face of all areas of the slope to be cut or filled should be blanketed with a drainage medium. The drainage medium would probably consist of select granular material meeting the pertinent filter criteria.

In addition, a series of perforated collector drains should be installed at regular intervals extending up the face of the slope within the granular blanket. Perforated, adequately filtered, lateral drains should be extended from the collector drains to intercept any localized seepage zones encountered. The drainage blanket and subdrain collectors should be extended up slope, as required, to drain the sand layer originally located at about elevation 200 metres. A horizontal subdrain constructed along the benches would also be considered beneficial. This drain should be constructed at an invert depth of typically 3 metres.

In order to control surface runoff and to minimize surface erosion, all benches should be sloped back toward the valley wall slope and the surface water directed to catch basins and a collector system. The collector system should discharge into protected, free flowing outlets located within the revetment.

13.6 Implementation

13.6.1 General

Based on the conceptual design outlined, it is estimated that following property acquisition, final engineering and awarding of a contract, and assuming that construction would be carried out essentially as a continuous effort, the project would take some 2 to 3 years to complete. The river widening works, as well as the construction of the toe berm and erosion protection, would not be feasible during periods of high flow. However, operations like clearing and grubbing and cutting of the upper slope could probably be carried out throughout much of the year. It is considered that the work would probably commence at the downstream limits of the site with the river works and progress upstream and upslope.

13.6.2 Phasing

The feasibility of a phased implementation of the recommended cut and fill remedial measure has been considered primarily as a means of distributing the financial burden over several years. Two alternatives have been considered including:

- i) a longitudinal scheme
- and ii) a vertical strip scheme.

The longitudinal scheme involves carrying out works in stages with each stage encompassing the entire length of the works. Work would commence with the river widening or relocation and then progress upslope in phases.

Since widening of the river and establishment of the toe berm together with providing temporary or permanent erosion protection is essential to the entire scheme, this work must be done at the outset to stabilize the lower slope thus facilitating work on the upper portion of the slopes. Consequently, the first phase of a longitudinal scheme must address river widening, construction of the toe berm and erosion protection along the entire river bank. This represents the major portion of the project and necessitates that all property be acquired prior to commencement of the work as a safeguard against potential loss of life and liability. This scheme has the advantage that the railway embankment could potentially be restored and service reinstated prior to the full completion of the project. There is, however, risk that, prior to completion of the upper slope works, instability could affect the railway.

The vertical strip method would entail completion of remedial works from the former river's edge to the top of the slope along a series of vertical sections of the valley wall. Prior to this, it would be necessary to relocate the river channel and acquire the property on top of the slope.

The vertical strip method has the advantage that all of the property acquisition need not be completed prior to commencing the initial phases of construction. Successive phases would be carried out in stages as finances permit. In contrast to the former scheme, the railway line could probably not be reinstated until completion of the entire project.

14. ADDITIONAL WORK

Due to the adverse site conditions and the nature and extent of the remedial measures recommended, extensive geotechnical input should be maintained throughout the final design and construction phases. In the interim, the existing instrumentation should be maintained and monitored on a routine basis to provide further information required for the final design of the remedial works.

The present risk to which land owners within the study area are exposed has been discussed previously. Clearly, the risks can be avoided by evacuating the buildings. The land owners should be advised of the risk to life and limb associated with ongoing occupancy and the City of Brantford's monitoring programme continued and extended, where required, to fringe areas of the slope movements.

SUMMARY OF EFFECTIVE STRESS SLOPE STABILITY ANALYSES

Preliminary Engineering Study
 Grand River Valley Wall Slope Failure
 Colborne Street East
Brantford, Ontario

<u>ZONE</u>	<u>C O M P U T E D F A C T O R O F S A F E T Y</u>		
	<u>Lower Slope</u>	<u>Upper Slope</u>	<u>Overall Slope</u>
A - Pre May 1986	<1.0	1.2	1.3
A - Post May 1986	<1.0	<1.0	1.7
B - Post May 1986	1.0	1.1	1.3
C - Post May 1986	1.3	1.2	1.2
D - Post May 1986	1.2	1.2	1.3

NOTE: For typical slope geometry and critical circles,
 see Figures II-3, II-4, II-5 and II-6

TABLE II-II

861-3257

COST COMPARISON OF SLOPE STABILIZATION SCHEMES

Preliminary Engineering Study
 Grand River Valley Wall Slope Failure
 Colborne Street East
 Brantford, Ontario

	C O S T I N D O L L A R S		
	<u>Fill</u>	<u>Cut & Fill</u>	<u>Cut</u>
Tree Removal	425,000	425,000	510,000
Clear and Grub	200,000	200,000	240,000
Fill	4,620,000	3,280,000	0
Cut	0	215,000	3,755,000
Drainage	25,000	30,000	65,000
Restoration	<u>130,000</u>	<u>130,000</u>	<u>160,000</u>
SUBTOTAL	5,400,000	4,280,000	4,730,000
Engineering	<u>600,000</u>	<u>420,000</u>	<u>470,000</u>
TOTAL	6,000,000	4,700,000	5,200,000

NOTE: Table to be read in conjunction with
 accompanying report.

REFERENCESA.1 Reports

Chapman, L.J., Putnam, D.F. The Physiography of Southern Ontario. Ontario Research Foundation, 1966.

Golder Associates Report No. 861-3127 entitled "Preliminary Geotechnical Assessment, Grand River Valley Wall, Colborne Street East, Brantford, Ontario", dated June 1986.

Golder Associates Report No. 861-3369 entitled "Interim Geotechnical Assessment, Monitoring Programme, Grand River Valley Wall, Colborne Street East, Brantford, Ontario", dated March 1987.

Golder Associates Report No. 871-3035 entitled "Geotechnical Investigation, Proposed Grand River Rechannelization, Colborne Street East, Brantford, Ontario", dated March 1987.

Industrial Mineral Report No. 37. Pleistocene Geology of the Brantford Area, Southern Ontario by W.R. Cowan, Ontario, Department of Mines and Northern Affairs, dated 1972.

Peto Associates Limited Report 69-F26 entitled "Soils Investigation, Sewers and Road Widening, City of Brantford, Ontario", dated 1969.

Report provided by the Ontario Ministry of Transportation and Communications entitled "Foundation Investigation Report for Proposed Crossing at CNR and Highway 54, Proposed Revision Line "L", Township of Onondaga, County of Brant, District No. 4 (Hamilton) W.J. 69-F-25--W.P. 310-66", dated 1969.

Trow Geotechnical Limited Project G86-0266-A/G entitled "Geotechnical Investigation, Brantford Landslide, Colborne Street, Brantford, Ontario, Volume I - Geotechnical Assessment, Volume II - Geotechnical Data", dated September 1986.

V.A. Wood Associates Limited Report No. 743-5-8 entitled "Geotechnical Investigation, Slope Stability, 937 Colborne Street East, Brantford, Ontario", dated August 1985.

A.2 Maps

Plan No. LR-80, entitled "T.H. & B Railway, Cainsville, Ontario: Plan showing contour lines at landslides", dated November 29, 1913, Scale 1" = 100 feet

Topographical Map of the Grand Valley Watershed, dated 1963, Scale 1" = 200 feet

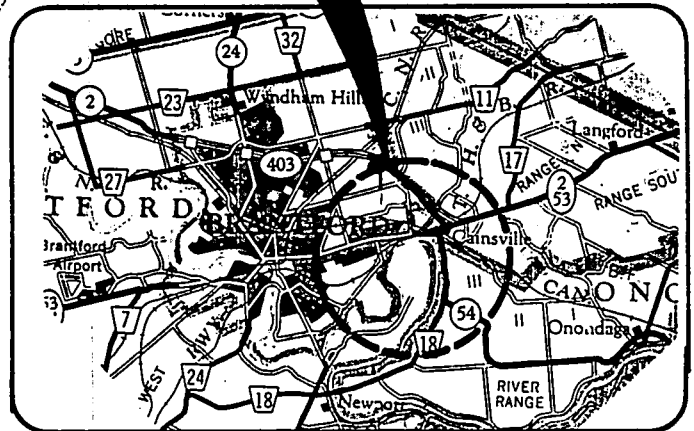
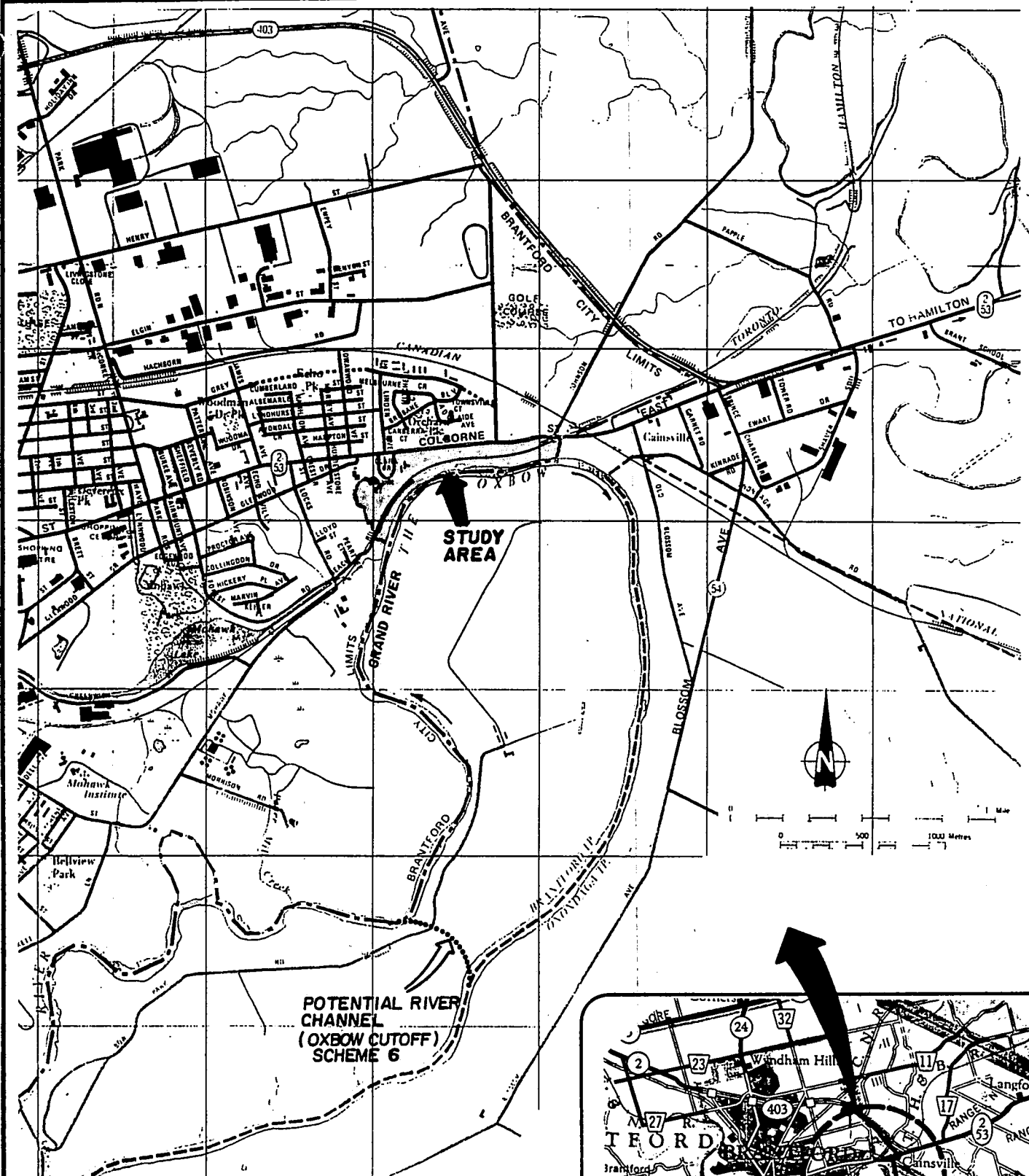
Topographical Map, City of Brantford by the The Photographic Survey Corporation Limited, Aerial Photography dated April 1955, Scale 1" = 100 feet

Topographical Mapping by Northway Map Technology Limited, photo date April 26, 1986 and dated July 15, 1986, Scale 1:1000

Topographical Mapping by Northway Map Technology Limited entitled "Brantford Slide Mapping", Scale 1:1000 (post-slide)

KEY PLAN

FIGURE II-1



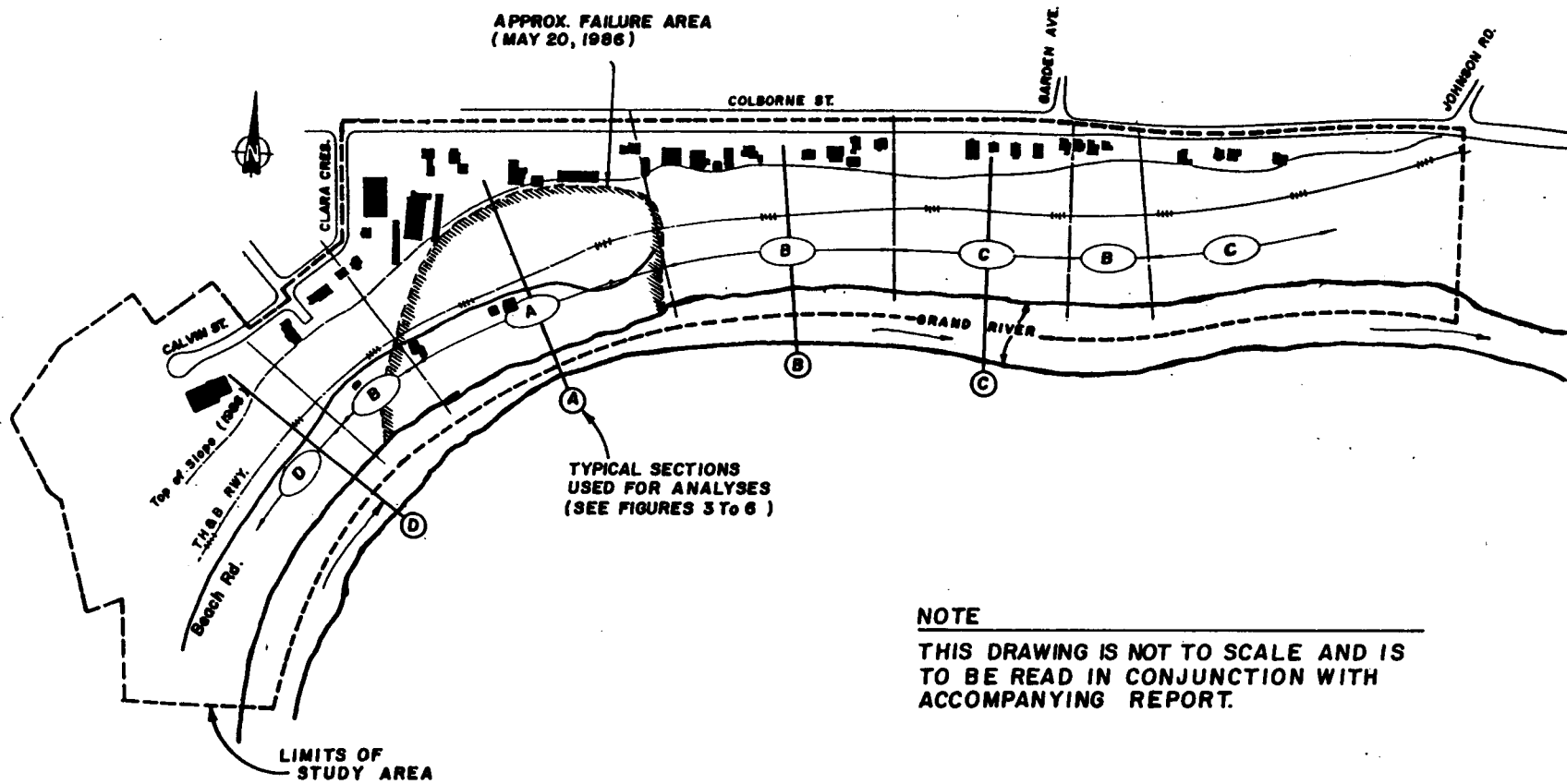
Date JULY, 1987.
Project 861-3257

Golder Associates

Drawn WF
Chkd. WF

LOCATION PLAN

FIGURE 11-2



Date JULY 1, 1987
Project 861.3257

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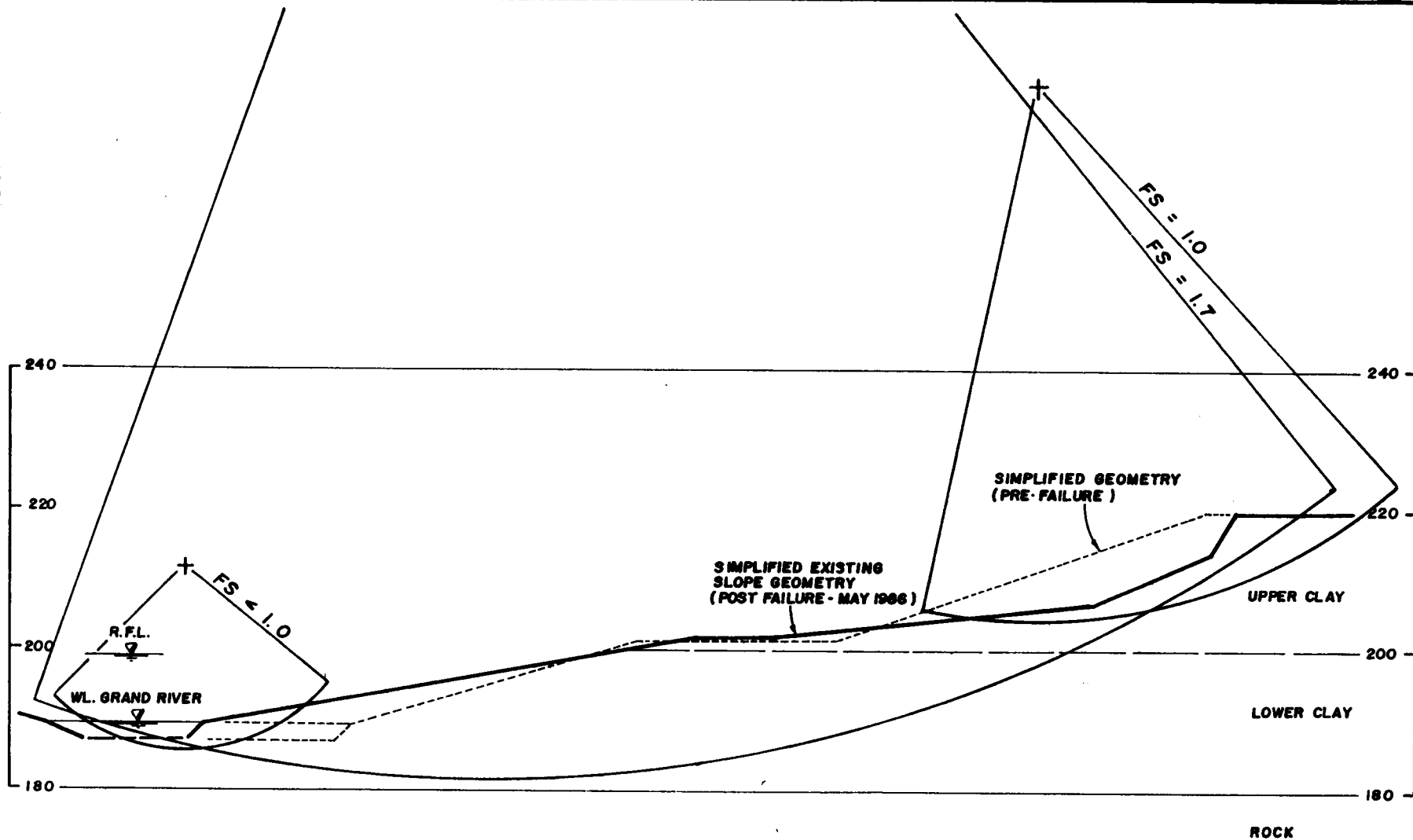
Drawn WFF
Chkd. [Signature]

SIMPLIFIED GEOMETRY - ZONE A

FIGURE II-3

Date JULY 1987
Project 861-3257

Golder Associates



NOTES

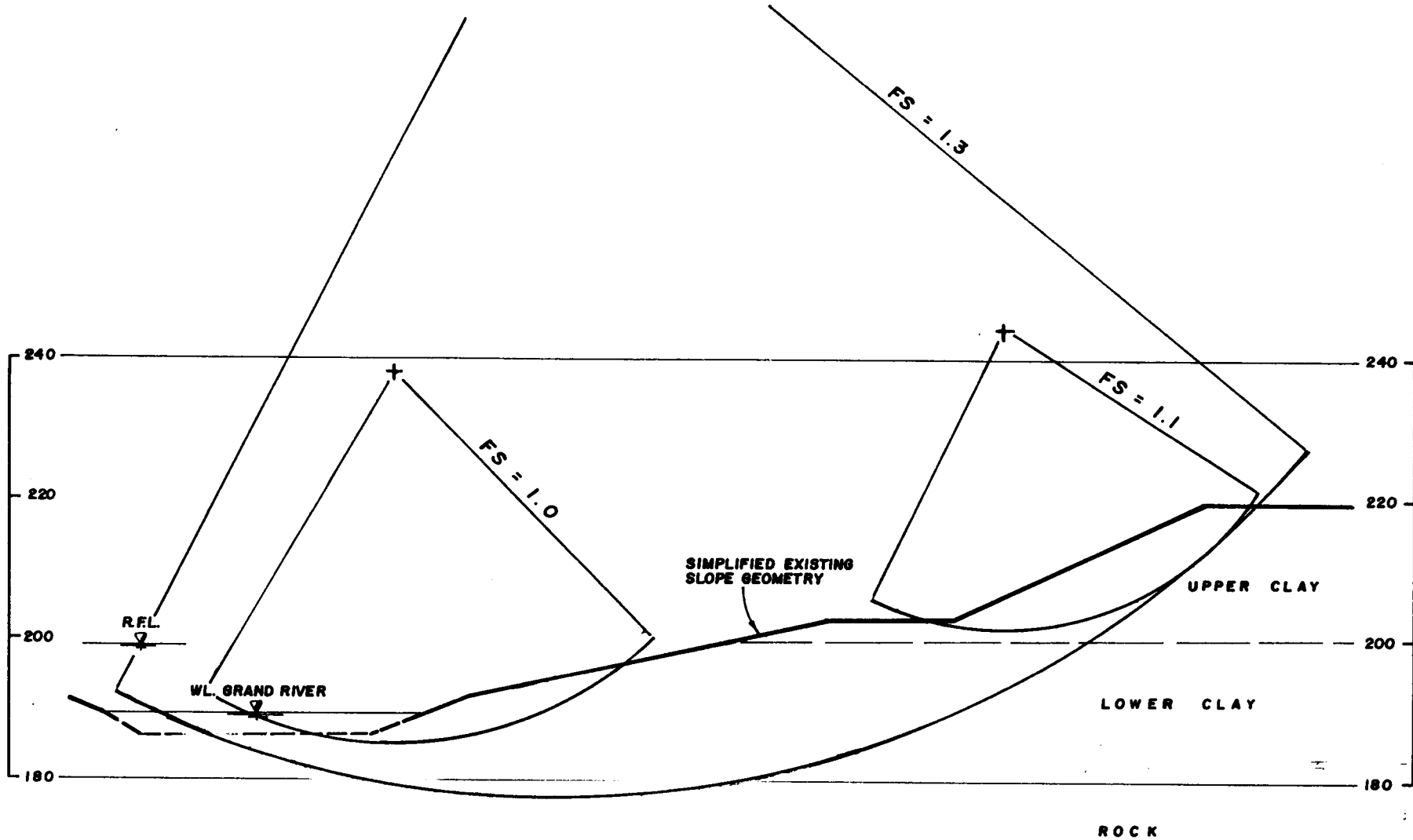
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FOR SIMPLIFIED GROUNDWATER CONDITIONS SEE FIGURE II-12.

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Chkd. [Signature]

SIMPLIFIED GEOMETRY - ZONE B

FIGURE II-4



NOTES

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FOR SIMPLIFIED GROUNDWATER CONDITIONS
SEE FIGURE II-12

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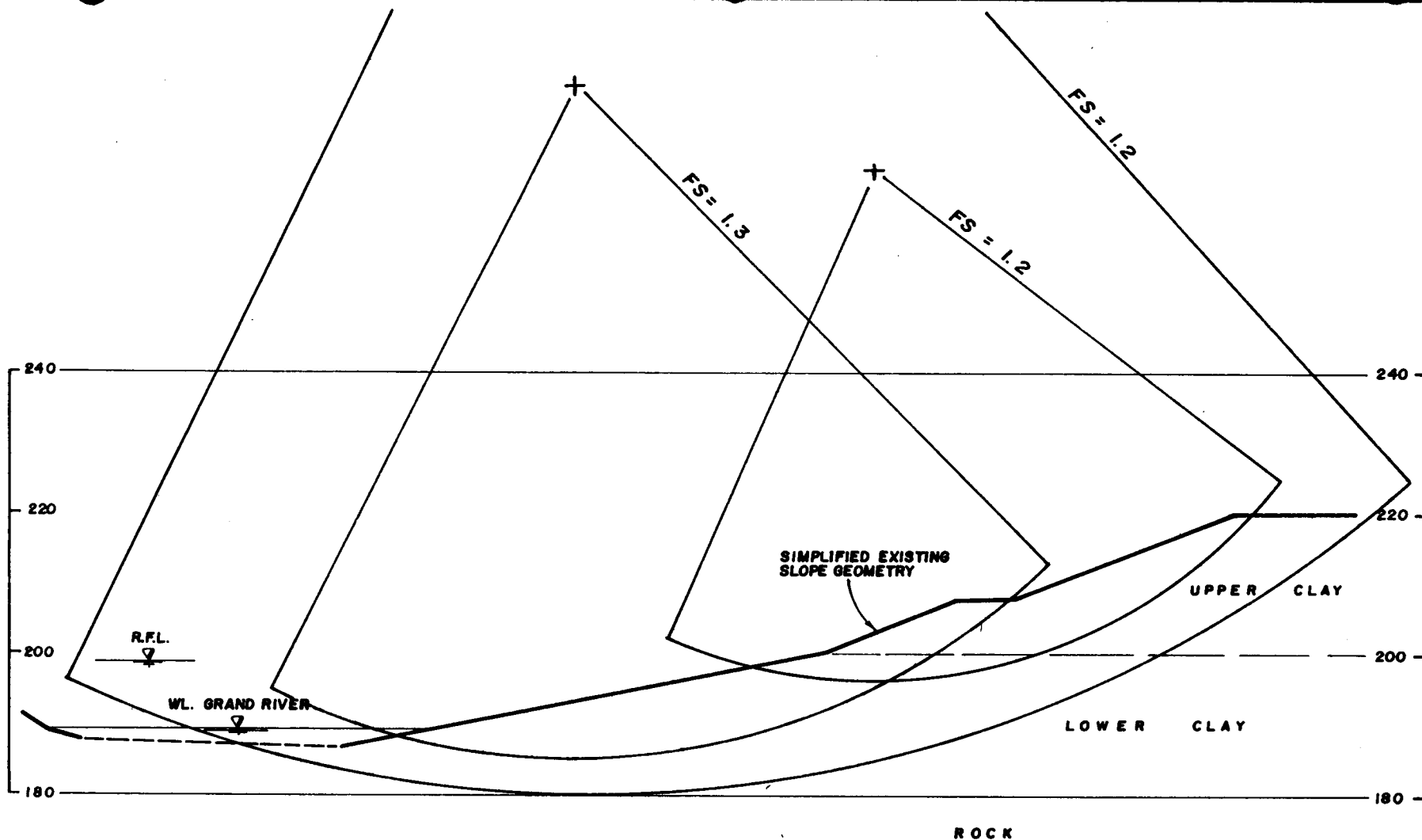
Drawn W/F
Chkd. W/F

SIMPLIFIED GEOMETRY - ZONE C

FIGURE II-5

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NOTES

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FOR SIMPLIFIED GROUNDWATER CONDITIONS
SEE FIGURE II-12

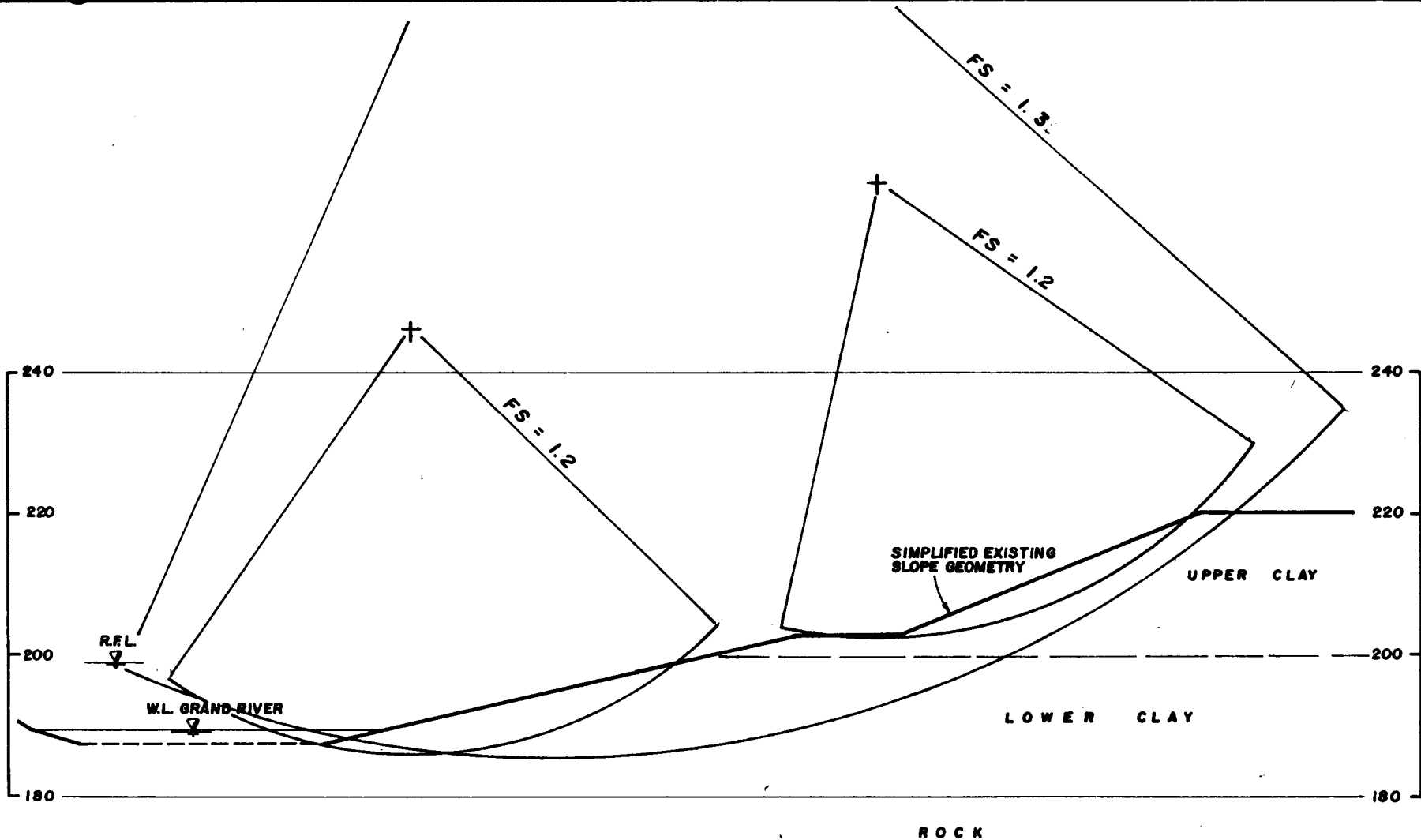
Drawn WF
Chkd. WF

SIMPLIFIED GEOMETRY - ZONE D

FIGURE II-6

Date JULY, 1987
Project 8613257

Golder Associates



NOTES

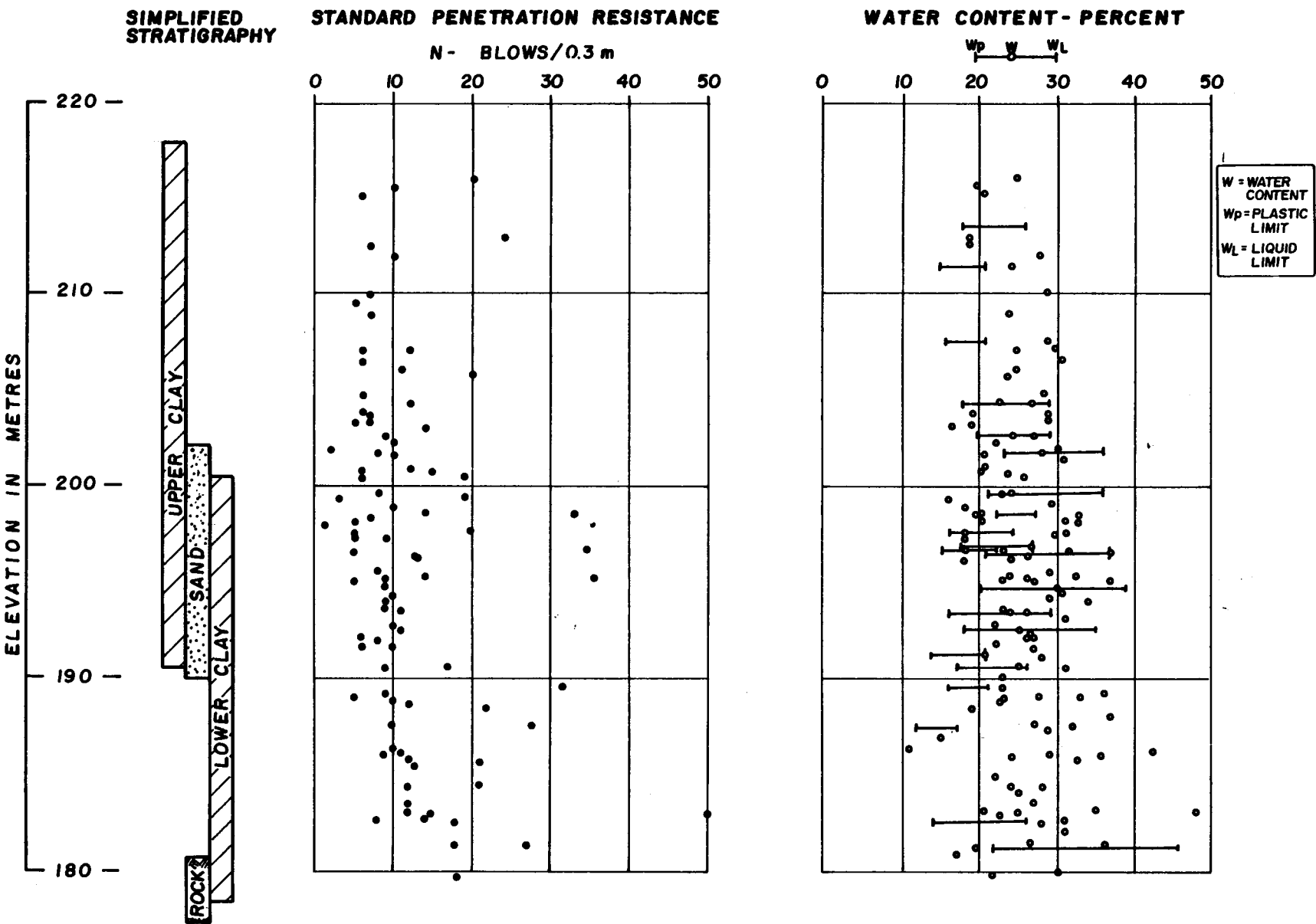
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IN CONJUNCTION WITH ACCOMPANYING REPORT.

FOR SIMPLIFIED GROUNDWATER CONDITIONS
SEE FIGURE II - 12

DRAWN W/F
CHKD. ---

GEOTECHNICAL SUMMARY (UNDISTURBED MATERIAL)

FIGURE 11-7



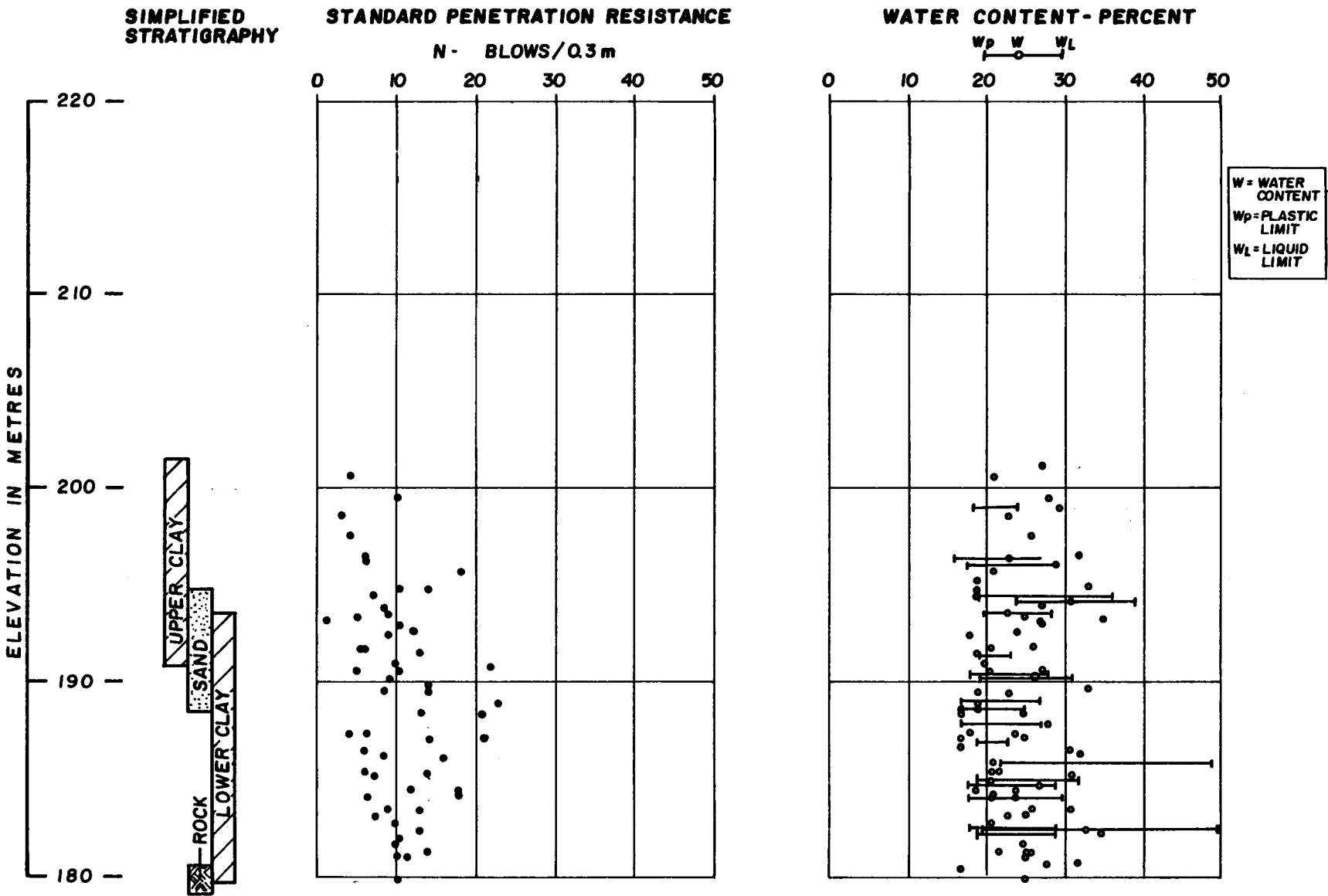
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Project 861.3257

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Chkd. 5

GEOTECHNICAL SUMMARY (DISTURBED MATERIAL)

FIGURE II-8



NOTE

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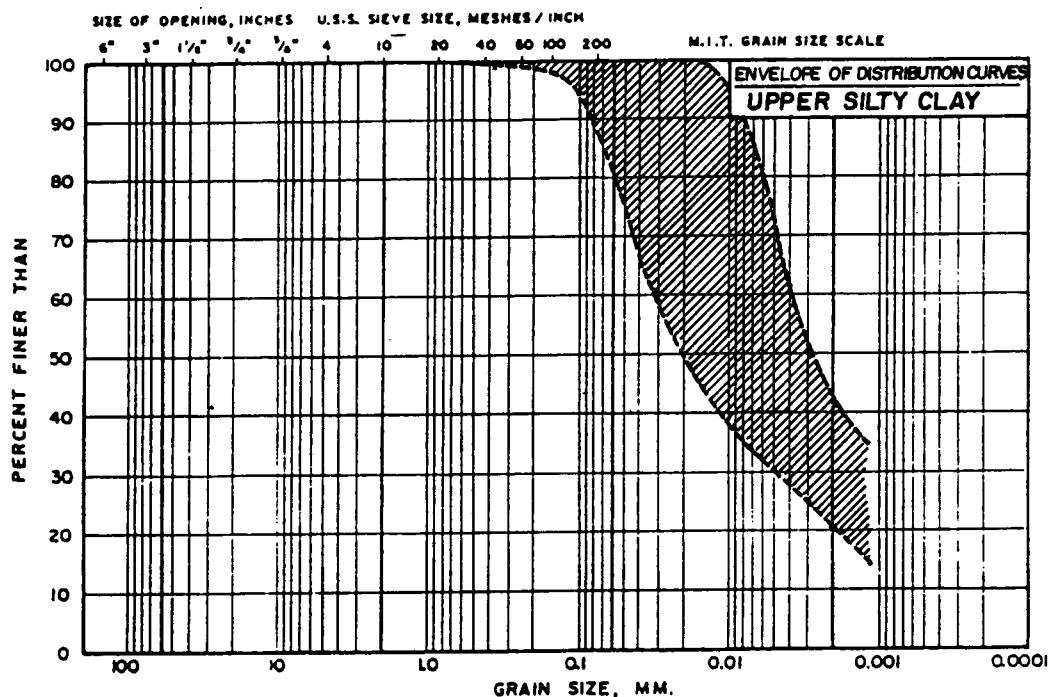
Golder Associates

Drawn W.F.
Chkd. _____

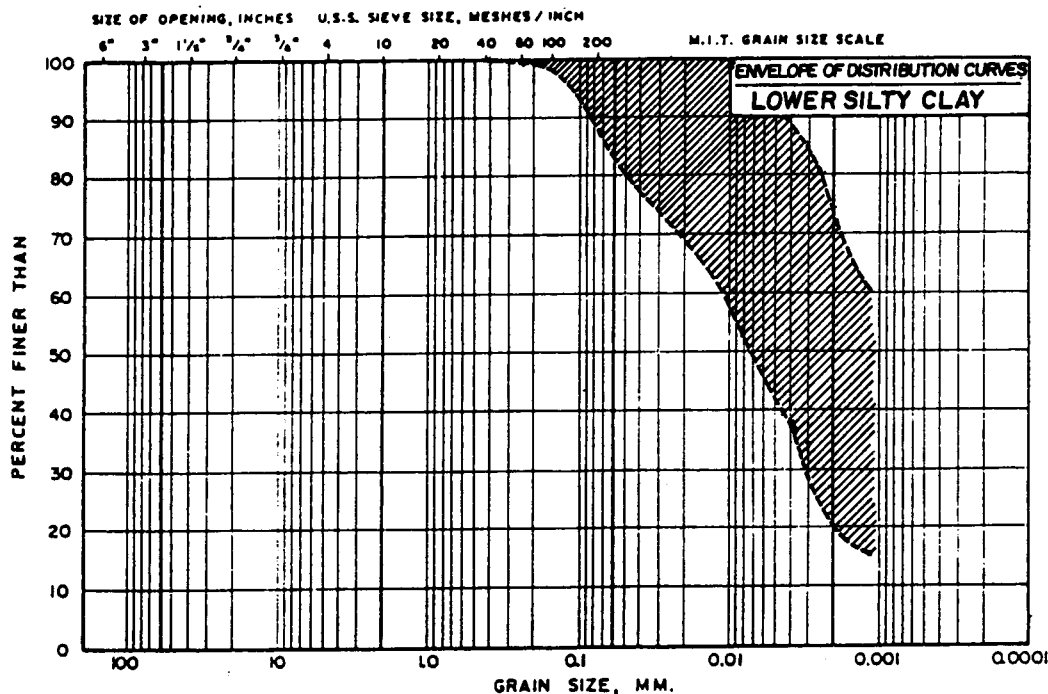
ENVELOPES OF GRAIN SIZE DISTRIBUTION CURVES

(UPPER AND LOWER SILTY CLAY)

FIGURE II-9



COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	



COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	

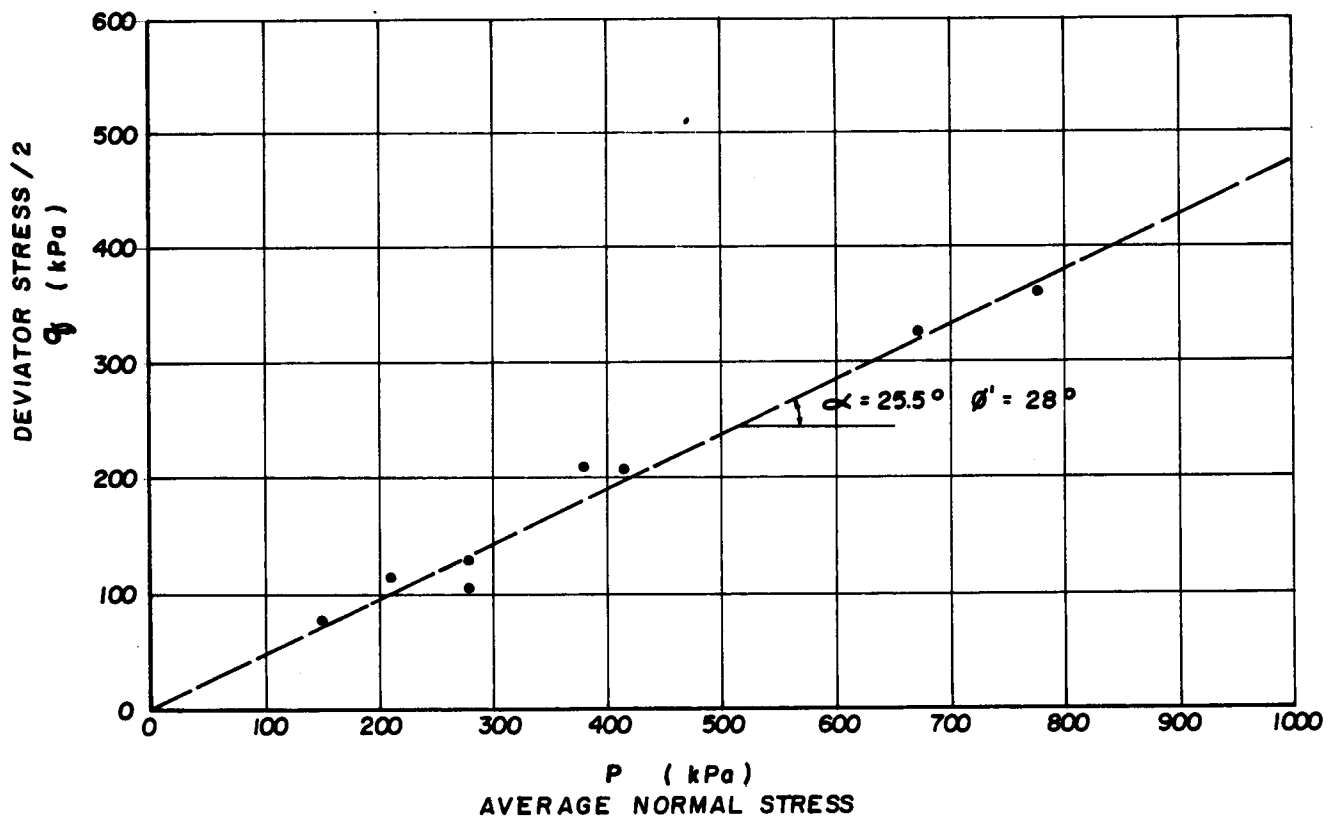
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Chkd. VB

EFFECTIVE STRESS PARAMETERS (UPPER CLAY)

FIGURE II-10



NOTE

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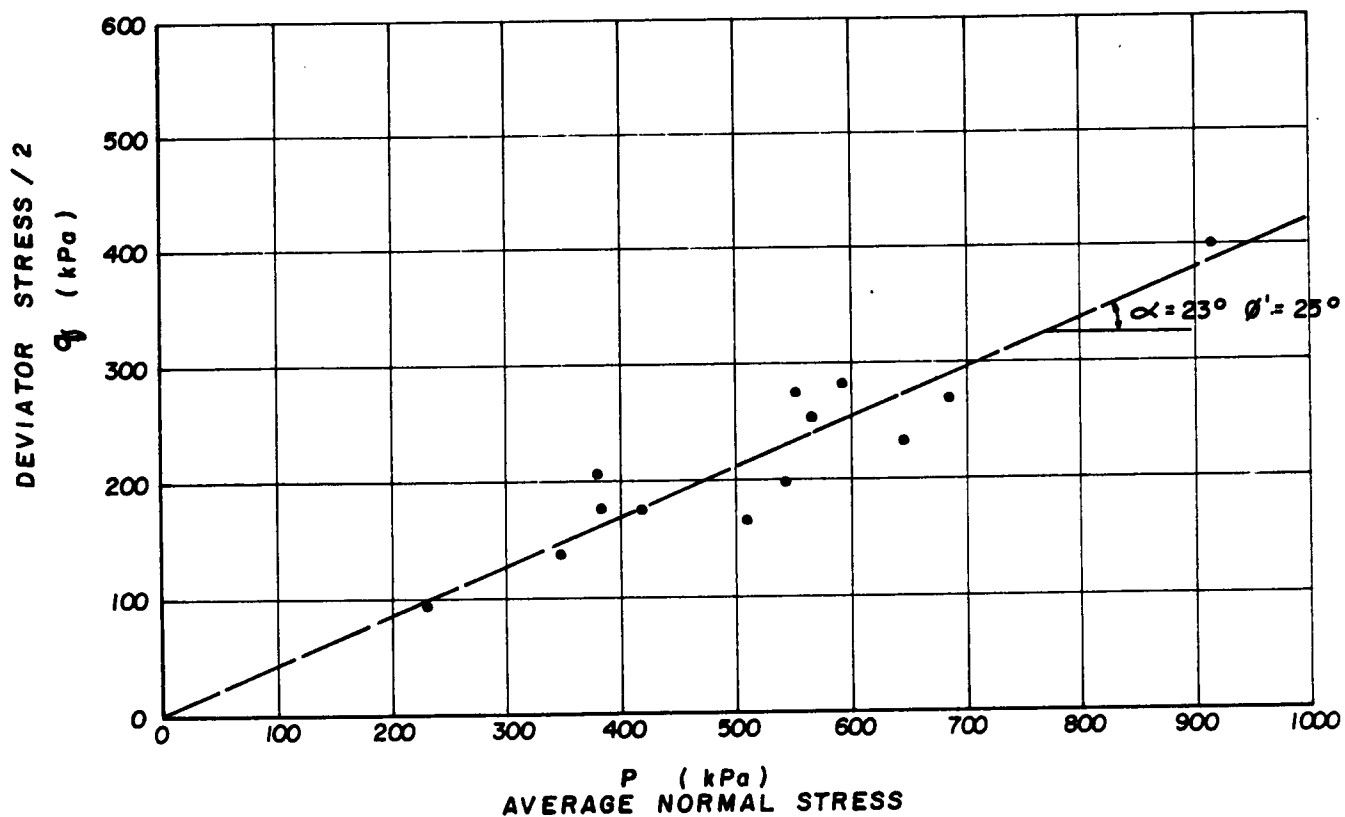
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Chkd. [Signature]

EFFECTIVE STRESS PARAMETERS (LOWER CLAY)

FIGURE II-II



NOTE

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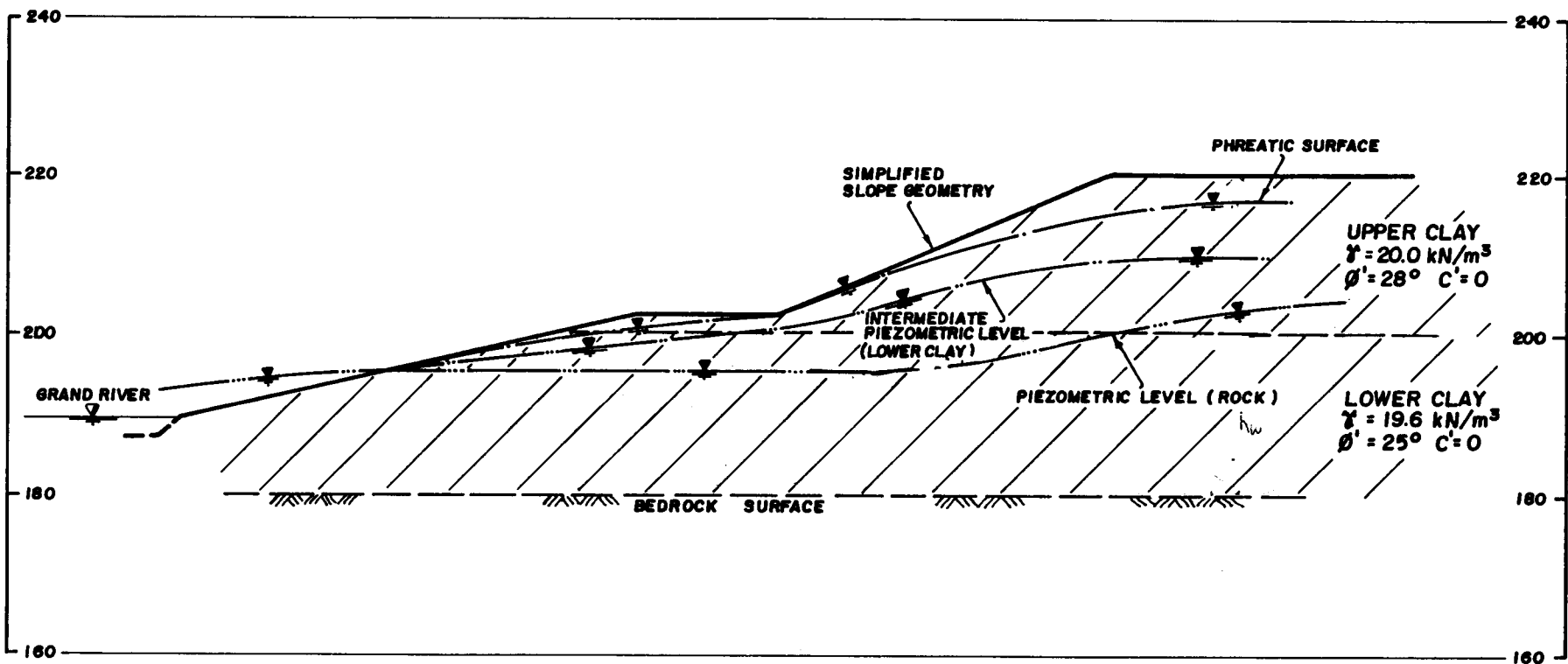
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Chkd. *[Signature]*

SIMPLIFIED CONDITIONS USED FOR STABILITY ANALYSES

FIGURE II-12



NOTE

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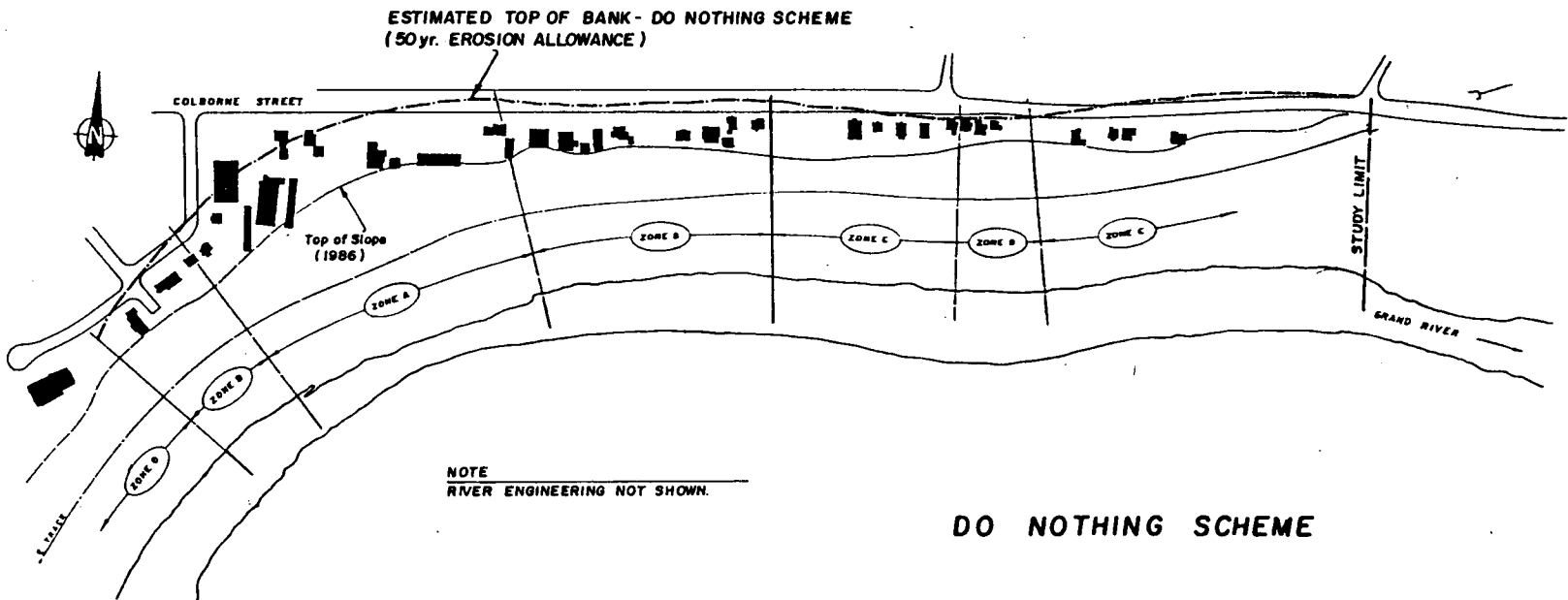
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Chkd [Signature]

LOCATION PLAN (DO NOTHING SCHEME)

FIGURE II-13



DO NOTHING SCHEME

NOTE
RIVER ENGINEERING NOT SHOWN.

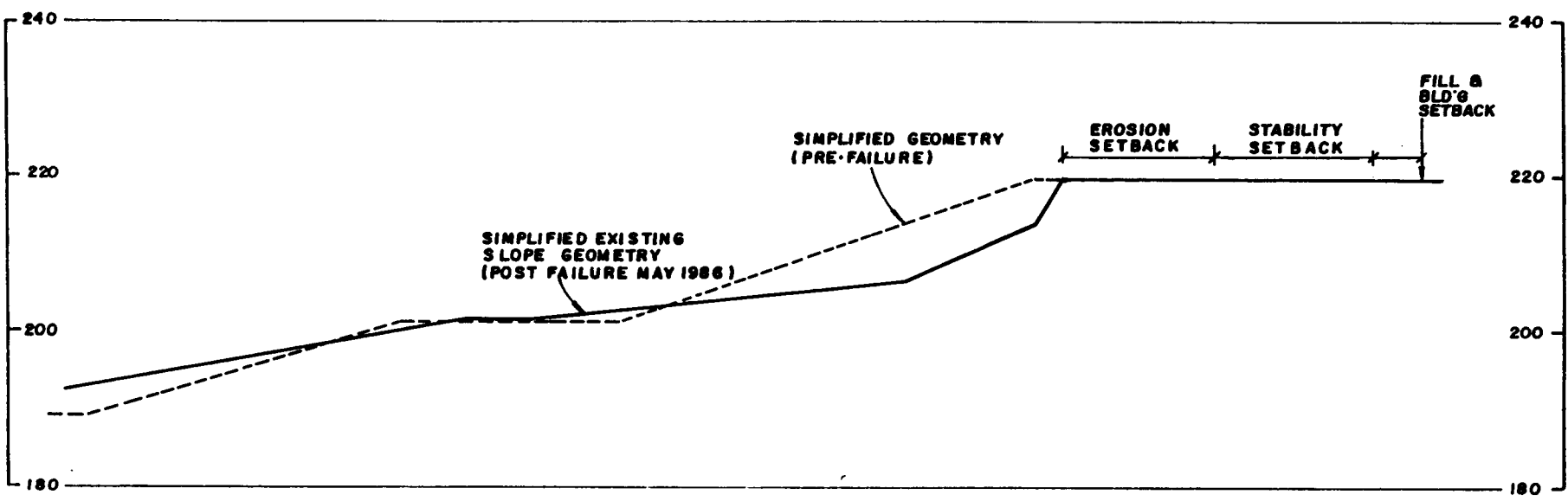
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Chkd. [Signature]

SCHEMATIC SECTION - ZONE A (DO NOTHING SCHEME)

FIGURE 11-14



NOTE

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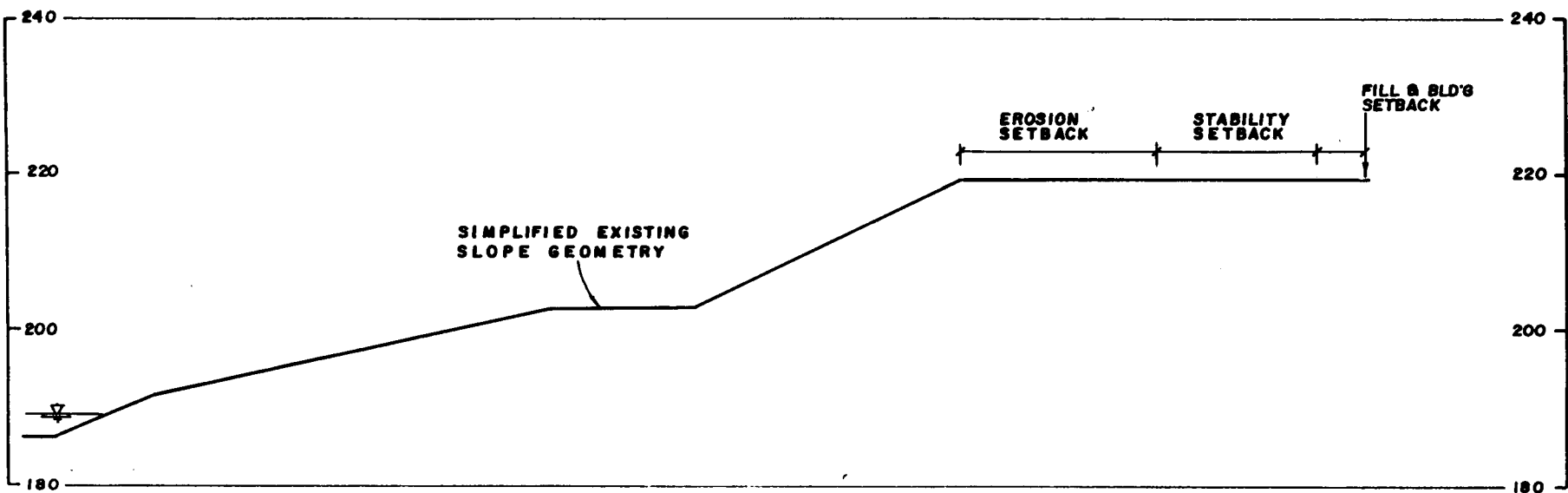
Drawn B.G.
Chkd. B.G.

SCHEMATIC SECTION - ZONE B
(DO NOTHING SCHEME)

FIGURE 11-15

Date JULY 1987
Project 861-3257

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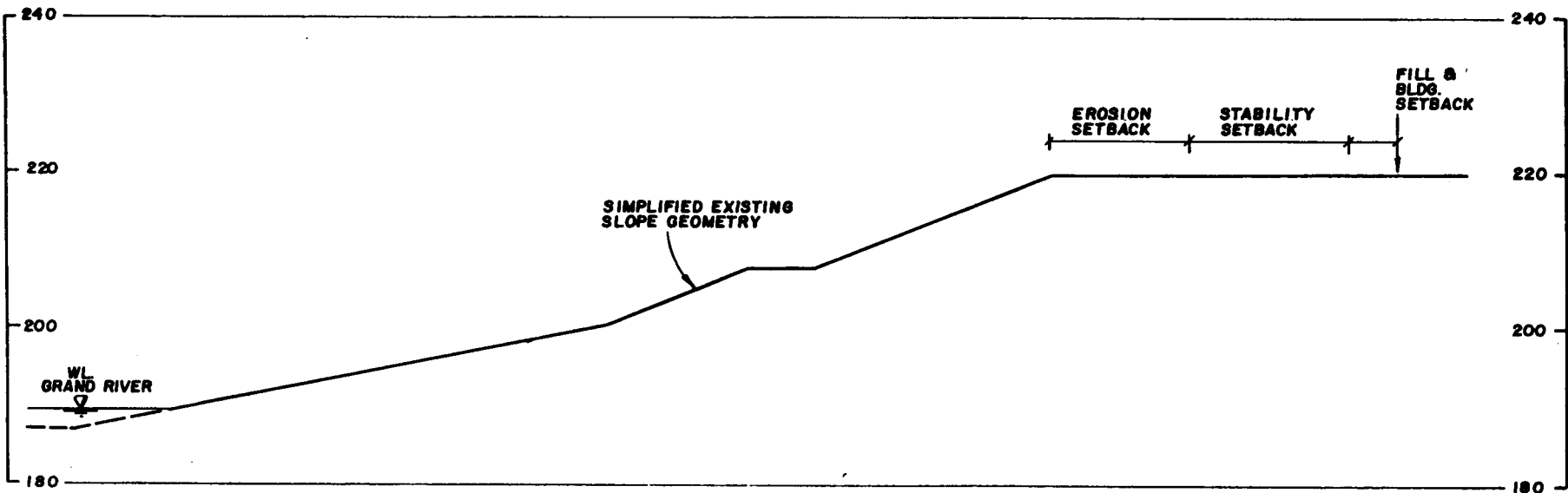
NOTE

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IN CONJUNCTION WITH ACCOMPANYING REPORT.

Drawn B.G.
Chkd [Signature]

SCHEMATIC SECTION - ZONE C (DO NOTHING SCHEME)

FIGURE 11-16



NOTE

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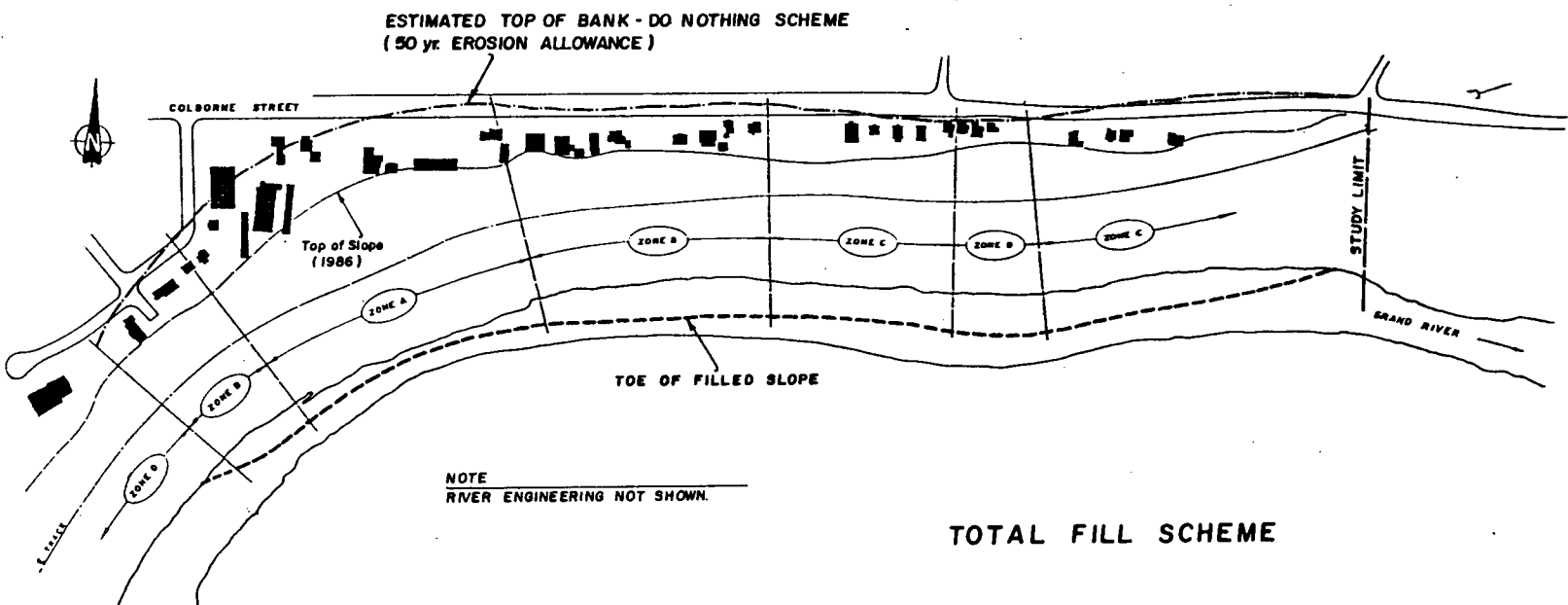
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Chkd.

LOCATION PLAN (TOTAL FILL SCHEME)

FIGURE II-17



TOTAL FILL SCHEME

NOTE
RIVER ENGINEERING NOT SHOWN.

STUDY LIMIT

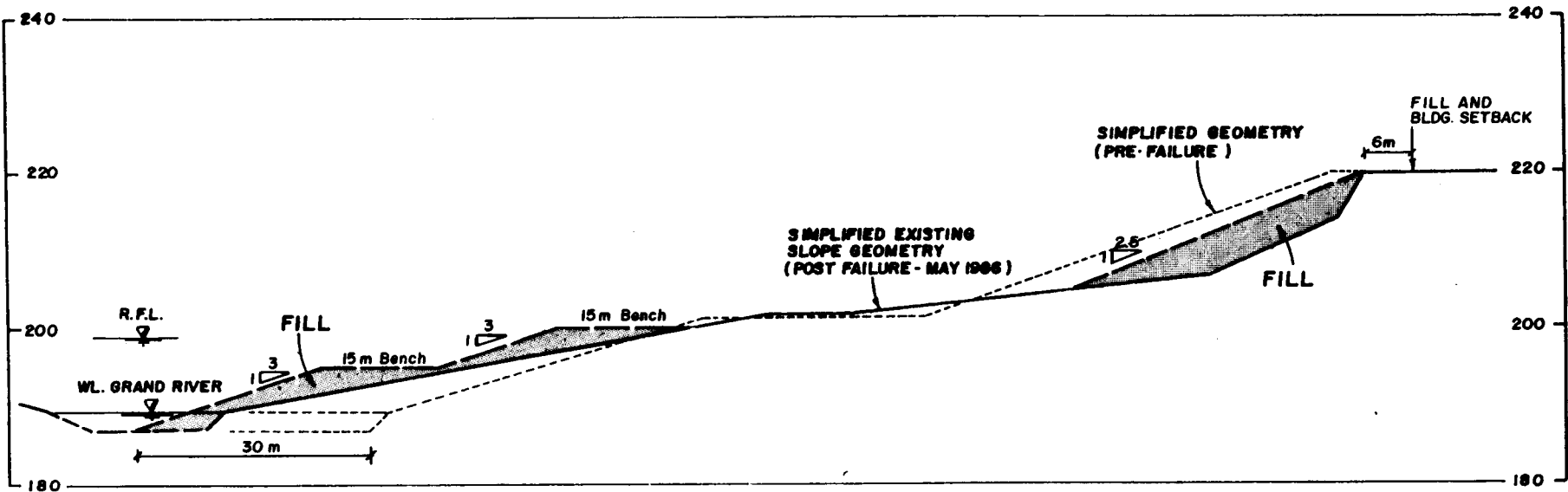
Date JULY 1987
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Golder Associates

DRAWN B.G.
CHKD. [Signature]

SCHEMATIC SECTION - ZONE A (TOTAL FILL SCHEME)

FIGURE 11-18



NOTE

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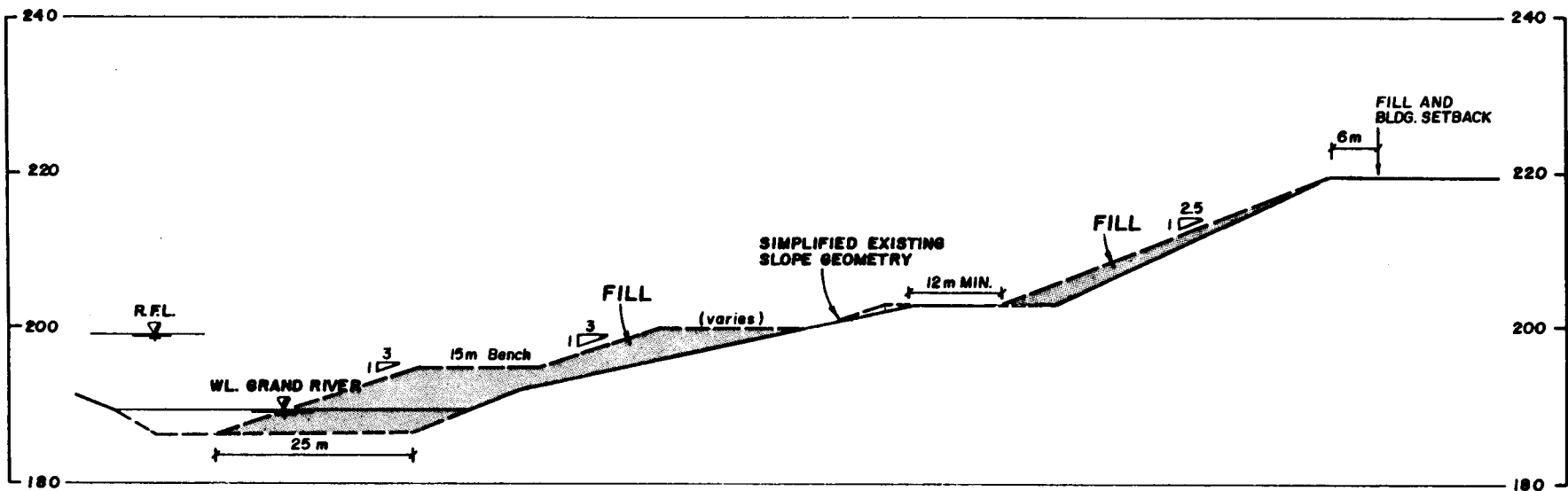
Date JULY 1987
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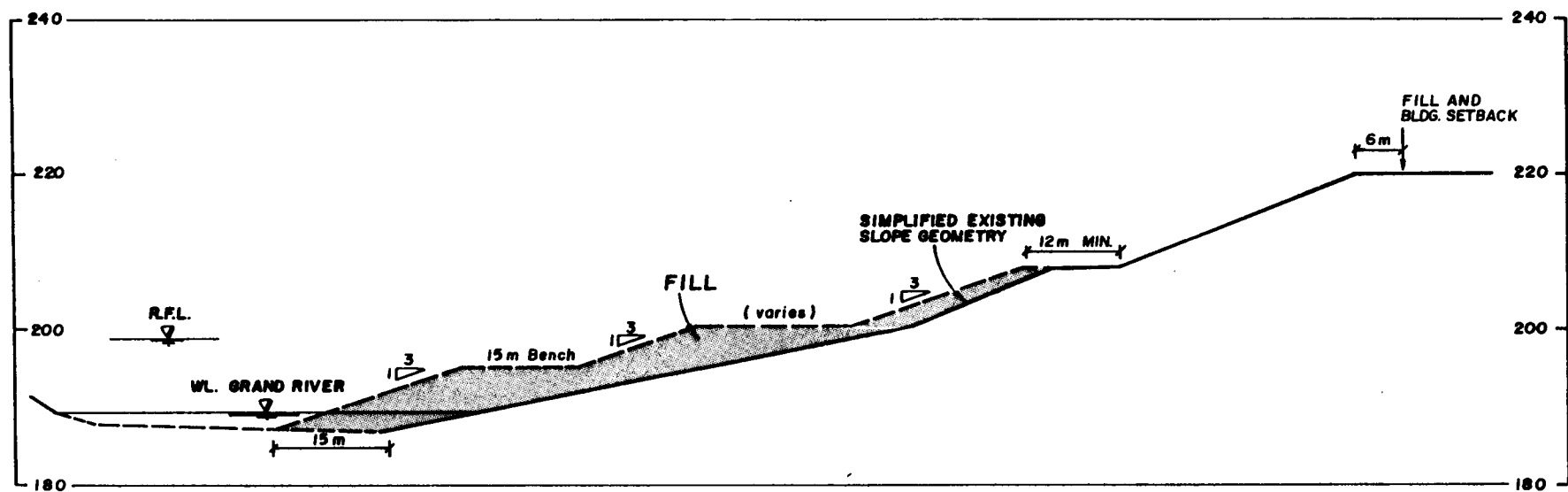
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SCHEMATIC SECTION - ZONE B
(TOTAL FILL SCHEME)

FIGURE **II-19**

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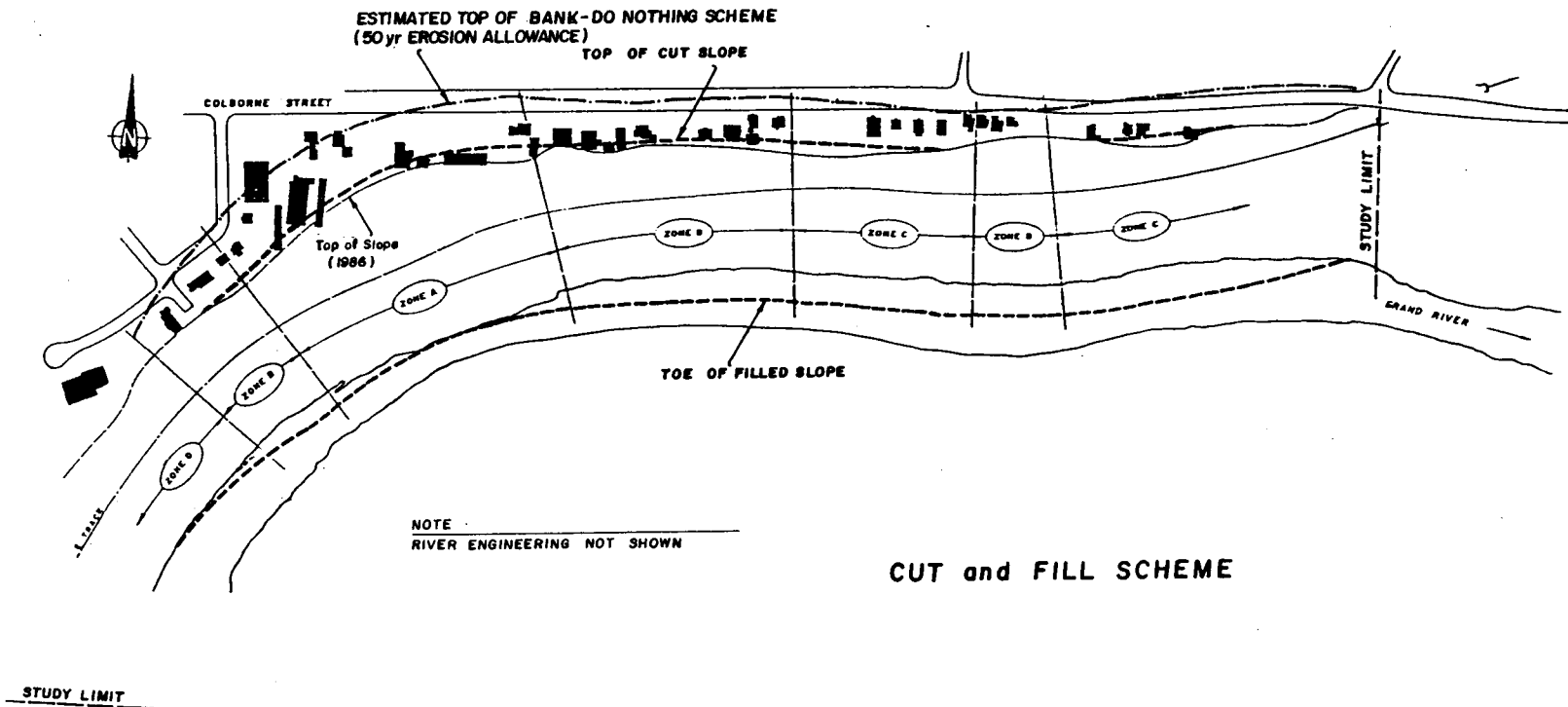
SCHEMATIC SECTION - ZONE C
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FIGURE II-20

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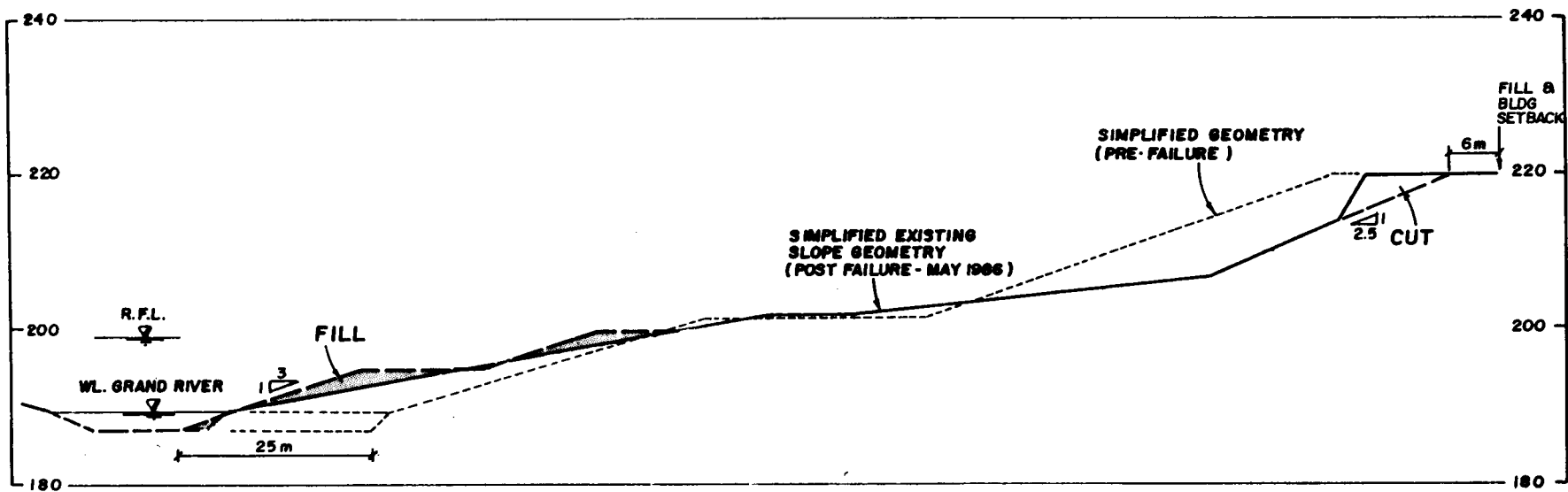


LOCATION PLAN (CUT and FILL SCHEME)

FIGURE 11-21

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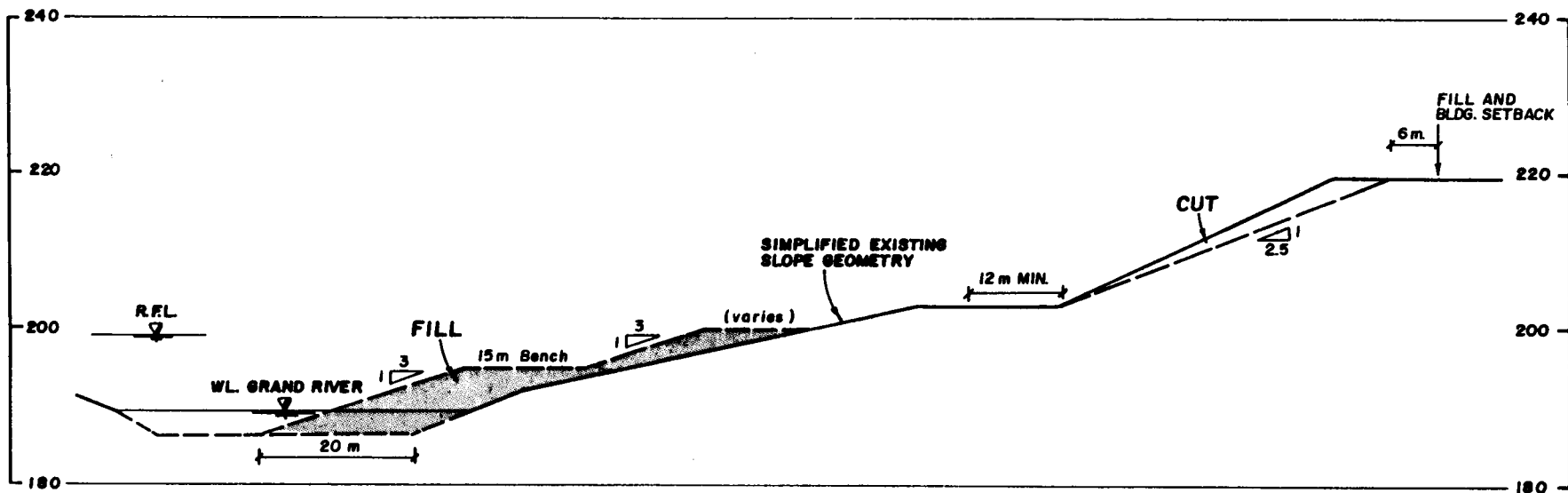
SCHEMATIC SECTION - ZONE A
(CUT & FILL SCHEME)

FIGURE II-22

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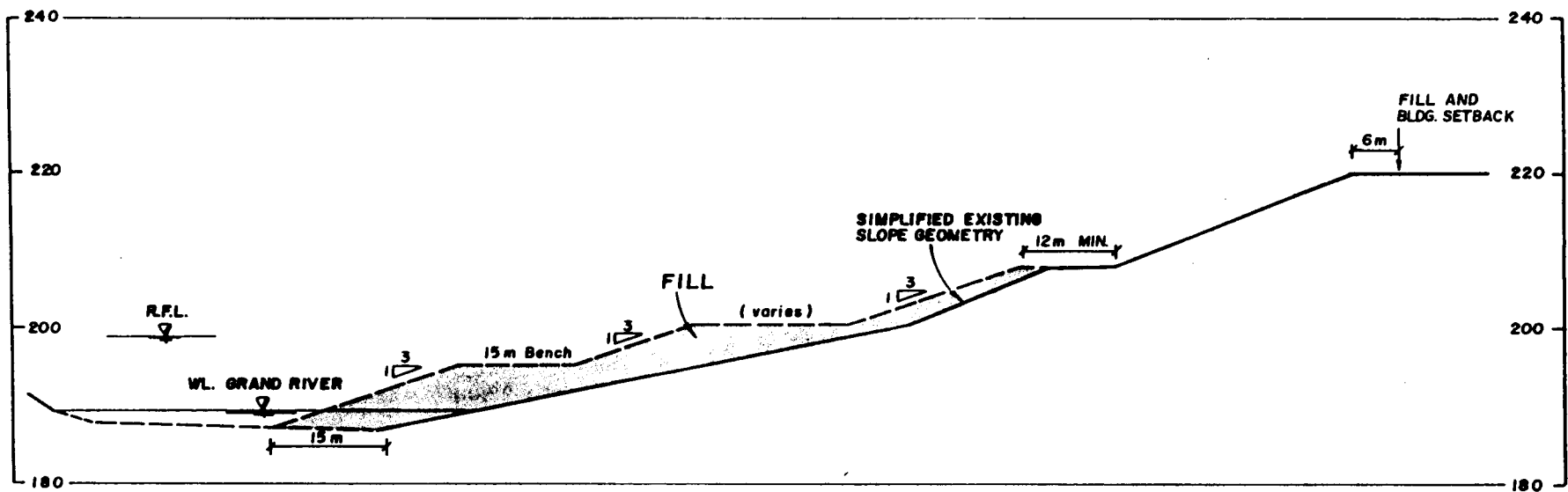
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SCHEMATIC SECTION - ZONE B
 (CUT & FILL SCHEME)

FIGURE 11-23

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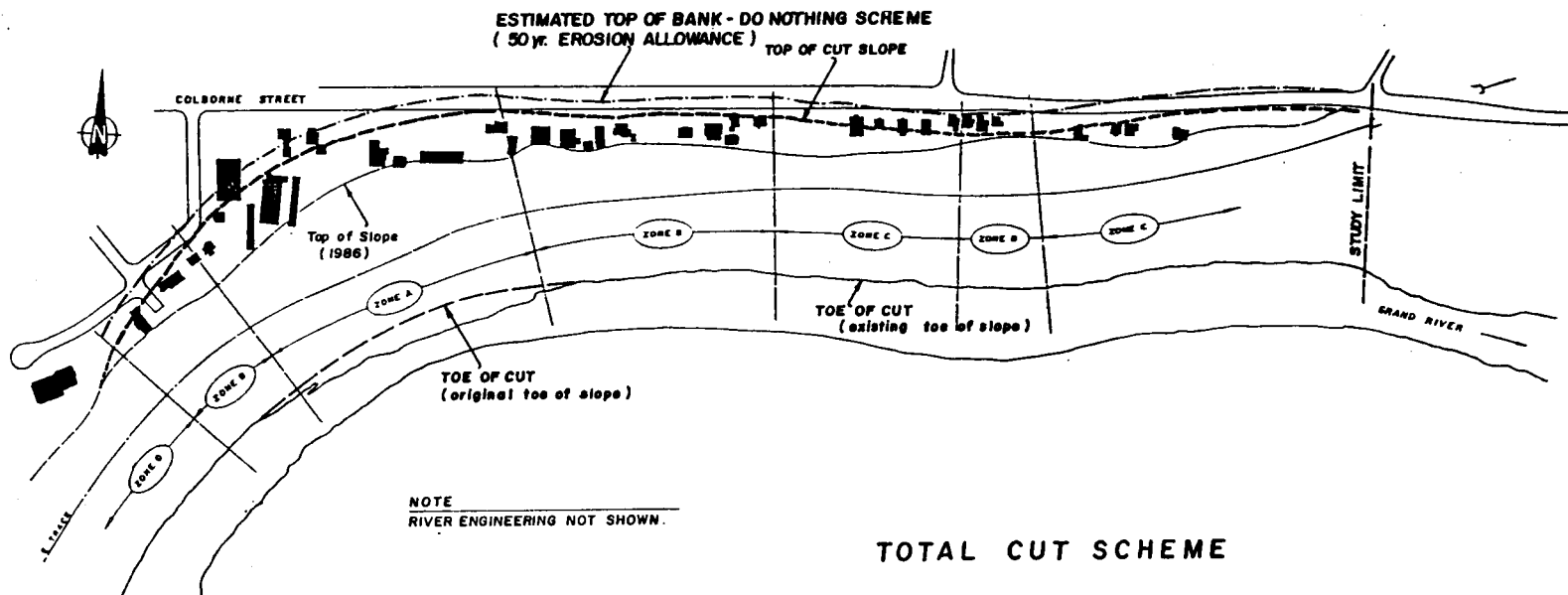
Drawn IVF
 Ckcd. CS

SCHEMATIC SECTION - ZONE C
(CUT & FILL SCHEME)

FIGURE II-24

LOCATION PLAN (TOTAL CUT SCHEME)

FIGURE II-25



NOTE
RIVER ENGINEERING NOT SHOWN.

TOTAL CUT SCHEME

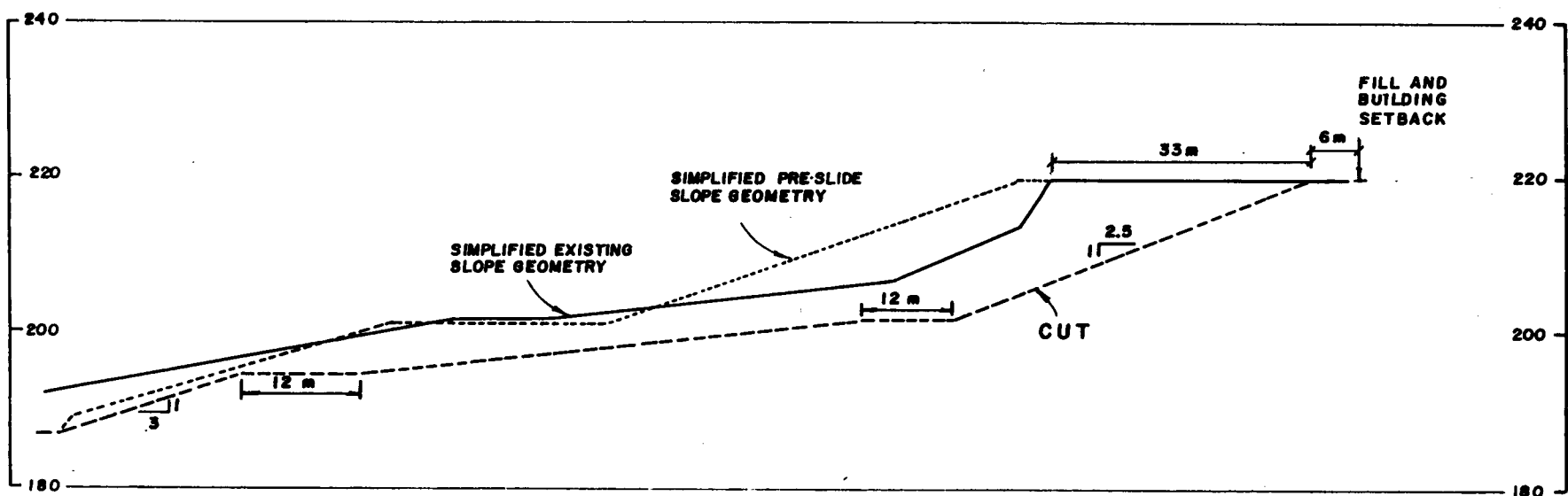
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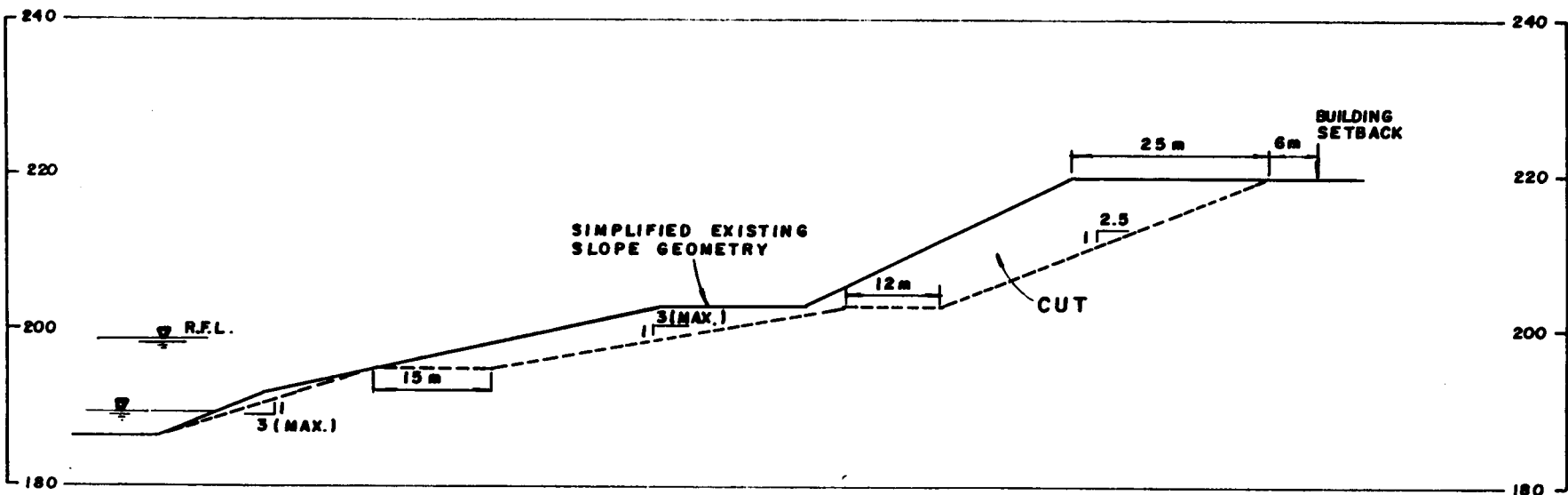
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 Chkd. B.G.

SCHEMATIC SECTION - ZONE A
 (TOTAL CUT SCHEME)

FIGURE 11-26

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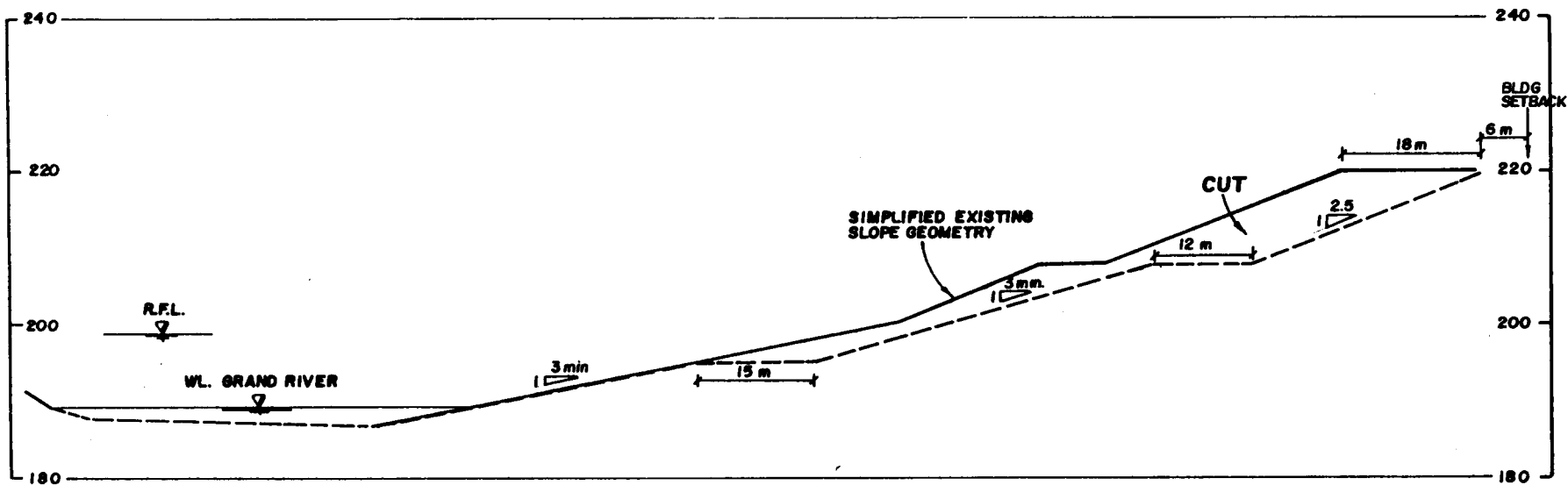
Drawn B.G.
 Chkd B.G.

SCHEMATIC SECTION - ZONE B
 (TOTAL CUT SCHEME)

FIGURE 11-27

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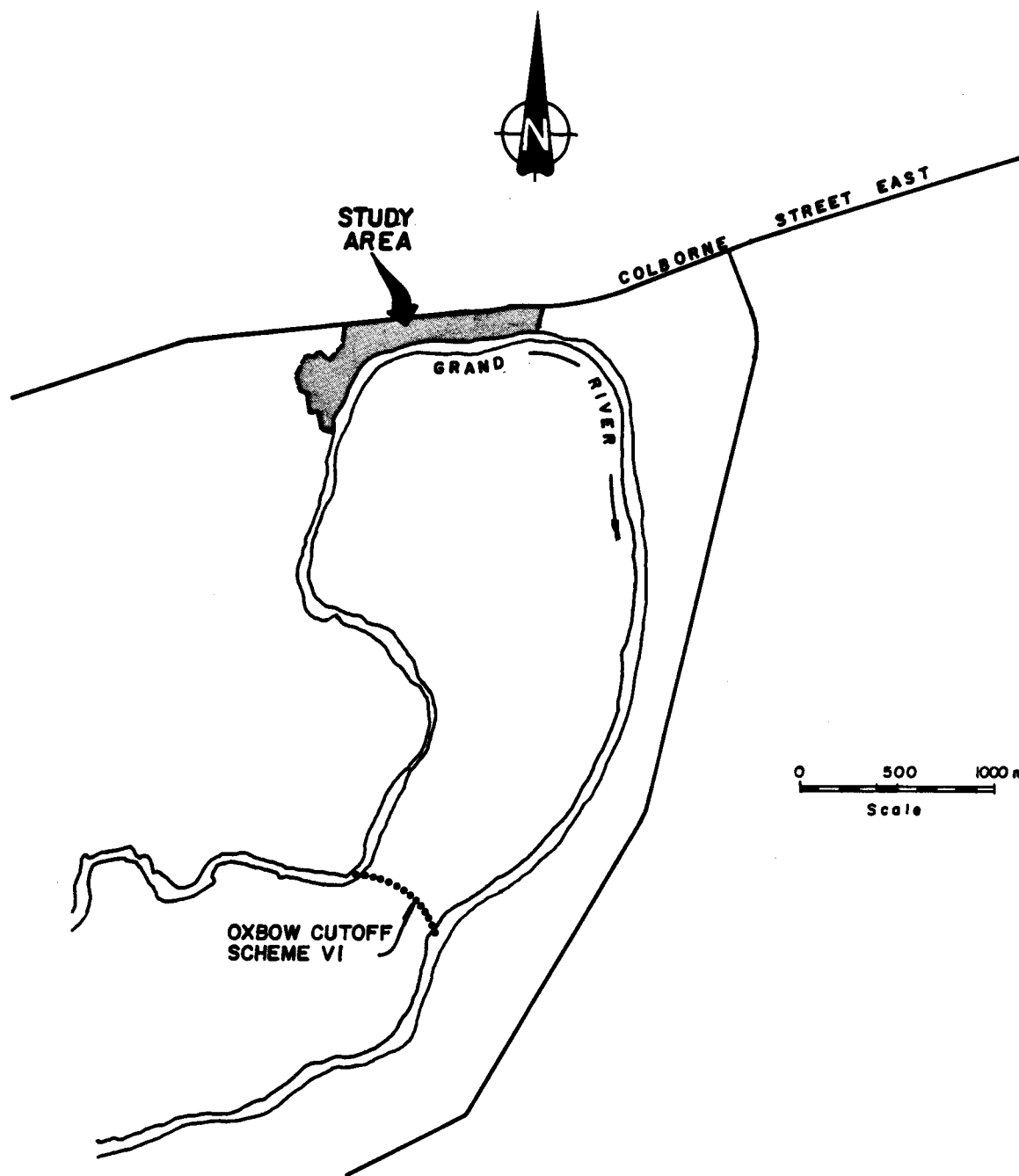
Drawn W.F.
 Chkd. [Signature]

SCHEMATIC SECTION - ZONE C
 (TOTAL CUT SCHEME)

FIGURE 11-28

LOCATION PLAN (OXBOW CUTOFF)

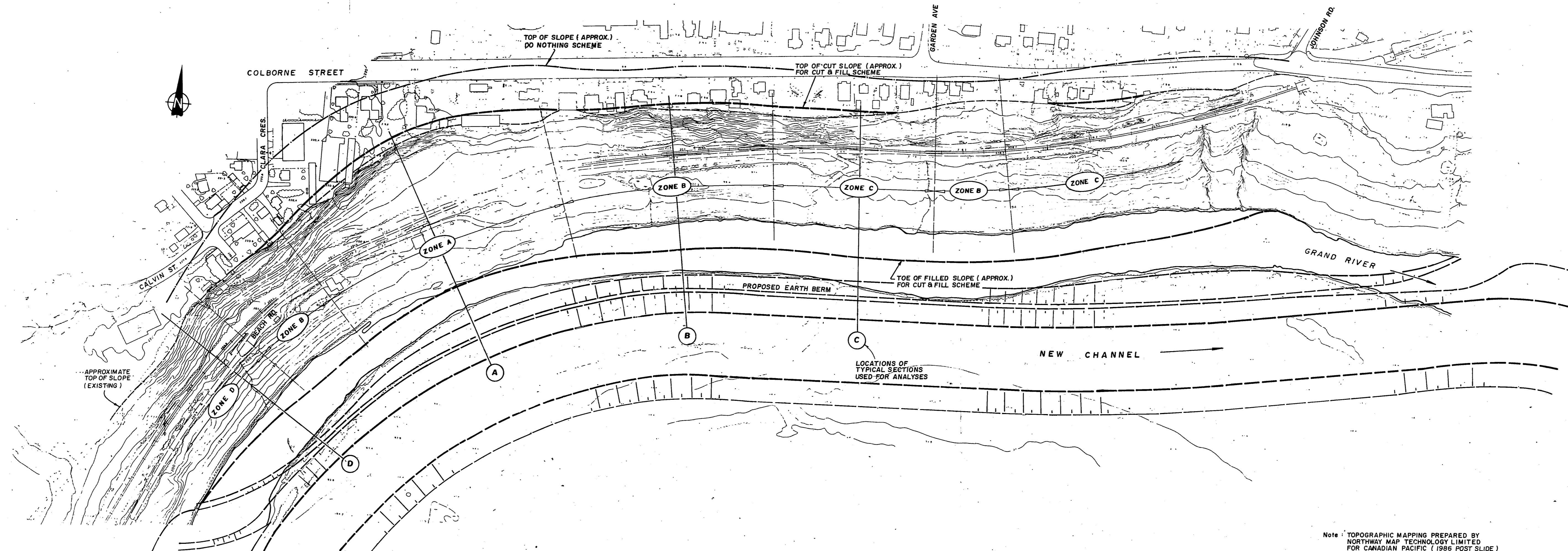
FIGURE II-29



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LOCATION PLAN (CUT & FILL SCHEME)

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DATE JULY, 1987

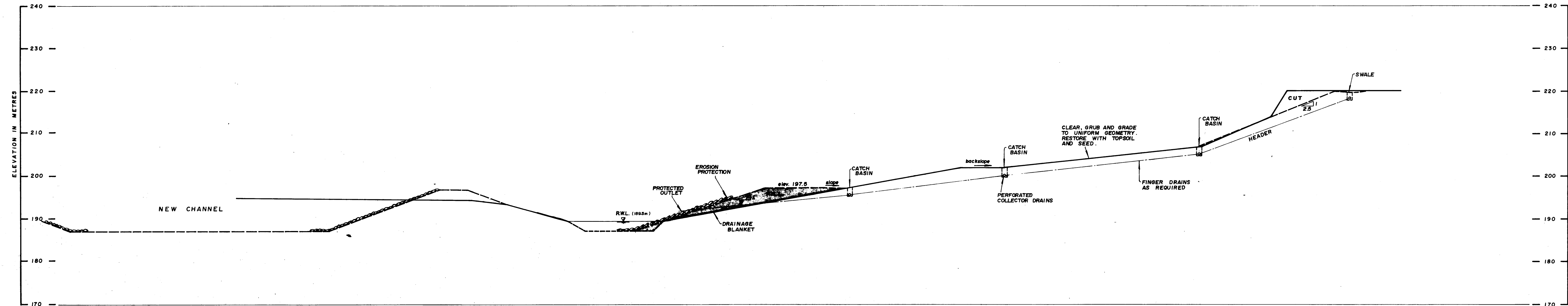
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FIGURE II-30

Note: TOPOGRAPHIC MAPPING PREPARED BY
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SCHEMATIC SECTION - ZONE A
(CUT & FILL SCHEME)

PROJECT No. 861-3257

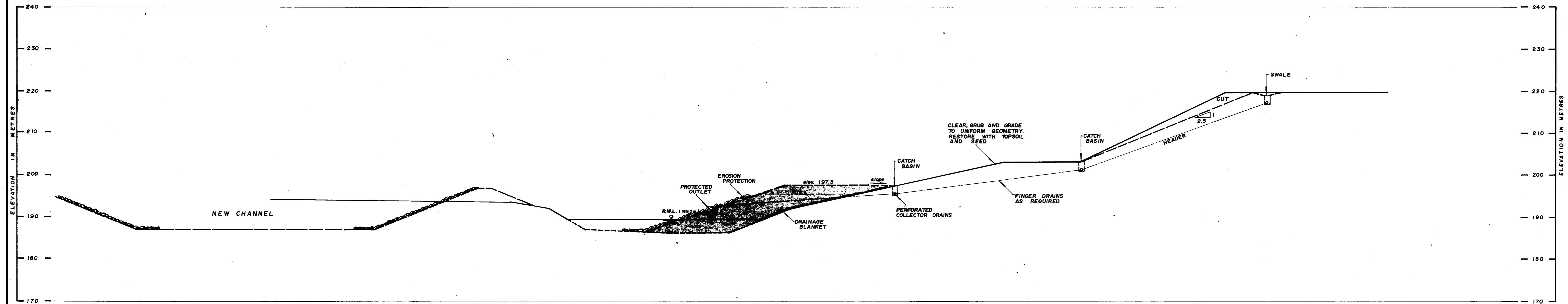
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FIGURE II-31



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SCHEMATIC SECTION - ZONE B
(CUT & FILL SCHEME)

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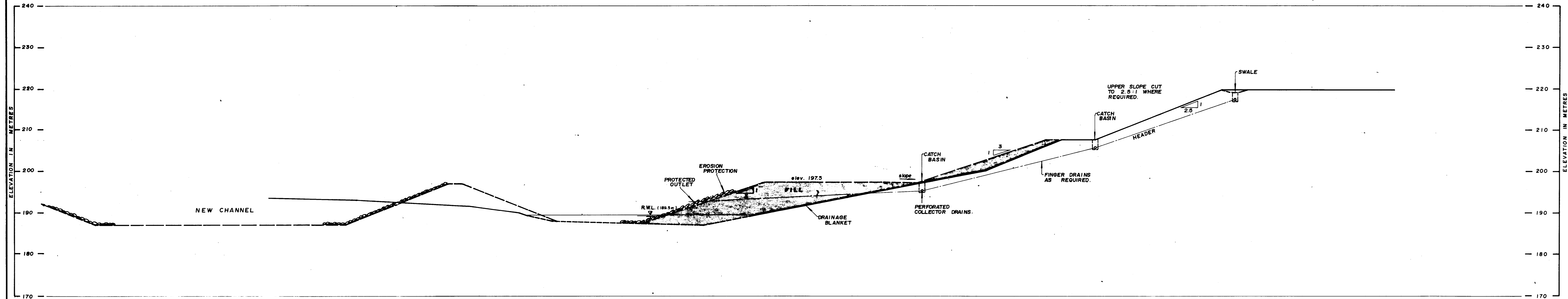
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FIGURE II-32



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SCHEMATIC SECTION - ZONE C
(CUT & FILL SCHEME)

PROJECT No. 861-3257

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FIGURE II-33



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**APPENDIX III
RIVER ENGINEERING**

**PRELIMINARY ENGINEERING STUDY
GRAND RIVER VALLEY WALL SLOPE FAILURE
COLBORNE STREET EAST
BRANTFORD, ONTARIO**

July 1987

Project: 86105

TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1
2.0 PHYSIOGRAPHY	
2.1 General	2
2.2 River Morphology	2
3.0 HYDROLOGY	7
4.0 RIVER HYDRAULICS	12
5.0 RIVER TRAINING ALTERNATIVES	19
5.1 Channel Reinstatement	19
5.2 Channel Widening	20
5.3 Channel Relocation	21
5.4 Oxbow Cutoff	22
6.0 SELECTION OF ALTERNATIVES	27
6.1 Hydraulic Analysis of Alternatives	27
6.2 Cost Comparison of Alternatives	28
7.0 PRELIMINARY DESIGN	30
7.1 Background	30
7.2 Channel Alignment	30
7.3 Channel Sections	31
7.3.1 Channel Relocation	31
7.3.2 Channel Widening	35
7.4 Estimated Costs	36
8.0 SUMMARY	46
9.0 LIST OF REFERENCES	49

LIST OF TABLES

Table No.	Description	Page
III-1	Physical Characteristics of the Grand River Watershed above Brantford	9
III-2	Water Surface Elevation Analysis	16
III-3	Channel Velocity Analysis (m/sec)	17
III-4	Right Over Bank (North Bank) Velocity Analysis	18
III-5	Cost Comparison of Alternatives	29
III-6	Preliminary Cost Estimates - River Relocation	38
III-7	Preliminary Cost Estimates - River Widening	40

LIST OF FIGURES

Figure No.	Description	Page
III-1	Key Plan	3
III-2	Optimum form of a Meander	6
III-3	The Grand River Watershed and Subwatershed Boundaries	10
III-4	The Grand River Watershed Profile	11
III-5	Hydraulic Cross Section Locations	15
III-6	Channel Reinstatement	23
III-7	Channel Widening	24
III-8	Channel Relocation	25
III-9	Oxbox Cutoff	26
III-10	Aerial Photography of Study Area	37
III-11	River Relocation - Preliminary Design Detail	42
III-12	River Widening - Preliminary Design Detail	43
III-13	River Relocation - Sections	44
III-14	River Widening - Sections	45

1.0 INTRODUCTION

The slope failure of May, 1986 resulted in an impact on the Grand River flowing along the toe of the slope. Specifically, slide material was deposited in the River Channel, creating a constriction to flow. This constriction to flow has had an impact on both the upstream and downstream river regimes.

In order to determine the effects of the slope failure on the river regime, a detailed impact assessment is required as a component of the Preliminary Engineering Study as detailed in the Terms of Reference¹. This report deals with these impacts and provides specific recommendations for remedial measures to mitigate the impacts of the slide on the river environment. In addition, an analysis of the potential impacts of continued marginal slope stability on the river regime is detailed.

A preliminary engineering design summarizes the recommendation of this component of the overall investigation. The preliminary design of the selected alternative(s) includes detailed cost estimates for the required river training activities with due regard to the preliminary design for slope stabilization².

2.0 PHYSIOGRAPHY

2.1 General

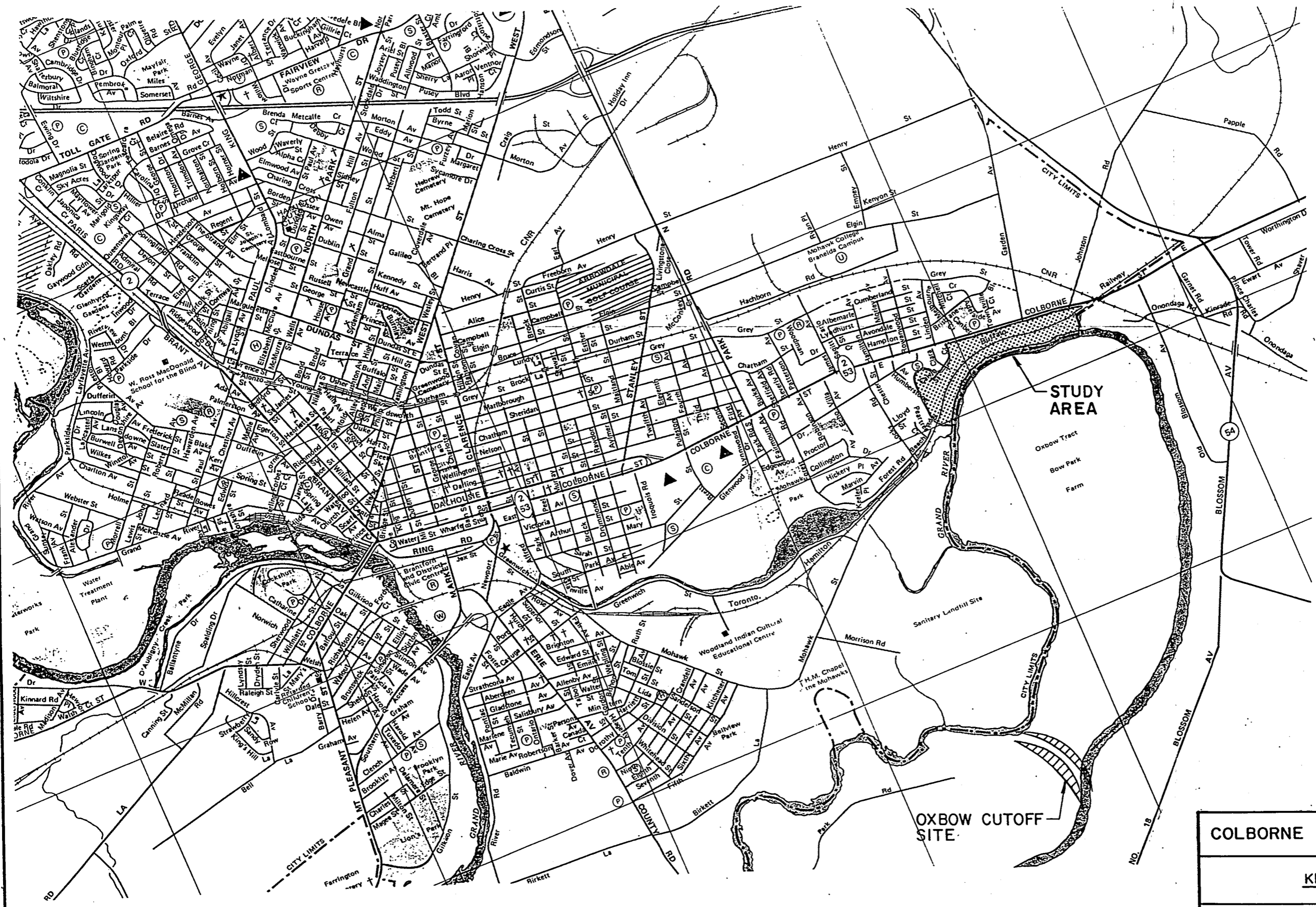
The City of Brantford is located on the Grand River approximately 200 kilometres from its headwaters, and about 100 kilometres upstream of Lake Erie.


The central portion of the Grand River Watershed, which includes the Brantford area, consists of rolling or undulating topography, with some hilly sections. Medium to coarse textured soils laid over a variety of tills, sand and gravel deposits. Soils in Brantford are predominated by fine textured soils overlying till and lacustrine deposits which are, in general, highly erodible.

A detailed description of site specific soils information is available for the area².

2.2 River Morphology

The river morphology of the Grand River through Brantford is typical of a dendritic river in soils of this nature. The River channel forms a series of meanders which are constantly moving as a result of the erosive and depositional characteristics of the river regime. The study area (Figure III-1) includes a portion of an active river meander. The median length of meandering streams is about 1.5 times the valley length³; i.e. the sinuosity averages about 1.5. The wavelength of meanders ranges from 7 to 11 times the channel width and the radius of curvature of the bend usually ranges between 2 and 3 times the channel width.



COLBORNE STREET SLOPE FAILURE		
KEY MAP OF AREA		
 Philips Planning + Engineering Limited	PROJECT NO. 86105	FIGURE NO. III-1

The amplitude of the meanders or width of the meander belt varies considerably and is controlled more by the characteristics of the bank material than by other factors. Amplitude usually ranges from 10 to 20 times the channel width. These parameters are realized prior to natural oxbow creation. A comparison of actual measured values on the subject meander to those theoretical values may provide insight into the future of meandering against the marginally stable north river bank. The optimum form of a meander is shown in Figure III-2 and would only be applicable in homogeneous soils in which the river velocity and velocity distribution are contingent on the tractive force required to move the soils forming the river bed and bank.

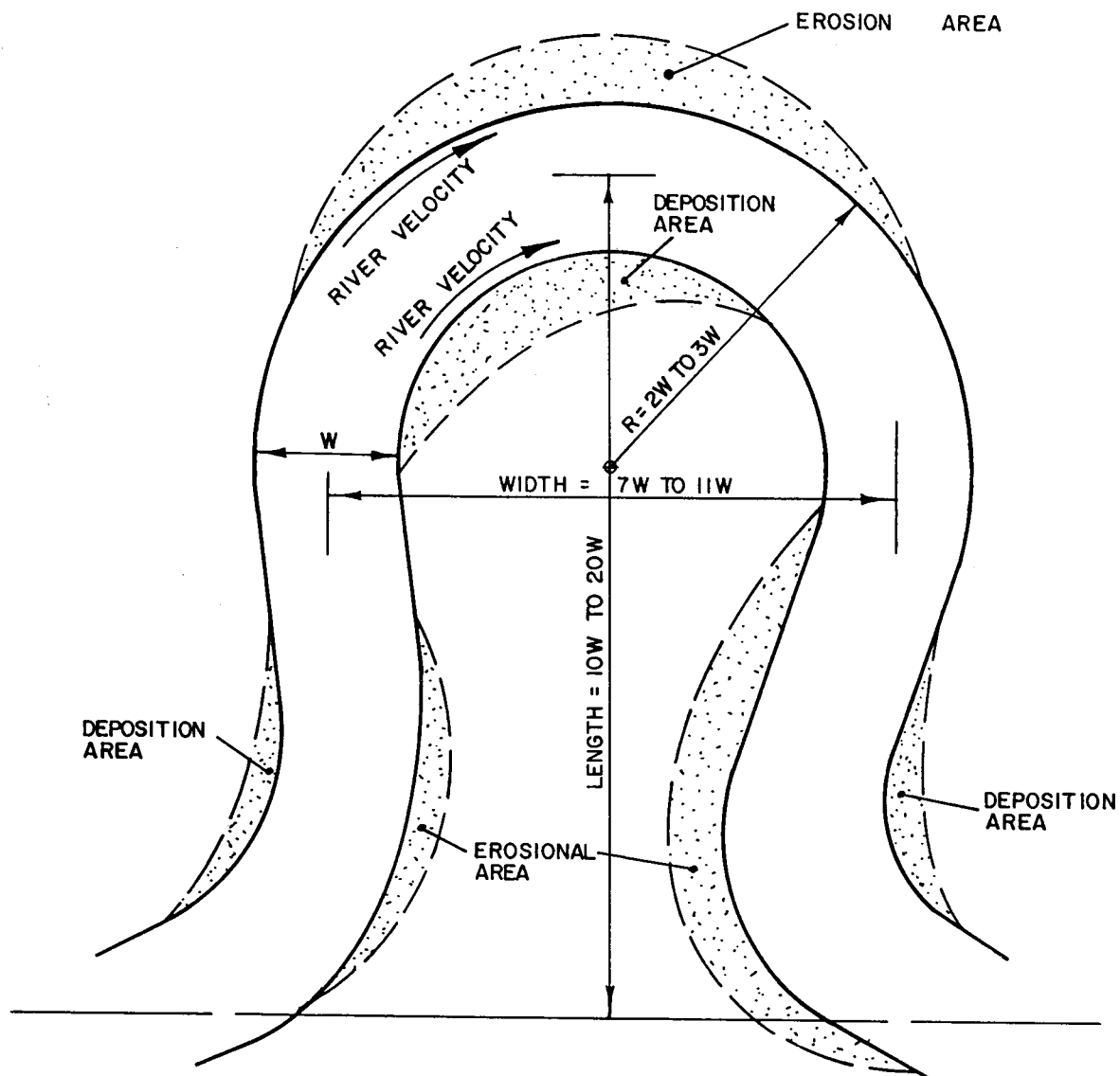
An investigation of aerial photographs of the river study site taken in 1949, 1963 and 1986 indicate that river erosion and subsequent meandering is an on-going process in the area.

The physical parameters measured for the river meander are as follows:

	Measured	Typically
Mean Channel Width =	60 m	60 m
Wavelength =	1200 m	420-660 m
Radius of Curvature =	600 m	120-180 m
Amplitude =	1200 m	600-1200 m

A comparison of these recorded parameters with those considered typical for a meandering stream indicate that the river sinuosity in the study area is complex and consists of a number of co-existent meanders rather than a simple single meander. The somewhat rectangular bend in the river forming the meander is the result of differences in the erodibility of the steep bank adjacent to the river. The angular reaction of the river with the bank increases rates of erosion at the bends.

River erosion and deposition are generally contingent on the erodibility of the soils forming the river bank and the velocity of flows adjacent to the erodible soils. Bank erosion has been shown to be a significant factor contributing to the recent (May 1986) major slope movement within the study area² with erosion rates averaging approximately 0.2 metres per year at the toe of the north bank. In addition to the May, 1986 slide, it is apparent that another major slide has occurred previously just downstream of the study area. These major slide sites correlate well with the major curvatures in the river meander and substantiate the conclusions relating to the continuing impact of toe erosion on slope stability.



COLBORNE STREET SLOPE FAILURE

THEORETICAL MEANDER



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FIGURE N^o

III - 2

3.0 HYDROLOGY

In March 1975, Philips Planning + Engineering Limited completed a hydrologic study in which the regional flood flows for the communities of Galt and Brantford were calculated⁴. The study methodology involved discretizing the Grand River watershed above the City of Brantford into 13 subcatchments (see Table III-1 and Figure III-3). These subcatchments ranged in size from 102.4 to 1105.9 square kilometres and were generally arranged to represent the major creeks and reservoirs within the watershed.

The Grand River watershed above the City of Brantford is made up of two different soil regions. In the upper watershed and the Conestogo basin, soils are dominated by Glacial Till, while the region from Paris to Brantford, sand and gravel make up the majority of the soil strata.

In profile the Grand River watershed consists of a relatively steep upper catchment with an average slope of 0.8% above Brantford, draining into a flatter, lower catchment with an average slope of approximately 0.3% between Brantford and Dunnville (see Figure III-5).

Three reservoirs and their attenuative effects were included in the regional flood calculations. Available storage in the following amounts were assumed:

Bellwood Reservoir	9800 Dam ³ (8000 Ac. Ft.)
Conestogo Reservoir	11000 Dam ³ (9000 Ac. Ft.)
Guelph Reservoir	6100 Dam ³ (5000 Ac. Ft.)

These values were based on normal reservoir conditions at the end of June which is the earliest a regional storm would occur.

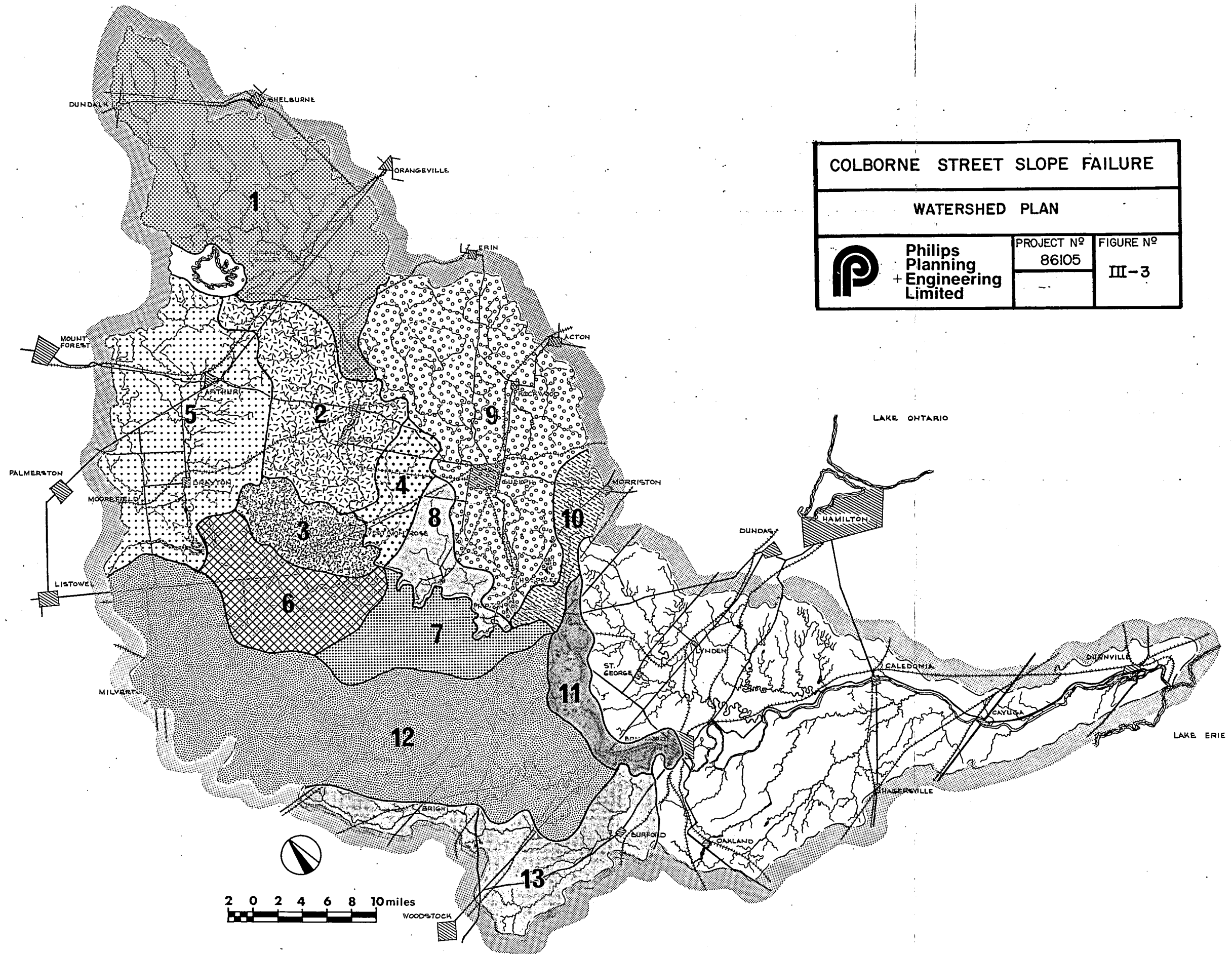
Regional Storm hydrographs for each subcatchment were computed utilizing the U.S. Soil Conservation Services Triangular Unit Hydrograph Methodology. Calibration was completed using calculated values of Snyder's Coefficients to adjust "time to peaks" in comparison to the observed runoff response for the May 1974 event.


Flood routing through the channel reaches was accomplished using the Muskingum method which was verified by gauge charts recorded during the May 1974 flood. Regional Flood routing parameters were adjusted to justify contrasting flow mechanisms.

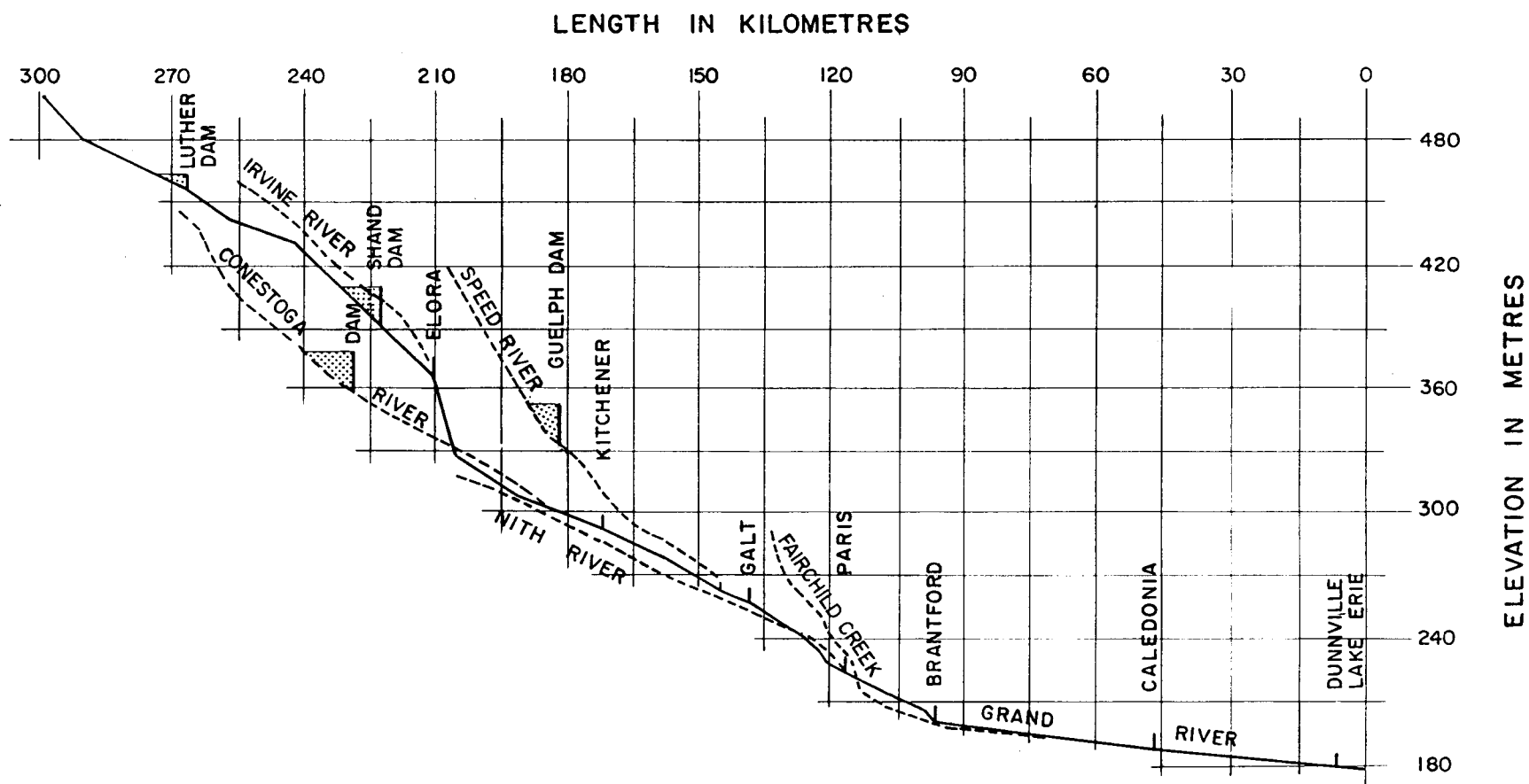
Final results of the 1975 report identified the Regional Flood within the City of Brantford to be 3400 cms (120,000 cfs) which included an allowance of 45 cms (1500 cfs) as a normal base flow under October (wet) conditions.

TABLE III-1
PHYSICAL CHARACTERISTICS OF THE GRAND RIVER WATERSHED
ABOVE BRANTFORD

Subwatershed No. (refer to Fig. III-3)	Description	Area (sq. km.)	Length (km)	Elev. Diff. In Basin (m)
1	Above Shand Dam on Grand River	791.0	70	114
2	Below Shand Dam and above West Montrose on Grand River	363.5	42	137
3	Canagagigue Creek Basin	140.0	26	122
4	Cox Creek Basin	102.4	21	64
5	Above Conestogo Dam on	563.2	43	98
6	Below Conestogo Dam and above Grand River Junction of Conestogo River	258.0	40	66
7	Schneider and Laurel Creek Basins	204.8	18	114
8	Hopewell Creek Basin	121.3	18	53
9	Speed and Eramosa River Basins	768.0	61	172
10	Galt Creek Basin	111.9	26	84
11	Below Galt and above Brantford on Grand River	145.9	38	61
12	Nith River Basin	1105.9	157	200
13	Whiteman Creek Basin	348.2	61	152



COLBORNE STREET SLOPE FAILURE		
WATERSHED PLAN		
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THE GRAND RIVER WATERSHED PROFILE

COLBORNE STREET SLOPE FAILURE



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FIGURE N^o

III - 4

4.0 RIVER HYDRAULICS

To determine the impact of the May, 1986 slide on flood levels and velocities in the Grand River, additional cross-sections were interpolated from mapping of the study area (Figure III-5) for both post slide and pre-slide conditions. This topographical data was incorporated to an existing HEC-2 hydraulic model of the Grand River through Brantford. The existing model was prepared using surveyed cross-sections through the City of Brantford and has been calibrated and updated to reflect current physical conditions.

The slope failure of May 1986, deposited a substantial amount of material into the Grand River Channel. In addition, the slope failure modified the north River Bank and reduced the cross-sectional area of flow. The degree of constriction varies and is generally greatest for lesser flows. The impact of the restriction is two-fold. The first impact of the constriction on flows is an increase in upstream flood levels. The degree of impact is only of significance when flood levels exceed the capacity of the river and result in flood damages. At the present time, the Brantford Flood Control Program is incomplete, and as a result, a substantial portion of Brantford remains susceptible to periodic, infrequent flooding. Generally, damages within Brantford would not be incurred unless flood flows exceeded the 850 cms (30,000 cfs) level. Therefore the impact analysis of the slope failure on upstream water levels was limited to flows of 850 cms (30,000 cfs) or greater.

The second major impact of a constricted channel is an increase in flow velocities immediately downstream of the slope failure site. Increased flow velocities are significant in terms of their increased erosion potential and the susceptibility of the river banks to the erosive forces of the river. Since the north river bank is only marginally stable², an increase in the rate of erosion could become a significant factor in terms of decreased bank stability and increased hazard to life, limb and property at the top of the slope. The geotechnical report² suggests that an opportunity for additional failures within the study area exists. Therefore, a sensitivity analysis was carried out to determine what further impacts would be incurred should an additional slope failure occur which further constricts the flow channel. For the purposes of analysis the hypothetical second slope failure was assumed to be identical to the

May, 1986 failure. This hypothesis results in an additional channel restriction which is approximately twice that incurred as a result of the May 1986 failure. The analysis of flood levels and river velocities was carried out using the U.S. Army Corp. of Engineers HEC-2 model for the following three cases:

- Case #1 Pre-slide conditions
- Case #2 Post-slide conditions
- Case #3 After a second slide event of similar magnitude to the 1986 slide.

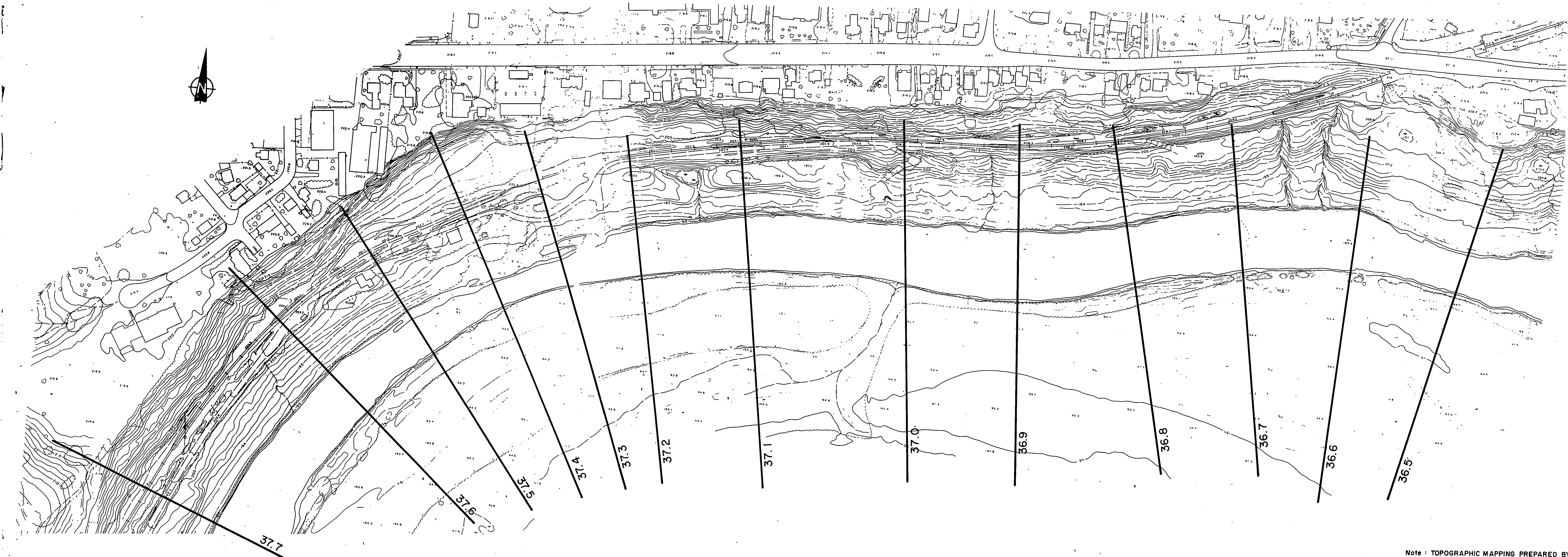
Water surface levels and velocities were calculated for a range of flows between 850 cms (30,000 cfs) (annual event) to 3400 cms (120,000 cfs) (regional storm response). Results indicate that the 1986 slide increased flood levels between 0.03 and 0.10 metres (see Table III-2) with the greatest increase at the lower flow values. If a second slide were to occur, flood levels would be increased over pre-slide conditions within the range of 0.11 and 0.24 metres. All increases in water surface elevations were translated well upstream however, and were reduced by 34% at a point immediately upstream of the Erie Avenue bridge.

Results of the velocity analysis (See Table III-3 and III-4) indicate that, as expected, upstream velocities are decreased as a result of the 1986 slope failure. Velocity regimes for the channel flow reduced from 2.51-1.39 m/sec to 2.48-1.37 m/sec.

Downstream of the slide area the results are far more significant. Channel velocities were increased for both Cases #2 and #3. The velocity increases for Case #2 were less than 0.3 m/sec. however, within Case #3 the channel velocity increased by about 1.05 m/sec. at 850 cms (30,000 cfs). The results of the hydraulic impact assessments indicate that the May, 1986 slope failure has increased flow velocities immediately downstream of the site of the slope failure particularly under normal annual flow conditions (45 to 850 cms or 1500 to 30,000 cfs).

It is apparent that the May 1986 slope failure has had a marginal impact on both flood elevations upstream and flow elevations downstream of the slope failure site.

The analysis does however suggest that additional slope failures which further constrict flows through the study area will increase these impacts to a level which warrants concern. These impacts would be considered significant in terms of potential for increased flood damages upstream and increased erosion potential downstream.



Note: TOPOGRAPHIC MAPPING PREPARED BY
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HYDRAULIC CROSS SECTION LOCATIONS

PROJECT No. 86105 DATE MAY 1987

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FIGURE III-5

TABLE III-2

WATER SURFACE ELEVATION ANALYSIS (Elevations in metres A.S.I.)

Cross Section and Location	Case #1 Pre-slide	Case #2 Post-slide	Case #3 Future Slide
Flow = 3400 cms (120,000 cfs)			
37.2 D/S of Slide	199.94	199.93	199.92
37.4 Mid Slide	200.01	200.10	200.12
37.7 U/S of Slide	200.10	200.20	200.24
242.0 U/S of Erie Ave.	201.07	201.10	201.15
Flow = 850 cms (30,000 cfs)			
37.2 D/S of Slide	195.61	195.61	195.59
37.4 Mid Slide	195.68	195.66	195.85
37.7 U/S of Slide	195.81	195.85	196.05
242.0 U/S of Erie Ave.	196.44	196.48	196.65

TABLE III-3
CHANNEL VELOCITY ANALYSIS (m/sec.)

Cross Section and Location	Case #1 Pre-slide	Case #2 Post-slide	Case #3 Future Slide
Flow = 3400 cms (120,000 cfs)			
37.2 D/S of Slide	2.73	2.80	2.90
37.4 Mid Slide	2.55	2.87	2.92
37.7 U/S of Slide	2.51	2.51	2.48
242.0 U/S of Erie Ave.	1.39	1.38	1.37
Flow = 850 cms (30,000 cfs)			
37.2 D/S of Slide	1.87	1.91	2.10
37.4 Mid Slide	1.75	2.38	2.80
37.7 U/S of Slide	1.42	1.41	1.35
242.0 U/S of Erie Ave.	1.22	1.20	1.15

TABLE III-4

RIGHT OVER-BANK (N. BANK) VELOCITY ANALYSIS (m/sec.)

Cross Section and Location	Case #1 Pre-slide	Case #2 Post-slide	Case #3 Future Slide
Flow = 3400 cms (120,000 cfs)			
37.2 D/S of Slide	1.25	1.20	1.27
37.4 Mid Slide	1.19	1.49	1.95
37.7 U/S of Slide	1.16	1.15	1.14
242.0 U/S of Erie Ave.	0.66	0.66	0.66
Flow = 850 cms (30,000 cfs)			
37.2 D/S of Slide	0.77	0.80	0.83
37.4 Mid Slide	0.73	1.13	2.16
37.7 U/S of Slide	1.42	1.41	1.35
242.0 U/S of Erie Ave.	0.40	0.39	0.39

5.0 RIVER TRAINING ALTERNATIVES

Three alternative schemes for slope stabilization have been suggested², each of which require varying degrees of toe stabilization to effect a stable slope configuration. In addition, several impacts have been quantified which relate to the present and possible future condition of the river channel through the study area. In order to mitigate the hydraulic impacts identified in Section 4.0 and accommodate the various alternatives for slope stabilization, channel improvements are required. The nature and degree to which river training is required is contingent on the impact that slope stabilization has on the river. Each of the identified alternatives will fulfill the requirements of erosion mitigation, velocity reduction immediately downstream and upstream floodplain stabilization if designed and implemented correctly.

5.1 Channel Reinstatement (Figure III-6)

With a total cut of the existing bank as a stabilization maneuver, an opportunity exists to reinstate the pre-slide river channel. Under a total cut scheme, material would be removed from the river enabling the channel to regain its original conveyance characteristics. This would not however, mitigate the impacts of continuing toe erosion on the slope stability. Therefore, in conjunction with the channel excavation, extensive erosion protection would be required along the north river bank throughout the study area to secure the bank from continued, regressive erosion.

The level of erosion protection, as with flood protection, is a function of the frequency of overtopping which can be safely and economically justified. Since erosive forces are primarily a function of the normal flows of the river as opposed to high, less frequent events, a design elevation of 197.0 metres (being the flood elevation recorded during the May, 1974 flood) has been considered generally acceptable for erosion mitigation⁵.

5.2 Channel Widening (Figure III-7)

The total fill and partial fill slope stabilization schemes require that fill be placed at the toe of the slope to provide a counterweight against further, deep seated rotational slope movements. These alternative slope stabilization measures involve, to different degrees, encroachment into the river and therefore, it is not feasible to reinstate the river to its pre-slide state. In order to ensure that the pre-slide hydraulic characteristics of the river are approximated, one alternative involves widening the existing river channel to the south. This is necessary to provide a flow area the same as or greater than that of the pre-slide channel.

This river training alternative will also require erosion protection to mitigate the impact of river velocities and tractive forces on toe erosion. As with the channel reinstatement option for a total cut scheme, the erosion protection proposed for the channel widening scheme will be extended to the 1700 cms (60,000 cfs) flood line (197.0 m) to provide an acceptable degree of erosion protection.

With a river widening option, the channel curvature at the inlet and outlet points will necessarily be increased. Therefore, the erosion protection measures at these points will be more substantial. The aspect of hardening of the erosion protection at the upstream and downstream confluences of the new, widened channel must therefore be a prime consideration in the preliminary design of a channel widening alternative.

5.3 Channel Relocation (Figure III-8)

Another option for river training which has been considered in conjunction with the total fill and partial fill methods of slope stabilization, is a total relocation of the river through the study area. This option involves the creation of a second river channel, approximately parallel to the existing channel, which would be capable of passing all of the river flow through the area. The existing channel which would be reduced in its cross-sectional flow area, could be maintained for local drainage and overflow purposes while the new channel would be designed to accommodate design flood flows. A groin and submerged sill system would be incorporated to act as a deflector to maintain higher flows within the new channel, permitting only lower flows to pass into the existing, restricted channel.

Alternatively, the existing channel could be completely filled and the new, relocated channel sized to convey all normal river flows.

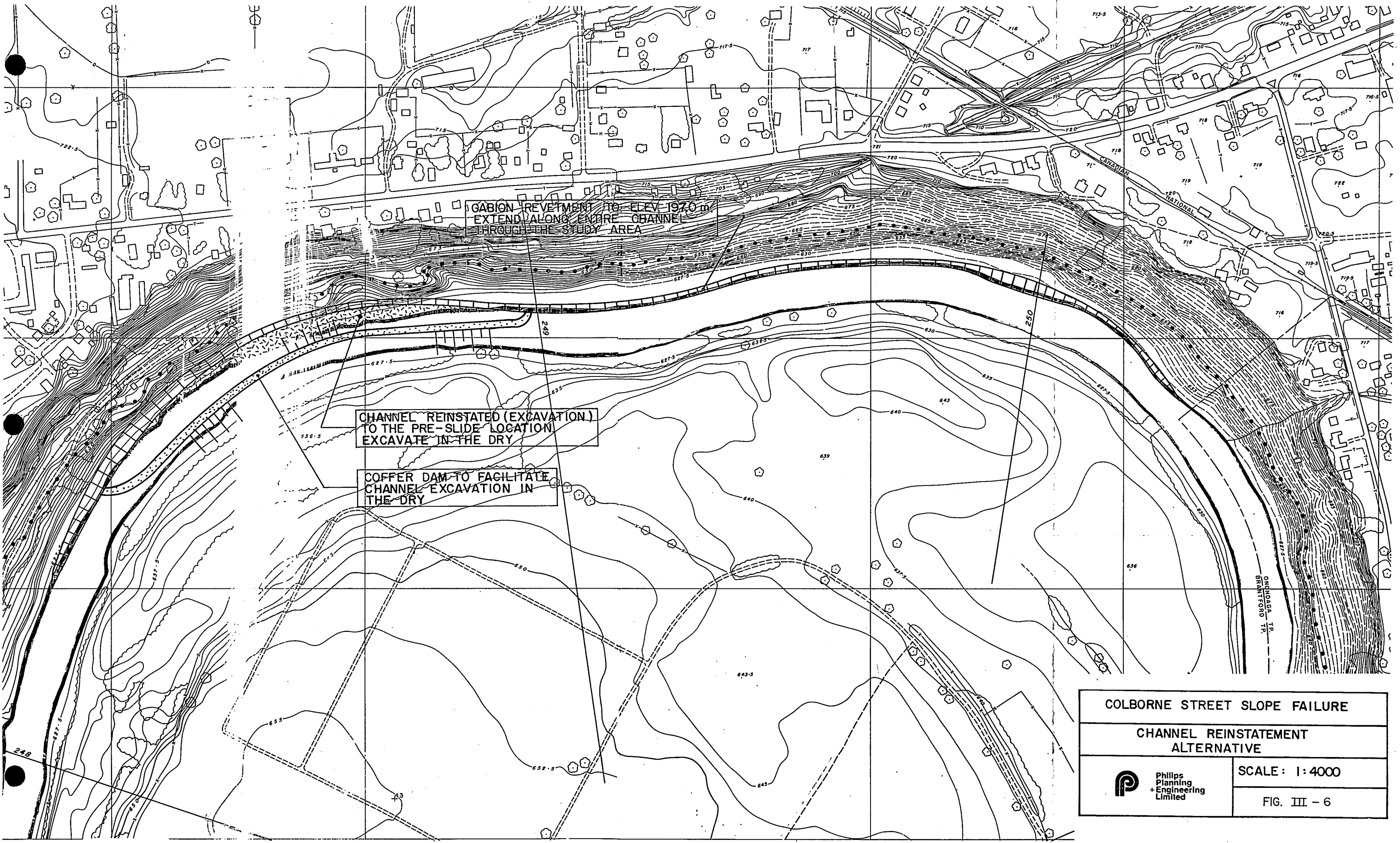
A channel relocation scheme has several advantages over a channel widening alternative. It enables the construction of the slope works to be carried out independent of the river hydraulics, since the new, relocated channel would have a capacity equal to or greater than that of the pre-slide channel and would be able to carry river flows while the slope modifications (involving encroachment into the existing river channel) proceeded. This is important when considering the phased implementation of any remedial measures.


Another advantage inherent in a river channel relocation is the creation of a "buffer zone" between the north river bank and the toe of slope. This "buffer zone" provides an additional factor of safety against potential toe erosion during protracted bank and slope stabilization work implemented over a period of several years.

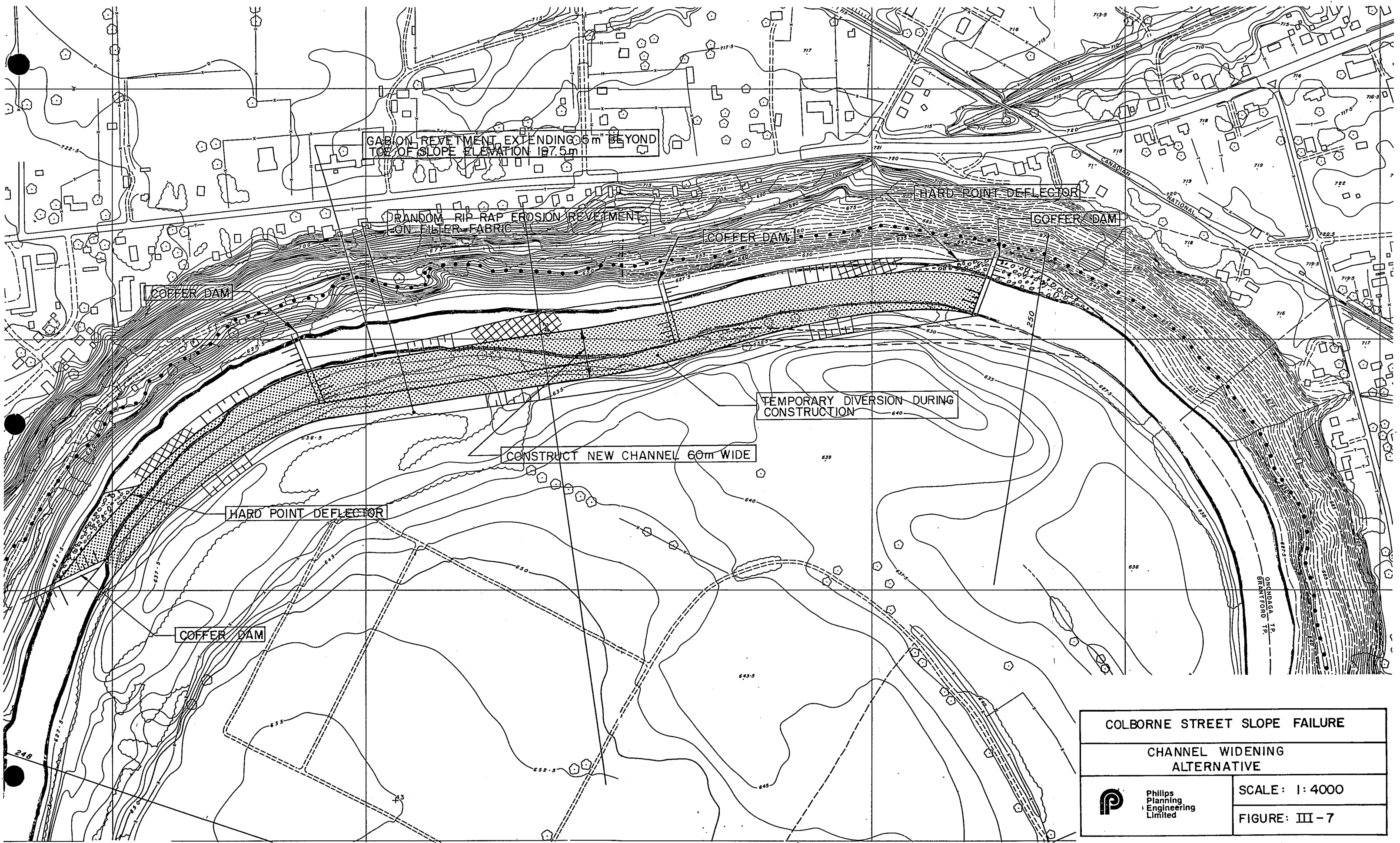
5.4 Oxbow Cutoff (Figure III-9)


Another, more intense method of eliminating toe erosion through the study area is to create an oxbow from the existing meander by an artificial Oxbow Cutoff. This Oxbow Cutoff would divert all flows from the meander thus completely eliminating toe erosion due to river flows. The additional benefit of an oxbow cutoff is the elimination of harmful toe erosion on adjacent, marginally stable slopes outside the defined study area.

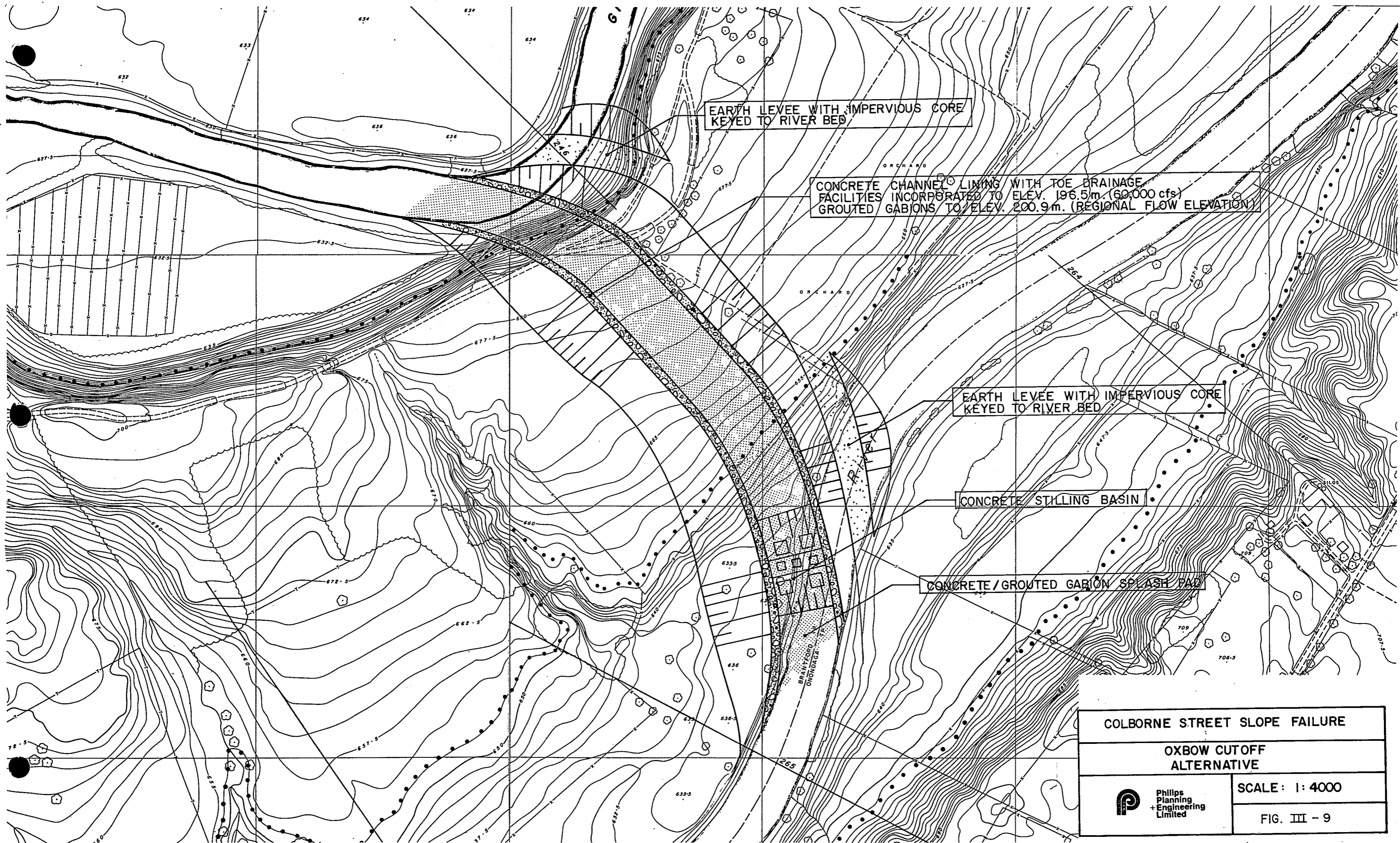
The oxbow cutoff alternative would be a much larger undertaking. The required cut to match grades at the upstream and downstream ends of the diversion is in the order of 15 metres vertical, generating approximately 1.2 million cubic metres of material for disposal. In addition, the grades involved in the diversion (approximately 9 percent) would necessitate the installation of a stilling structure to match the outlet velocities with that of the downstream river channel to minimize increased erosion potential at the outlet. An energy dissipation structure of the magnitude required to generate the velocity reduction required on a design flow of 1700 cms (60,000 cfs) would be substantial and expensive. In addition, flow velocities in the diversion would require that the channel be completely lined with a suitable, velocity resistant material to avoid up-lift pressures and scouring resulting from these relatively high flow velocities.



COLBORNE STREET SLOPE FAILURE	
CHANNEL REINSTATEMENT ALTERNATIVE	
 Philips Planning + Engineering Limited	SCALE: 1:4000
	FIG. III - 6



COLBORNE STREET SLOPE FAILURE	
CHANNEL WIDENING ALTERNATIVE	
 Philips Planning Engineering Limited	SCALE: 1:4000
	FIGURE: III - 7



6.0 SELECTION OF ALTERNATIVES

Each River Training alternative considered for analysis has been formulated to provide toe erosion mitigation when considered in conjunction with the slope stabilization works proposed by Golder Associates. The river training is thus an integral component of an overall bank stabilization scheme and therefore, it is not possible to qualitatively select a single, most desirable option for river training without due consideration of the entire engineering solution for stabilization and the proposed implementation period. It is, however, possible to rank each alternative in terms of its hydraulic efficiency and to determine the various parameters that can be considered in a detailed benefit versus cost analysis of the full set of engineering alternatives.

6.1 Hydraulic Analysis of Alternatives

A HEC-2 hydraulic model was prepared with cross-sectional information relating to each of the four alternative channel alignments. Hydraulic modelling of each alternative was carried out for river flows of 850 cms (30,000 cfs), 1700 cms (60,000 cfs) and 3400 cms (120,000 cfs) corresponding to the annual flood flow, May 1974, flood flow and Regional flood flow respectively. Section number 37.7 was used as being a representative section with the greatest impact in terms of flood levels as summarized in Section 4.0. Similarly, Section 37.4 was used for comparison purposes in determining downstream flow velocity impact. The channel configuration was iteratively adjusted to provide conveyance characteristics similar to, or better than those of the pre-slide river channel.

From a hydraulic standpoint, the options favouring lower curvatures are considered more desirable in that they require less extensive measures to obviate the increased potential for erosion at the inlet and outlet of the proposed channel.

6.2 Cost Comparison of Alternatives

The costs associated with construction of each of the four alternatives for River Training are summarized in Table III-5.

These costs are based upon the following unit rates which are representative of the rates presently prevailing in the construction industry in Brantford.

ITEM	UNIT	RATE
Tree Removal	ha	\$42,500.00
Clear and Grub	ha	\$ 8,900.00
Gabions	m ³	\$ 210.00
Rip Rap	m ³	\$ 45.00
Drains	m ³	\$ 6.50
Earth Excavation	m ²	\$ 5.80

Engineering fees associated with the design and construction of the river works have been estimated at 10 per cent of the construction costs (3% for the Oxbow Cutoff) and are included in the amounts shown in Table III-5.

The costs of an oxbow cutoff alternative are substantially higher than the other three schemes. The difference in the costs of each of the alternatives is primarily a function of the excavation requirements of each, since erosion protection is a feature common to all schemes. In the case of the oxbow cutoff, erosion mitigation involves a complete channel lining (as opposed to bank erosion protection only) and the construction of an energy dissipation for downstream flow velocity maintenance.

Although it is not possible to definitively select alternatives solely on the basis of costs, it is apparent that the oxbow cutoff scheme is not financially viable. Nevertheless, it has been carried forward and will represent a valid alternative for consideration in the final benefit versus cost analysis.

TABLE III-5
COST COMPARISON OF RIVER TRAINING ALTERNATIVES

Preliminary Engineering Study
Grand River Valley Wall Slope Failure
Colborne Street East
Brantford, Ontario

	Oxbow Cutoff (\$ x 1000)	Channel Reinstatement (\$ x 1000)	Channel Widening (\$ x 1000)	Channel Relocation (\$ x 1000)
1. Tree Removal	825	100	850	600
2. Clear and Grub	525	50	150	200
3. Excavation	19000	550	1500	2600
4. Erosion Protection	27000	1200	1400	1700
5. Restoration	<u>650</u>	<u>100</u>	<u>200</u>	<u>300</u>
SUBTOTAL	48000	2000	3800	5400
Engineering	<u>2000</u>	<u>200</u>	<u>400</u>	<u>500</u>
TOTAL	50000	2200	4200	5900

NOTE: Table to be read in conjunction with accompanying report.

7.0 PRELIMINARY DESIGN

7.1 Background

A detailed benefit versus cost and economic analysis has defined the preferred alternatives for both an unphased implementation program and a phased implementation program. Recent discussions with members of the Technical Co-ordinating Committee have indicated a possible preference towards a phased approach. This approach favours a River Relocation alternative of river training since it affords the opportunity to phase the provision of toe erosion protection thus enabling the vertical strip phasing of slope stabilization suggested by Golder Associates. The river widening scheme is least costly and is preferred if a phased implementation approach is not taken. This preliminary design report provides preliminary details relating to both the river widening and the river relocation scheme and are presented in a manner consistent with the requirements of the terms of reference.

7.2 Channel Alignment

Several factors influence the selection of the optimum alignment for both the widened and relocated channel. These factors are:

1. Excavation Quantities (and cost factors)
2. Hydraulic Optimization (radius at river bends)
3. Environmental (trees, etc.)

To a large extent, the optimum channel alignments will be selected on the basis of a detailed site survey to be undertaken at the final design stage. There is however, enough information available to determine preliminary channel configurations and alignments for the purposes of defining the preliminary design.

The preferred channel alignments for both the channel relocation and channel widening were derived by considering the factors outlined previously, from interpretations of recent aerial photography (June, 1986)

and from mapping interpolated from the photos. In order to ensure the hydraulic efficiency at the inlet and outlet of the proposed alignments, earlier mapping (Jan., 1963) (Figure III-10) was used as the base mapping for establishing the alignments. Once the alignments were established, they were transferred to the up-to-date mapping base for comparison with existing topographic conditions. This approach was carried out iteratively to establish the final alignments shown in both Figures III-11 and Figure III-12. The new channel profiles were assumed to have a constant slope over the channel length. A detailed hydraulic assessment at the final design stage may modify this profile by providing a steeper slope along the straighter channel sections, thus permitting a slope reduction (and resulting velocity reduction) at the areas with greater curvature.

7.3 Channel Sections

The proposed channel alignment requires three (3) distinctly different channel cross-sectional configurations to define the preliminary design fully. These sections are typically located as sections A-A', B-B' and C-C' in both Figures III-11 and III-12.

7.3.1 Channel Relocation

Section A-A' (Figure III-13a) is typical of the channel cross-section proposed at the inlet of the new channel. The 1700 cms (60,000 cfs) design flood has been used for the purposes of erosion mitigation. This flow is equivalent to the peak flow generated by the May, 1974 flood in Brantford. This design criterion has been used for erosion protection of the flood levees through Brantford⁵ and in other areas of the Grand River Watershed. Section A-A' is unique for this alignment in that it incorporates the following features:

1. A deflection berm to ensure that flows in excess of the 1700 cms (60,000 cfs) to be conveyed by the channel configuration are deflected away from the downstream bank.
2. A submerged groin and sill structure to control the flow distribution between the new channel and the old, restricted river alignment.
3. Enhanced erosion revetment protection to mitigate the erosion potential at the inlet (where river curvature has been increased) and to provide additional freeboard for centrifugal effects at the outside of the curves.
4. The level of freeboard of the erosion revetment protection has been increased from 0.3 metres above the 1700 cms (60,000 cfs) flood level (197.4 metres) to 0.6 metres to provide an additional safety factor.

It has been assumed that the existing flow channel would remain. This assumption is based upon lower construction costs and environmental considerations for preliminary design purposes. An option does exist to completely fill the existing flow channel and convey all flows within the relocated channel. Consideration of this alternative is considered a final design detail and would be considered should a channel relocation scheme be adopted as the most desirable river training alternative.

For the purposes of preliminary design, a rock filled gabion form of erosion protection is proposed as it has been successfully implemented on the Grand River through Brantford at other locations having similar hydraulic conditions.

The primary benefits and costs associated with gabions are as follows:

Benefits	Costs
- flexible to settlement of the subgrade	- relatively expensive (labour intensive) to install as compared to random rip rap (for example)
- proven resistance to ice damage	- requires placement in the dry
- widely available	- more time consuming to install
- uses less expensive gabion (100mm to 150mm) rock as opposed to more expensive, less available rip-rap	- requires a smooth grade for installation (as opposed to random rip-rap)
- subgrade material migration is less significant	- requires a contractor qualified in gabion construction
- can be placed on a thinner, less expensive filter material (less chance of filter damage during construction)	
- can be easily repaired	
- low annual maintenance costs	

As a result, a gabion section has been considered most desirable for typical section A-A'. A grouted surface is a component of the gabion section on the outer (north) river bank. This is necessary to provide additional protection of the erosion blanket against the scouring effects of river ice flows. It also reinforces the bank and necessitates the installation of sub-drains to minimize excessive pore pressures in the subgrade materials.

A gabion, submerged groin is proposed as a flow deflector. The use of gabions as a flow deflector will ensure minimum maintenance throughout the project life.

A flow deflector would be placed on the bank at the regional flood level to ensure that flows in excess of channel capacity are deflected away from the marginally stable slope. This will minimize erosion of the bank during infrequent flood events and help to ensure the long term integrity of slope stabilization measures.

Section B-B' (Figure III-13b) represents a typical cross-section through the channel alignment. It illustrates bank erosion protection on both the new channel and the old channel. The velocity of flow through the channels dictates the extent of erosion protection to be provided. In the case of the new channel, in which the majority of the flows are to be diverted, a gabion mat slope protection extending approximately 10 metres beyond the river toe on the north bank is proposed. The existing river channel incorporates a rip-rap form of revetment protection to the 197.0 metre elevation as an erosion resistant blanket. A levee constructed of excavated material is located between the channels to increase the flow capacity of the new channel.

Section C-C' (Figure III-13c), located at the confluence of the existing river channel and the proposed, new relocated channel, represents a third level of erosion protection. Similar to Section A-A', this section incorporates a gabion revetment form of protection with an enhanced free board to account for velocity run-up at the outside of the curvature and to provide additional factors of safety against detrimental stream bank erosion. One additional consideration in the design of the outlet section, of which Section C-C' is typical, is the marginal stability of the adjacent embankment.

As discussed previously, an older slide site exists immediately downstream of the study site. The channel alignment has been deliberately extended beyond this point (as interpreted visually from the available mapping) in an effort to afford toe erosion protection to this area. Nevertheless, the slope at the outlet of the channel relocation is adjacent to a steep slope which is already potentially subject to failure and subsequent channel constriction.

It is not possible to predict the timing or nature and extent of this failure, and the extension of the channel relocation beyond the bounds of the potential instability is beyond the terms of reference for these works.

Therefore, suitable modifications have been incorporated in the outlet section C-C' to allow for increased safety factors against river constriction due to slope failure. These factors include:

1. decreased north bank slope
2. extended erosion protection
3. widened channel section at the outlet

These factors should afford adequate safe guards to minimize the impacts of an additional slide on the conveyance system.

It should be noted that there are no sudden changes of channel section. A gradual transition from one section type to another is proposed and has been incorporated into the preliminary design of the channel relocation scheme.

7.3.2 Channel Widening

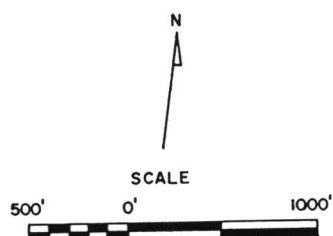
Typical cross-sections for the Channel Widening scheme (Figure III-14a,b and c) were derived using similar techniques as discussed for the Channel Relocation scheme. Since only one conveyance channel exists, the gabion erosion protection is provided along the entire length of the widened channel. Grouted gabion hard points are incorporated at both the upstream and downstream limits of the proposed channel improvements.

7.4 Estimated Costs

The refinement in the detail of the river relocation and river widening alternatives as a result of the preliminary design, as well as the integration of river works with slope stabilization, enables the production of more realistic and accurate cost estimates. Although detailed cost estimation will follow the final design of the selected alternative, a preliminary cost estimates for both the River Relocation and River Widening have been determined (Table III-6 and III-7). Unit costs are representative of costs incurred on similar projects in Brantford, inflated to 1987 dollars. Certain items in the preliminary estimates may be representative of aggregate costs associated with certain items. For instance, the "Grouted Rip-Rap" item reflects all costs related to that item, such as the cost of grout, rip-rap and placement costs. All estimates are in 1987 dollars.



Photo by SPARTAN AIR SERVICES LTD. May & June 1963



COLBORNE STREET SLOPE FAILURE



**Philips
Planning
Engineering
Limited**

PROJECT N^o
86105

FIGURE N^o

III-10

TABLE III-6
PRELIMINARY COST ESTIMATES
RIVER RELOCATION

Phase I - Channel Excavation and Protection

	Unit	Estimated	Unit	Amount
1.0 Clearing and Grubbing-Trees	Hectare	10	\$42,500.00	425,000
-Other	Hectare	5	\$ 8,900.00	44,500
2.0 Stripping and Stockpiling	m ³	40,000	\$ 4.20	168,000
Topsoil				
3.0 Supply and Place Topsoil	m ³	10,000	\$ 5.20	52,000
4.0 Channel Excavation	m ³	220,000	\$ 6.00	1,320,000
5.0 Earth Removal and Haulage				
5.1 Slope Grading	m ³	40,000	\$ 6.00	240,000
5.2 Levee Construction	m ³	40,000	\$ 6.50	260,000
5.3 Cofferdams	m ³	20,000	\$ 5.00	100,000
6.0 Rock Filled Gabion Baskets and Mats				
6.1 Baskets	m ³	2,500	\$ 180.00	450,000
6.2 Mats	m ³	8,000	\$ 210.00	1,680,000
7.0 Slurry Grout of Gabion	m ³	200	\$ 180.00	45,000
Baskets/Mats				
8.0 Supply & Install Filter	m ²	10,000	\$ 3.50	35,000
Fabric				
9.0 Supply & Install Toe	Each	24	\$ 200.00	4,800
Drains				
10.0 Random & Grouted Rip-rap				
10.1 Random Rip-Rap	m ³	7,000	\$ 45.00	315,000
10.2 Grouted Rip-Rap	m ³	1,000	\$ 50.00	50,000
11.0 Road and Driveway Restoration				
11.1 Granular 'A'	m ³	600	\$ 12.00	7,200
11.2 Granular 'B'	m ³	400	\$ 11.00	4,400
11.3 H.L. 3	Tonne	150	\$ 80.00	1,200
11.4 H.L. 5	Tonne	150	\$ 79.00	11,850
11.5 Calcium Chloride	Tonne	10	\$ 500.00	5,000
11.6 Water	1000L	1,000	\$ 5.00	5,000
11.7 Single Surface Treatment	m ²	2,500	\$ 2.50	6,250
12.0 Seed Mulch	m ²	20,000	\$ 0.80	16,000

TABLE III-6
PRELIMINARY COST ESTIMATES (continued)
RIVER RELOCATION

	Unit	Estimated	Unit	Amount
13.0 Nursery Sod Staked and Watered	m ²	2,500	\$ 1.80	4,500
14.0 Contingency Allowance	Allow			100,000
TOTAL PRELIMINARY ESTIMATE				\$ 5,361,000*

* Increase to \$5,811,000 for a single channel configuration.

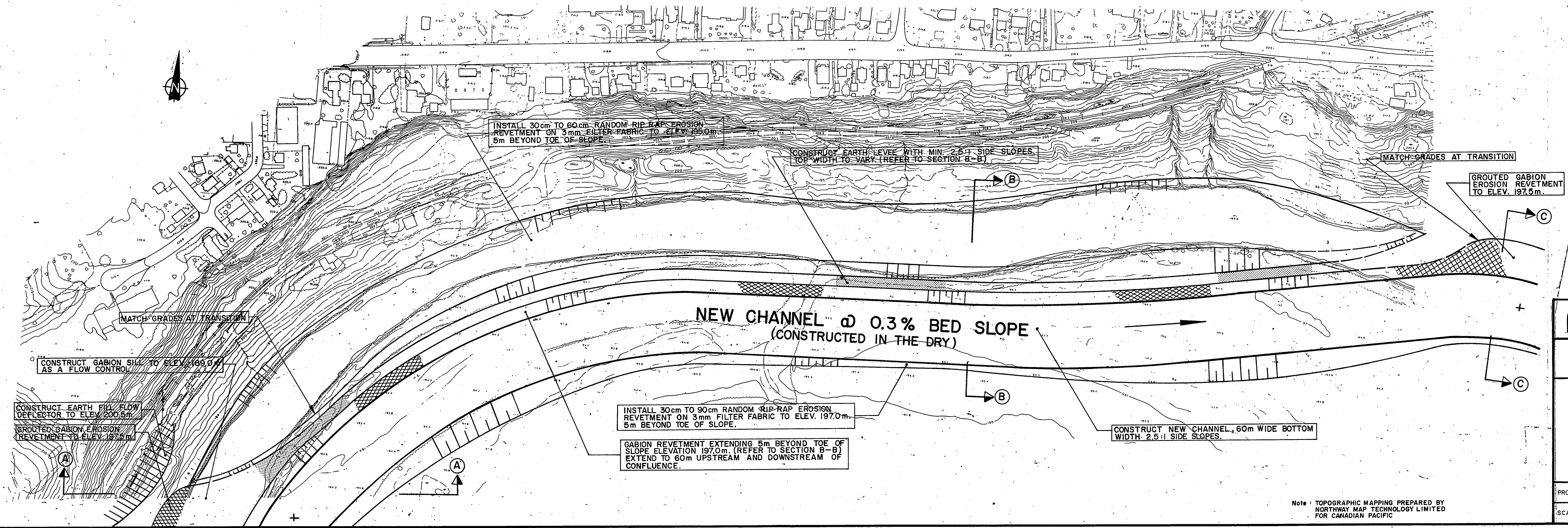
TABLE III-7
PRELIMINARY COST ESTIMATES
RIVER WIDENING

Phase I - Channel Excavation and Protection


	Unit	Estimated	Unit	Amount
1.0 Clearing and Grubbing-Trees	Hectare	3	\$42,500.00	127,500
-Other	Hectare	2	\$8,900.00	17,800
2.0 Stripping and Stockpiling	m ³	15,000	\$ 4.20	63,000
Topsoil				
3.0 Supply and Place Topsoil	m ³	5,000	\$ 5.20	26,000
4.0 Channel Excavation	m ³	120,000	\$ 6.00	720,000
5.0 Earth Removal and Haulage				
5.1 Slope Grading	m ³	40,000	\$ 6.00	240,000
5.2 Cofferdams	m ³	20,000	\$ 5.00	100,000
6.0 Rock Filled Gabion Baskets and Mats				
6.1 Baskets	m ³	2,500	\$ 180.00	450,000
6.2 Mats	m ³	8,000	\$ 210.00	1,680,000
7.0 Slurry Grout of Gabion	m ³	250	\$ 180.00	45,000
Baskets/Mats				
8.0 Supply & Install Filter	m ²	8,000	\$ 3.50	28,000
Fabric				
9.0 Supply & Install Toe	Each	24	\$ 200.00	4,800
Drains				
10.0 Random & Grouted Rip-rap				
10.1 Random Rip-Rap	m ³	1,000	\$ 45.00	45,000
10.2 Grouted Rip-Rap	m ³	1,000	\$ 50.00	50,000
11.0 Road and Driveway Restoration				
11.1 Granular 'A'	m ³	600	\$ 12.00	7,200
11.2 Granular 'B'	m ³	400	\$ 11.00	4,400
11.3 H.L. 3	Tonne	150	\$ 80.00	12,000
11.4 H.L. 5	Tonne	150	\$ 79.00	11,850
11.5 Calcium Chloride	Tonne	10	\$ 500.00	5,000
11.6 Water	1000L	1,000	\$ 5.00	5,000
11.7 Single Surface Treatment	m ²	2,500	\$ 2.50	6,250
12.0 Seed Mulch	m ²	15,000	\$ 0.80	12,000

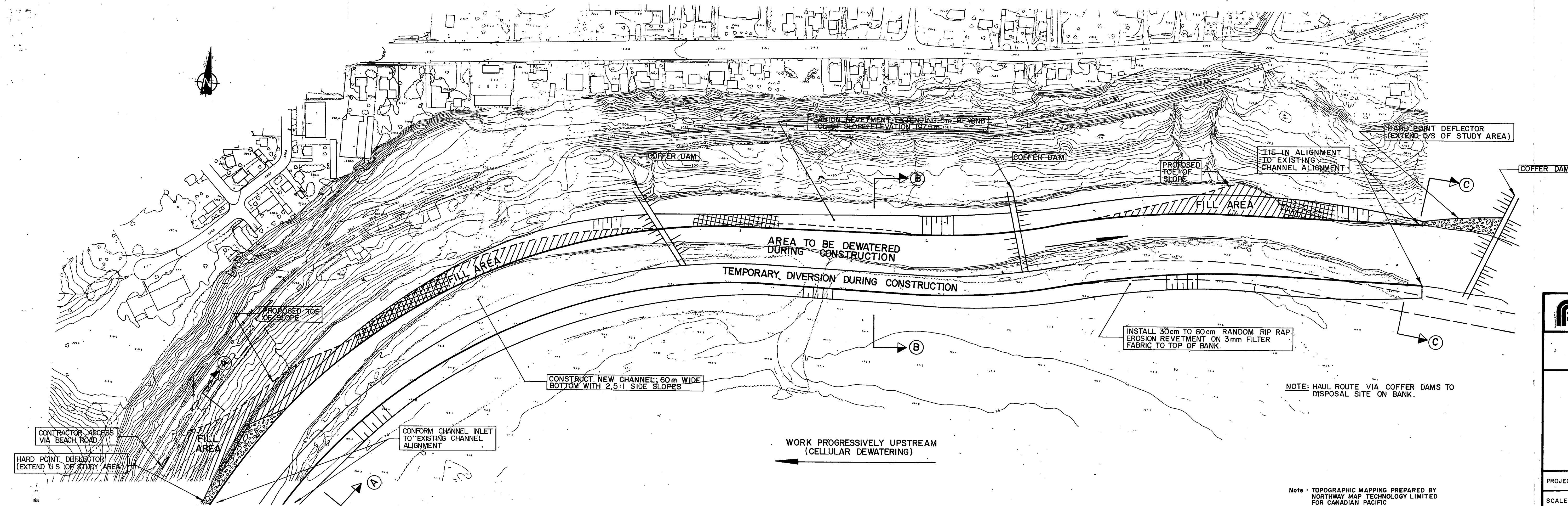
TABLE III-7
PRELIMINARY COST ESTIMATES (continued)
RIVER WIDENING

	Unit	Estimated	Unit	Amount
13.0 Nursery Sod Staked and Watered	m ²	1,500	\$ 1.80	2,700
14.0 Contingency Allowance	Allow			100,000
TOTAL PRELIMINARY ESTIMATE				\$ 3,458,500




Note : TOPOGRAPHIC MAPPING PREPARED BY
NORTHWAY MAP TECHNOLOGY LIMITED
FOR CANADIAN PACIFIC

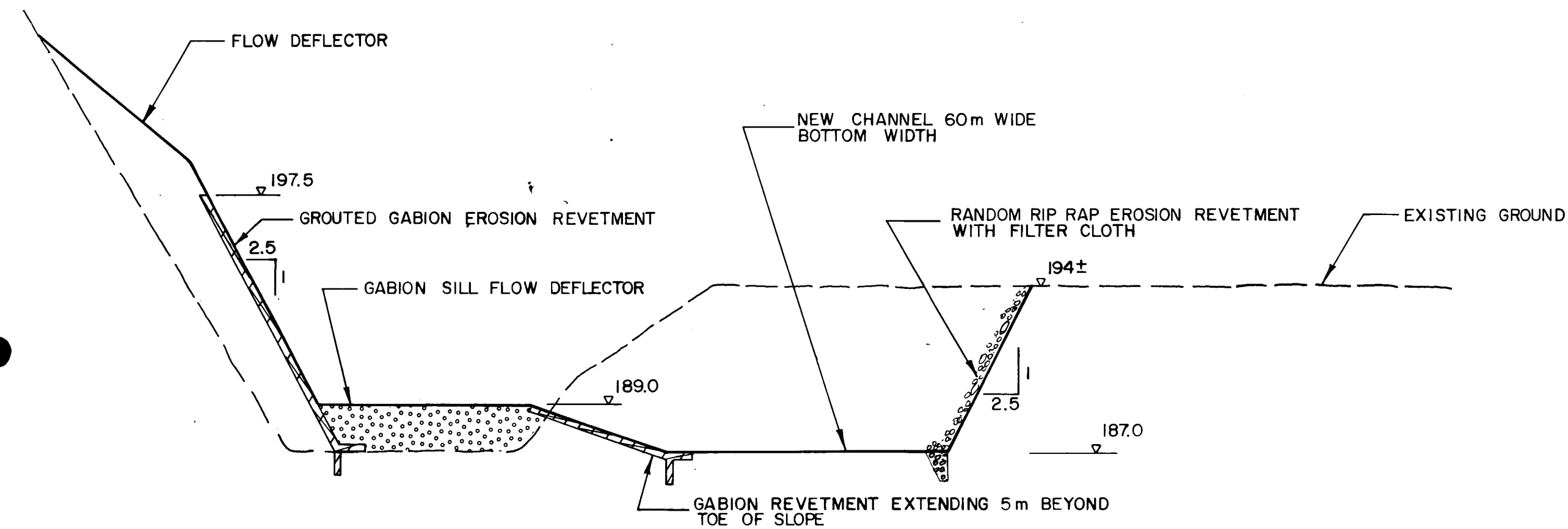
 Philips Planning Engineering Limited		
PRELIMINARY DESIGN RIVER RELOCATION SCHEME		
PROJECT No. 86105	DATE MAY, 1987	FIGURE III - 11
SCALE 1:2000	DRAWN	



NOTE: TOPOGRAPHIC MAPPING PREPARED BY NORTHWAY MAP TECHNOLOGY LIMITED FOR CANADIAN PACIFIC

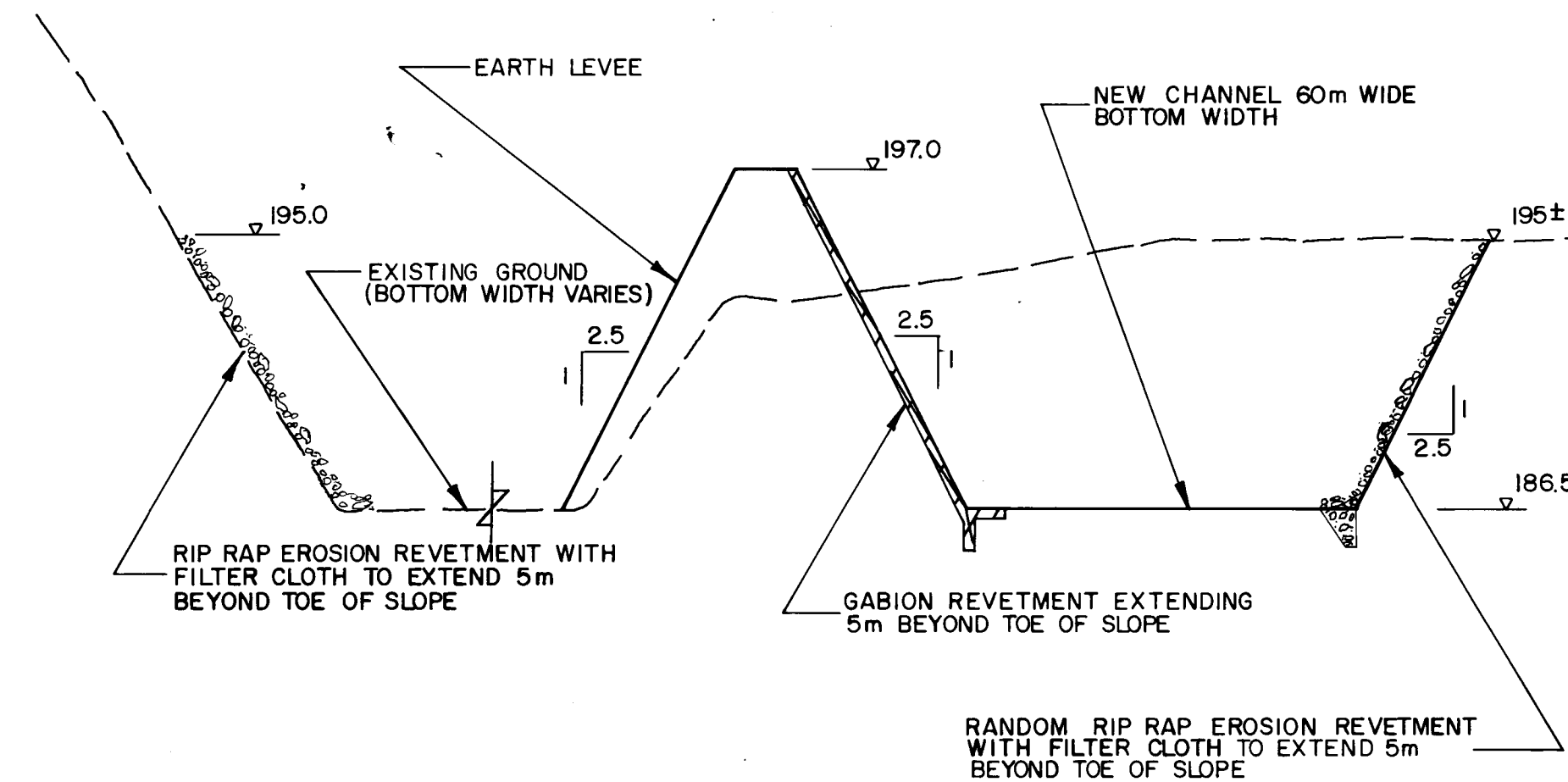
 Phillips Planning Engineering Limited		
<h2>PRELIMINARY DESIGN</h2> <h3>RIVER WIDENING SCHEME</h3>		
PROJECT No. 86105	DATE - MAY 1987	FIGURE III - 12
SCALE 1:2000	CHKD. C.T.M.	

13A



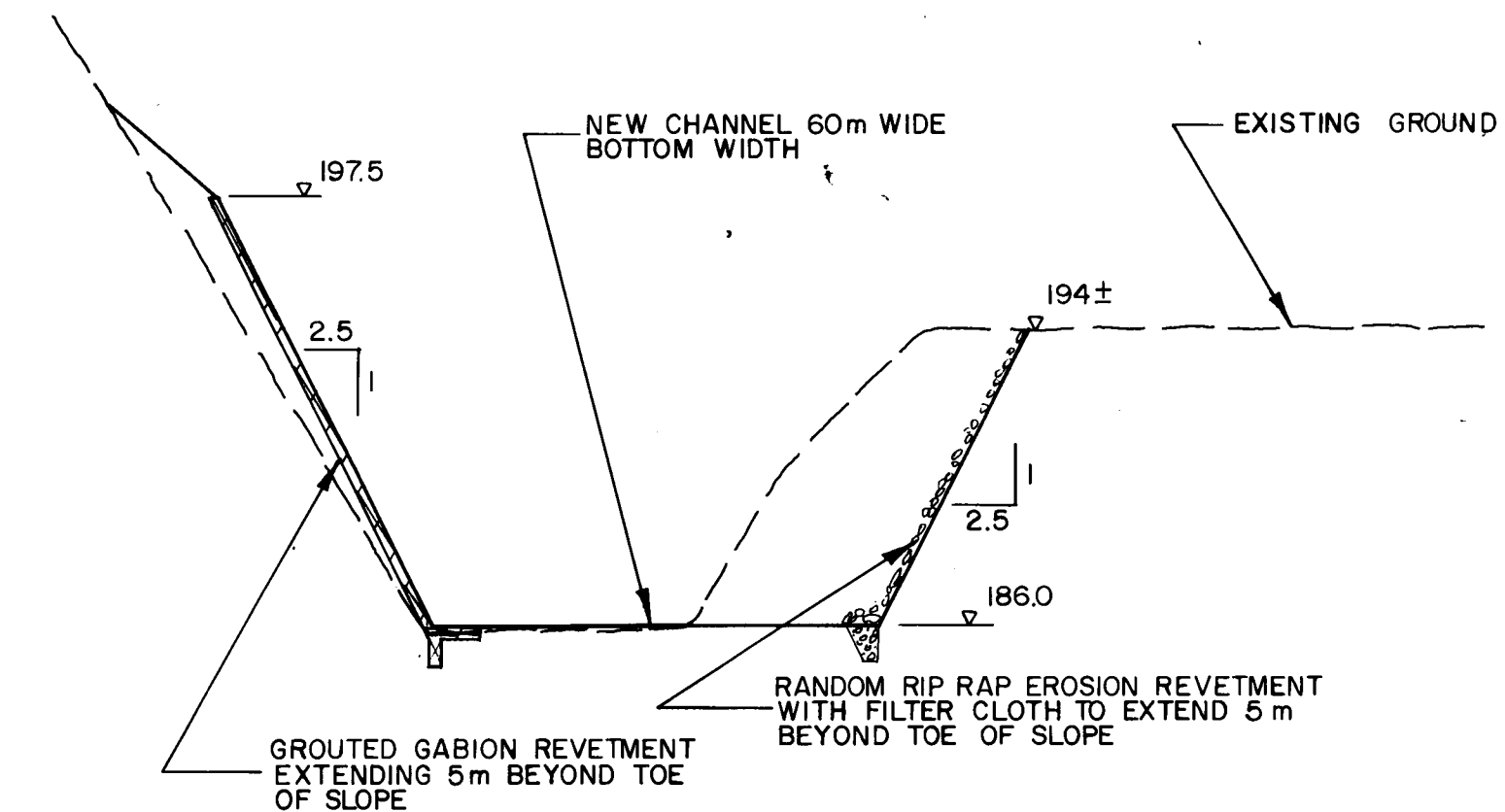
SECTION A-A

13B



SECTION B-B

13C



SECTION C-C

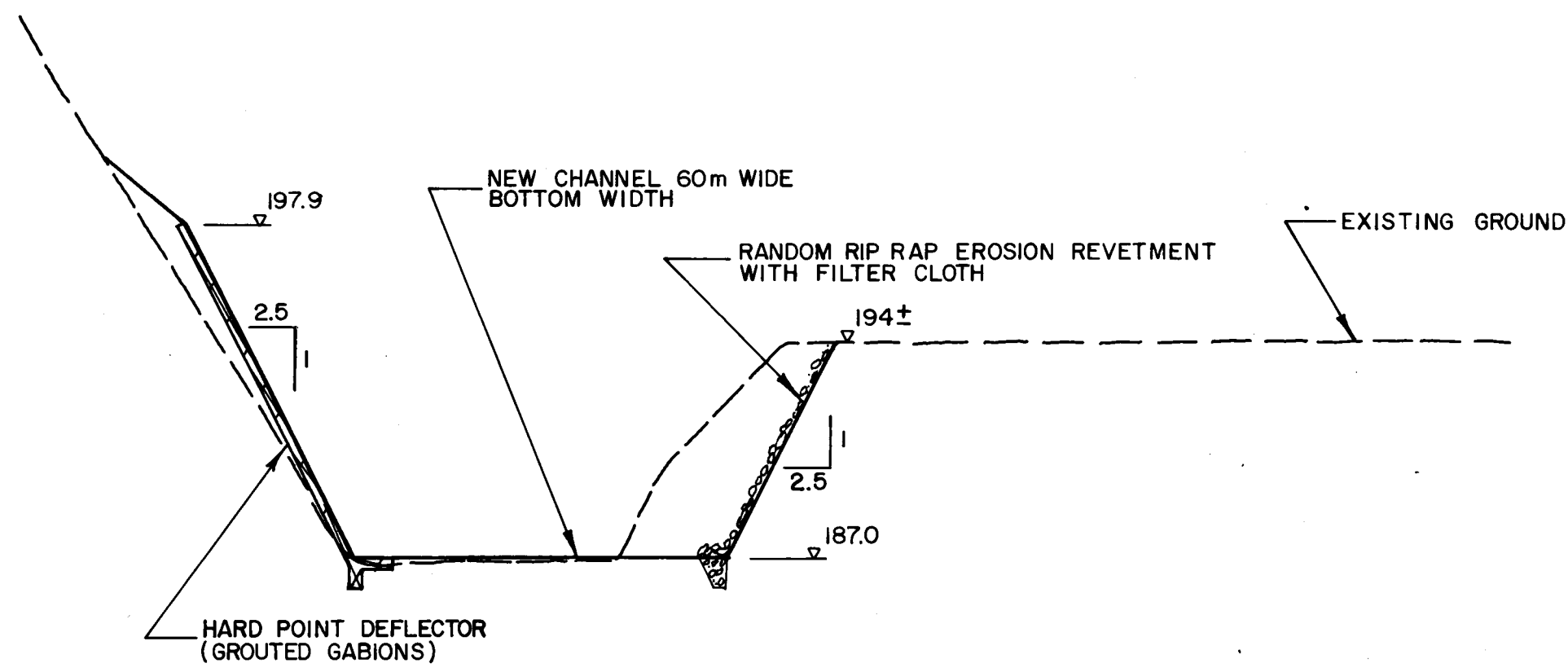
COLBORNE STREET SLOPE FAILURE

CHANNEL RELOCATION ALTERNATIVE
TYPICAL SECTIONS

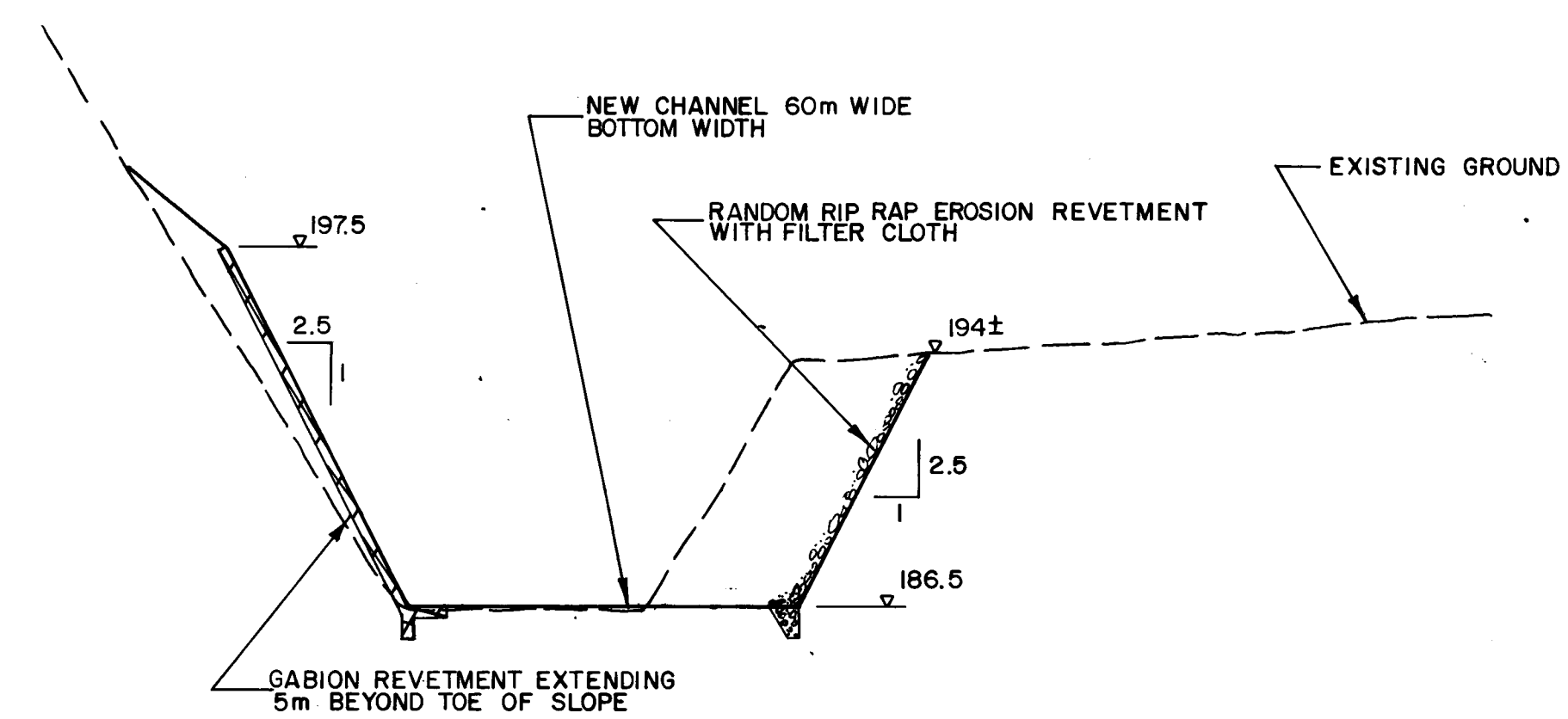
Philips
Engineering
Limited

SCALE: 1:1000 HOR.
1:200 VERT.

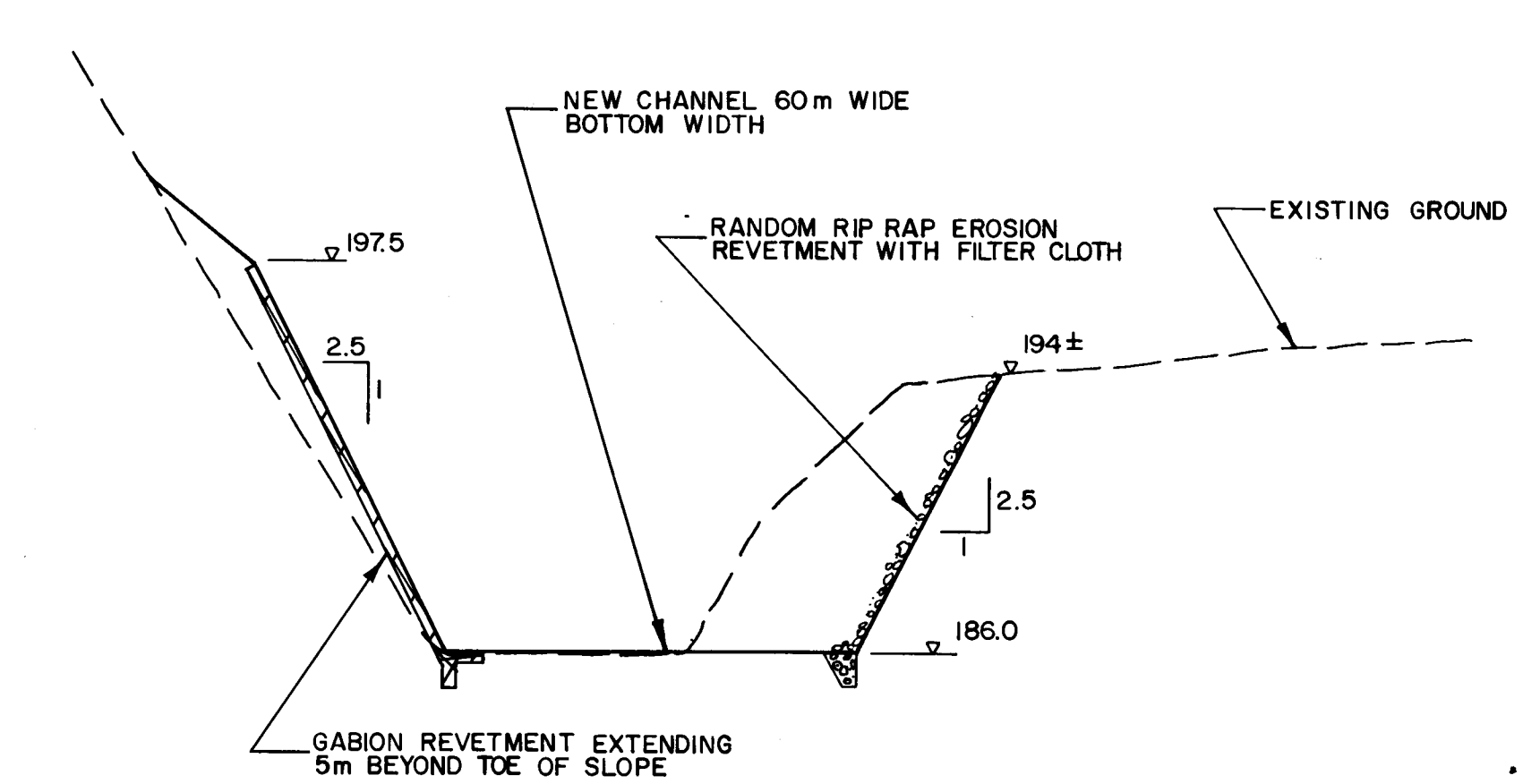
FIGURE: III-13




SECTION A-A'



SECTION B-B'



SECTION C-C'

COLBORNE STREET SLOPE FAILURE	
RIVER WIDENING ALTERNATIVE TYPICAL SECTIONS	
	SCALE: 1:1000 HOR. 1:200 VERT.
	FIGURE: III-14

8.0 SUMMARY

The slope failure in May of 1986 resulted in the deposition of slope materials in the Grand River. This material created a constriction in the river channel. A hydraulic assessment was undertaken to determine the impact of the channel constriction on upstream flood levels and flow velocities. The impact assessment was carried out for three scenarios:

- CASE 1) Pre-Slide Conditions
- CASE 2) Post-Slide Conditions
- CASE 3) Considering a Second Failure of
a magnitude similar to that of
May, 1986.

The third case subject to investigation considered the on-going marginal slope stability and the real possibility of further slope failures which might create an additional restriction to flows in the Grand River.

The impact assessment of the post-slide channel, concluded that the restriction has had an adverse impact on both upstream levels of flooding and river flow velocities, when compared with pre-slide conditions. Specifically, upstream flood levels were increased by between 0.03 and 0.10 metres (0.10 to 0.35 feet), while downstream flow velocities were increased by between 0.08 to 0.63 metres per second (0.25 to 2.00 feet per second). The results of the CASE #3 assessment indicated a more substantial impact, with upstream flood levels potentially increased by between 0.11 and 0.24 metres (0.36 to 0.80 feet) and downstream velocity increases of 0.47 to 1.15 metres per second (1.54 to 3.77 feet per second). Although a flood protection program is on-going in Brantford, these increased flood levels will further increase the costs of carrying out the required flood protection works by an estimated \$1.5 million (based on engineering estimates for flood control works already in place in Brantford) if no action is taken in the study area. The effects of increased downstream velocities are not as easily quantified, but are equally significant. The increased flow velocities will accelerate the erosion of the toe of the slope and since toe erosion has been identified as a contributor to slope instability, downstream slopes adjacent to the river will be potentially affected.

In order to mitigate the post-slide impacts, it is necessary to carry out improvements to the river channel to restore its conveyance characteristics to those of the pre-slide channel. In addition, to avoid the impacts associated with additional slides, the channel must be located away from the toe of the slope unless slope stability can be secured. The method used in river training is therefore contingent upon the manner used to secure the stability of the bank. The three (3) alternative methods suggested involve a Cut scheme, a Fill scheme and a combination of a Cut and Fill scheme. Only the Cut scheme will enable the existing river channel to be reinstated to its pre-slide state, since this scheme involves the removal of all failure debris from the river. On the other hand, the Fill and Cut/Fill alternatives involve additional filling at the toe of the slope and subsequent additional encroachment into the river. To deal effectively with each scenario, the following river training alternatives were formulated:

1. Channel Reinstatement (Cut only option)
2. Channel Widening (Fill and Cut/Fill options)
3. Channel Relocation (Fill and Cut/Fill options)
4. Oxbow Cutoff (applicable to all options)

The Oxbow Cutoff involves creating a diversion channel to completely eliminate river flows through the meander and against the toe of slope, thus eliminating toe erosion. The other alternatives require an erosion-resistant material along the channel's north bank to eliminate toe erosion.

Both a Channel Widening and the Channel Relocation were subsequently identified as preferred schemes for river training in conjunction with a Cut/Fill scheme, contingent upon whether or not a phased approach to construction is considered. A preliminary design, involving a channel alignment and cross section, has been derived for each of the two schemes. Alignments have been established based on an iterative assessment of hydraulic conditions to minimize impact at the upstream and downstream limits of the project. The preferred channel cross section incorporates a gabion anti-erosion revetment along the north bank of the new channel alignments. Gabions have been selected primarily due to their proven effectiveness against erosion, resistance to ice damage, hydraulic efficiency and cost-effectiveness. Rip-rap erosion protection

is proposed at other locations identified as erosion-prone. Hard point deflectors are shown along the north channel bank at the upstream and downstream ends of the alignments to provide an additional safeguard against erosion at points of greatest alignment curvature, where flow velocities are a maximum.

Preliminary design drawings and preliminary estimates of costs for both the channel widening and channel relocation schemes are presented in Section 7.0.

9.0 LIST OF REFERENCES

1. Grand River Conservation Authority, Terms of Reference for carrying out a Preliminary Engineering Study of the Colborne Street Failure, Brantford, Ontario, August 11, 1986, (Appendix I).
2. Refer to Appendix II; Colborne Street Slope Failure - Preliminary Engineering Report Golder Associates.
3. J. T. Hack, Studies on Longitudinal Stream Profiles in Virginia and Maryland, U.S. Geologic Survey, Prof. Paper. 294-B pages 45 to 97, 1957.
4. Regional Storm Hydrology - Grand River in Brantford, April, 1975, Philips Planning + Engineering Limited
5. Preliminary Engineering Report for the Brantford Flood Levees, Philips Planning + Engineering Limited, June 1975.

APPENDIX IV
TRANSPORTATION AND MUNICIPAL
SERVICE CONSIDERATIONS

PRELIMINARY ENGINEERING STUDY
GRAND RIVER VALLEY SLOPE FAILURE
COLBORNE STREET EAST,
BRANTFORD, ONTARIO

July 1987

86-1628

TABLE OF CONTENTS

	<u>Page</u>
1. INTRODUCTION	1
2. MAJOR CONSIDERATIONS	2
3. ALTERNATE REMEDIAL MEASURES	7
3.1 Schemes Considered	7
3.1.1 Schemes 2 and 5 - Relocation of Colborne Street East to the North ...	8
3.1.2 Schemes 3, 4 and 5 - Relocation/ Re-establishment of Canadian Pacific Railway Line	10
3.2 Summary of Alternative Schemes	11

TABLE OF FIGURES

ESTIMATED TOP OF SLOPE AND EROSION SETBACK	FIG. IV-1
RE-ALIGNMENT OF COLBORNE STREET EAST	FIG. IV-2
CROSS-SECTION LOCATIONS	FIG. IV-3
CROSS-SECTIONS FOR SCHEME 3 RECHANNEL THE RIVER AND STABILIZE SLOPE BY FILLING	
- SECTIONS 1 - 2	FIG. IV-4.1
- SECTIONS 3 - 4	FIG. IV-4.2
- SECTIONS 5 - 6	FIG. IV-4.3
- SECTIONS 7 - 8	FIG. IV-4.4
- SECTIONS 9 - 10	FIG. IV-4.5
- SECTIONS 11 - 12	FIG. IV-4.6
CROSS-SECTIONS FOR SCHEME 4 RECHANNEL THE RIVER AND STABILIZE THE SLOPE BY A COMBINATION OF CUTTING AND FILLING	
- SECTIONS 1 - 2	FIG. IV-5.1
- SECTIONS 3 - 4	FIG. IV-5.2
- SECTIONS 5 - 6	FIG. IV-5.3
- SECTIONS 7 - 8	FIG. IV-5.4
- SECTIONS 9 - 10	FIG. IV-5.5
- SECTIONS 11 - 12	FIG. IV-5.6
CROSS-SECTIONS FOR SCHEME 5 RE-ESTABLISH THE RIVER AND STABILIZE THE SLOPE BY CUTTING	
- SECTIONS 1 - 2	FIG. IV-6.1
- SECTIONS 3 - 4	FIG. IV-6.2
- SECTIONS 5 - 6	FIG. IV-6.3
- SECTIONS 7 - 8	FIG. IV-6.4
- SECTIONS 9 - 10	FIG. IV-6.5
- SECTIONS 11 - 12	FIG. IV-6.6

TRANSPORTATION AND MUNICIPAL CONSIDERATIONS

1. INTRODUCTION

On May 20, 1986, a major slope failure occurred in the river valley wall of the Grand River adjacent to Colborne Street East in the City of Brantford. The massive slope movement directly affected three residences on Beach Road which is located near the toe of the slope, the C.P. Rail tracks (formerly T.H.B.R.) which are located part way up the slope, two commercial establishments and a residence located at the top of the slope south of Colborne Street East. In addition, significant slope movement occurred for a significant distance east of the main failure area.

The C.P.R., as a result of this slope failure, has been forced to reroute the Nanticoke train via the C.N.R. Hagersville Subdivision to the C.N.R. Caso Subdivision to the T.H.B.R. Welland Subdivision. The C.P.R. estimates that the rerouting of this train will increase its annual operating costs by about \$270,000.

As a result of additional slope movements which have occurred since May 1986, additional residential and commercial properties, on the south side of Colborne Street East, are now impacted.

This study has been undertaken to review the previously outlined slope stabilization alternatives and to recommend a proposed solution which would take into consideration the required river works, municipal services and the transportation concerns associated with Colborne Street East and the C.P. Rail tracks.

This report will determine the impact that the following alternate schemes will have on the existing municipal services and the road and rail transportation facilities.

Scheme 1 Do Nothing

Scheme 2 Relocate Colborne Street East Without Any Slope Stabilization or River Channel Work

Scheme 3 Rechannel the River and Stabilize the Slope by Filling

Scheme 4 Rechannel the River and Stabilize the Slope by a Combination of Cutting and Filling

Scheme 5 Re-establish the River and Stabilize the Slope by Cutting

Scheme 6 Create an Oxbow Cut-off in Conjunction with any of the Above-Noted Slope Stabilization Methods.

2. MAJOR CONSIDERATIONS

From a transportation perspective an analysis of the six previously mentioned alternate schemes was undertaken. Our conclusions as to the impact that these alternate slope stabilization schemes have on the existing transportation system (Colborne Street East and Canadian Pacific Railway trackage) and the municipal services of water, sanitary sewer, storm sewer, hydro, gas, and Bell telephone may be summarized as follows:

Scheme 1 - DO NOTHING

This Scheme is the base assumption and forms the basis for the comparison of all other schemes. Although the historical records for this slope failure zone indicate that the top of slope may re-

gress northerly into Colborne Street East within 50 years and thus jeopardize the vehicular use of the street and the municipal services located within the right-of-way, we have assumed for study purposes that there will be no improvements undertaken in this scheme.

Scheme 2 - RELOCATE COLBORNE STREET EAST WITHOUT ANY
SLOPE STABILIZATION OR RIVER CHANNEL WORK

Realizing that the integrity of Colborne Street East is in jeopardy under the DO NOTHING alternative and the fact that City of Brantford's transportation system and municipal services system rely to a great extent on the continued uninterrupted use of this facility, it was decided to include in the analysis a scheme which would not solve the slope instability but would resolve the potential impact that this slope instability would have on Colborne Street East. It was therefore decided that this scheme should determine the options associated with relocating Colborne Street East.

Our investigation indicated that within the study area that there are only two basic options for relocating Colborne Street East.

The first is to reconstruct Colborne Street East in its present location at a lower grade so that it would not be influenced by future slope instability (about 50 years). This solution would require lowering Colborne Street East by about 4 metres and as a result of this grade change, all of the existing utilities within the right-of-way would also have to be relocated. This solution would also result in the entrances to the properties on the north side of Colborne Street East being regraded to slopes in excess of 10%.

The second option is to acquire the properties on the north side of Colborne Street East and to relocate the road and utilities to the north so that they would not be impacted by any future (50 years) slope instability.

After reviewing these two options it was decided that the best and safest solution would be to relocate Colborne Street East to the north as the lowering of the grade on Colborne Street East as suggested in the first alternative would have a significant impact on the municipal services and the properties on the north side of the street. The relocation of Colborne Street East to the north would also require the extension/reconstruction of the existing grade separation with the Canadian Pacific Railways.

Under this Scheme, no efforts would be made to reinstate the Canadian Pacific Railway tracks but the grade separation structure would be rebuilt with Colborne Street.

Scheme 3 - RECHANNEL THE RIVER AND STABILIZE THE SLOPE
BY FILLING

This Scheme, which would solve the slope instability problem by either widening or relocating the Grand River to the south and then adding fill between the north river bank and the existing top of slope, would not require any changes to Colborne Street East or to the utilities located within its right-of-way.

This fill option, which has a number of 12 metre wide horizontal benches, would permit the reconstruction of the Canadian Pacific Railway tracks within its present right-of-way on one of the 12 metre wide horizontal benches or steps.

Scheme 4 - RECHANNEL THE RIVER AND STABILIZE THE SLOPE
BY A COMBINATION OF CUTTING AND FILLING

The slope instability problem in this scheme would be resolved by either widening or relocating the Grand River to the south and then placing fill at the bottom of the slope and undertaking minor cuts at the top of the slope.

This Scheme, as in Scheme 3, would not require any changes to Colborne Street East or the utilities located within its right-of-way.

The 12 metre benches or steps located within this cut and fill section would permit the re-establishment of Canadian Pacific Railway tracks within its present right-of-way.

Scheme 5 - RE-ESTABLISH THE RIVER AND STABILIZE THE SLOPE
BY CUTTING

This approach to stabilizing the slope would require the re-establishment of the north bank of the Grand River to the location it occupied prior to the May 20, 1986 slope failure. From this location, the slope would be stabilized by cutting the slope to achieve a stable inclination. The resultant top of slope for this Scheme would extend into the Colborne Street East right-of-way

and thus require the relocation of the road and the utilities located within the right-of-way. Based on our review of the road relocation options in Scheme 2, we have assumed that this Scheme would result in relocating Colborne Street East and the existing utilities to the north.

As in Schemes 3 and 4, the Canadian Pacific Railway tracks may be re-established on one of the 12 metre wide benches or steps, however, because the entire slope is located farther north in this cut only slope stabilization solution, it is not possible to locate the railway tracks within the existing railway right-of-way. This northerly shift of the railway would result in a new railway grade separation being required for Colborne Street East as it would be impossible to meet the alignment and grade requirements for the existing grade separation structure.

Scheme 6 - CREATE AN OXBOW CUTOFF IN CONJUNCTION WITH ANY OF THE ABOVE-NOTED SLOPE STABILIZATION METHODS

In general the Oxbow Cut-off involves the construction of a new river channel that would divert the Grand River flow away from the slope failure area. However, this river diversion only removes the toe of slope erosion problem and does not solve the slope instability problem.

Therefore the Oxbow Cut-off solution, if it is to solve the slope stability problem, must be used in conjunction with the previously mentioned stability solutions of fill only, cut and fill or cut only.

3. ALTERNATIVE REMEDIAL MEASURES

3.1 Schemes Considered

As mentioned in the previous section, 6 alternate schemes were reviewed and analysed.

From a transportation and municipal services perspective (road and utilities) only Scheme 2, which does nothing but relocate Colborne Road East and Scheme 5 which stabilizes the slope by cutting into the existing top of slope, requires the relocation of Colborne Street East and the existing utilities. None of the other schemes require the relocation of Colborne Street East or the existing utilities, except for the storm sewer outfall.

If the slope is not stablized, the storm sewer outlet should be relocated outside the area of instability and if the slope is stabilized, it may be prudent to investigate alternate storm sewer outlet opportunities.

It has been determined from discussion with Golder Associates that although the top of slopes for these two schemes is similar, the engineered setback requirement for Colborne Street East for Scheme 2 is greater than for scheme 5 as the slope instability and river bank erosion are not corrected in the do nothing alternative (Scheme 2).

From a railway operation perspective schemes 3, 4 and 5 all permit the re-establishment of the Canadian Pacific Railway tracks, however Scheme 5, which locates the railway to the north, would require the replacement of the existing rail/road grade separation

on Colborne Street East and may require the replacement of the rail to rail grade separation which is located just east of the study area.

The remainder of this section outlines in more detail the concepts for:

- o the relocation of Colborne Street East and the utilities located within the road allowance and
- o the re-establishment/relocation of the Canadian Pacific Railway tracks.

3.1.1 Schemes 2 and 5 - RELOCATION OF COLBORNE STREET EAST TO THE NORTH

From plans provided by Golder Associates, a top of slope for the cut scheme (5) has been determined based on the re-establishment of the north river bank to its prior May 20, 1986 location (see Figure II-1). Based on historical records and an anticipated slope failure gradient, it is estimated that the top of slope for scheme 2, 50 years from now, will very closely approximate the top of slope location determined for the cut only slope stabilization scheme. However, since the slope has not been stabilized in Scheme 2, an engineered setback line has been developed which allows for future erosion.

Therefore, the engineering setback requirement of 26 and 6 metres from the top of slope will be considered to be the southerly limits of any future road right-of-way requirements for schemes 2 and 5 respectively.

For preliminary planning purposes, it has been assumed that a 28 metre right-of-way will be required to permit the development of an 18 metre wide urban four lane section with a centre left turn lane.

As illustrated in Figure II-2 this re-alignment of Colborne Street East will commence at a location about 550 metres west of Johnson Road to a point about 750 metres east of Johnson Road, a total distance of 1300 metres and will require the widening of the existing structure over the Canadian Pacific Railway to the north-east.

This shift in alignment to the north will necessitate the acquisition of the majority of properties on the northside of Colborne Street East. (The property acquisition component is discussed in detail in Volume II, Appendix VI).

Based on the preliminary construction cost table, it is estimated that the relocation costs will be:

Preliminary Construction Cost Estimates

o	Relocate and construct Colborne Street East	\$ 2,650,000
o	Replace Colborne Street East Structure over the C.P.R.	910,000
o	Relocate Utilities	910,000
o	Engineering and Contingencies	<u>530,000</u>
	Total	\$ 5,000,000

In addition to the road construction work a new storm sewer outlet will be required. It is estimated that this new storm sewer outlet will cost about \$165,000.

In total the road and utility relocation costs, associated with schemes 2 and 5, are estimated to be \$5,165,000.

3.1.2 Schemes 3, 4 and 5 - RELOCATION/RE-ESTABLISHMENT OF CANADIAN PACIFIC RAILWAY LINE

To determine the opportunities for re-establishing the railway, a series of 12 cross-sections have been developed for each slope stabilization scheme. The locations of these cross-sections are illustrated in Figure II-3 with the actual sections being illustrated in Figures II-4 (Scheme 3), II-5 (Scheme 4) and II-6 (Scheme 5).

These cross-sections show the post May 20, 1986 ground surface and the final recommended stabilized slope section for fill, cut and fill and cut only.

For the purpose of this study we have assumed that the Canadian Pacific Railway track would be re-established on a uniform grade of 0.7% between the existing tracks at the west limits of our study area and the tracks at the southwest end of the railway underpass structure at Colborne Street West, a distance of 1,080 metres.

Based on these sections, we have determined that for the fill and cut and fill schemes (3 and 4) it is possible to re-establish the rail facilities on a 12 metre wide bench within the railways existing right-of-way at an estimated cost of \$550,000 for ballast, ties and rails.

However, the cut only scheme (5) would not permit the railway to be re-established within its existing right-of-way if the existing rail gradient is to be maintained. From our cut only sections 3.1.2-5, we have determined that the railway line would have to be relocated approximately 30 metres to the north. This northward shift of the alignment would require the construction of a new road/rail grade separation structure at Colborne Street East and may require a new rail to rail grade separation structure at the Canadian National Railway line. The need for this structure has not been confirmed as it is outside our study area.

The estimated railway costs for the cut only scheme are \$550,000 for the ballast, ties and rails (the construction of a new railway grade separation for Colborne Street East is included in the road costs). It should be noted that these cost estimates do not include an allowance for any property acquisition.

3.2 SUMMARY OF ALTERNATIVE SCHEMES

In conclusion the impact that the alternate slope stabilizing schemes have on the road and rail transportation facilities and the existing municipal utility systems may be summarized as follows:

Scheme 1 - Do Nothing

This do nothing scheme does not solve the existing problems associated with the damaged rail facilities or storm sewer outlet and assumes that the municipality would undertake, in the future, any

work that is required to protect the integrity of the utilities and road facilities located within the Colborne Street East right-of-way.

Estimated road, rail and utility costs NIL

Scheme 2 - Do Nothing But Relocate Colborne Street East

This scheme does not solve the problems associated with the rail facilities, but does safeguard Colborne Street East and the utility system by relocating the road and utility facilities to the north.

Estimated road and utility relocation Costs \$ 5,000,000

Scheme 3 - Fill Only

In this scheme, the integrity of the existing road facility and utility system located within the Colborne Street East right-of-way are safeguarded by the stabilization of the slope. This stabilized slope would also permit the rail facilities to be re-established in its existing right-of-way.

Estimated cost to re-establish rail facilities .. \$ 550,000

Scheme 4 - Cut and Fill

In this scheme, the integrity of the existing road facility and utility system is safeguarded by the stabilization of the slope. The configuration of this stabilized slope would permit the rail facilities to be re-established within its existing right-of-way.

Estimated cost to re-establish rail facilities ... \$ 550,000

Scheme 5 - Cut Only

This cut only scheme would require the road facility and utility system to be relocated to the north and for the rail facilities to be relocated to the north and a new grade separation with Colborne Street East to be constructed.

Estimated cost to relocate the road, rail and Utilities	\$ 550,000
--	------------

Scheme 6 - Oxbow Cut-off

To safeguard the integrity of the road, rail and utility facilities, this river diversion scheme would necessitate the implementation of either Scheme 3, 4 or 5.

5.2 Comparison of Schemes

5.2.5 Colborne Street East and Municipal Services

Except for the reinstatement/reconstruction of the storm sewer outfall which is required for any scheme that is going to stabilize the slope, the relocation of Colborne Street East and the utilities that are located within the road allowance, are required for schemes 2 and 5.

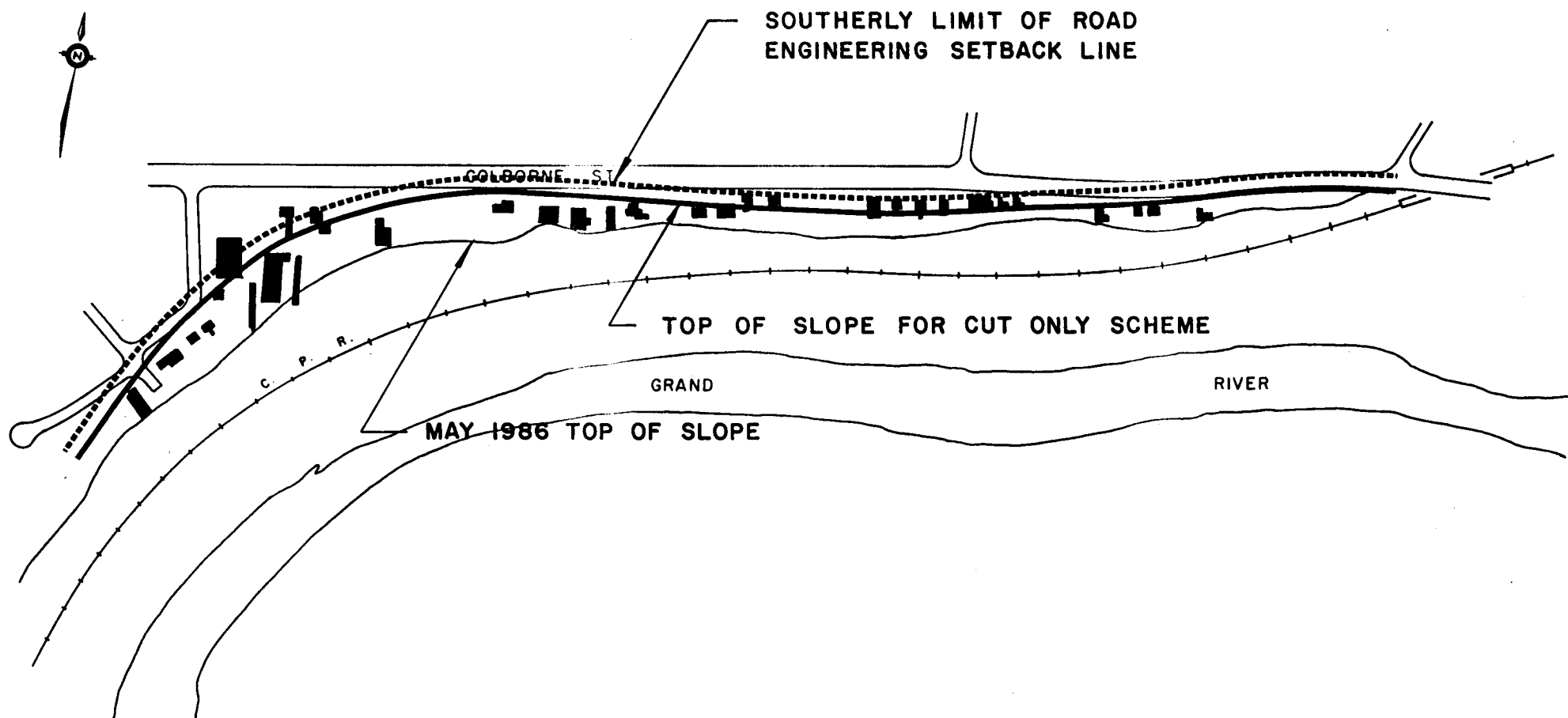
The relocation concept developed for preliminary planning purposes requires that 1,300 metres of Colborne Street be relocated about 15 metres to the north along with the utilities located within the right-of-way. This relocation concept would also require the extension or reconstruction of the existing grade separation with the Canadian Pacific Railway.

5.2.6 Canadian Pacific Railway

For the purpose of this study we have assumed that the Canadian Pacific Railway track would be re-established on a uniform grade of 0.7% between the existing tracks at the west limits of our study area and the tracks at the southwest end of the railway underpass structure at Colborne Street West, a distance of 1,080 metres.

Based on these sections, we have determined that for the fill and cut and fill schemes (3 and 4) it is possible to re-establish the rail facilities on a 12 metre wide bench within the railways existing right-of-way.

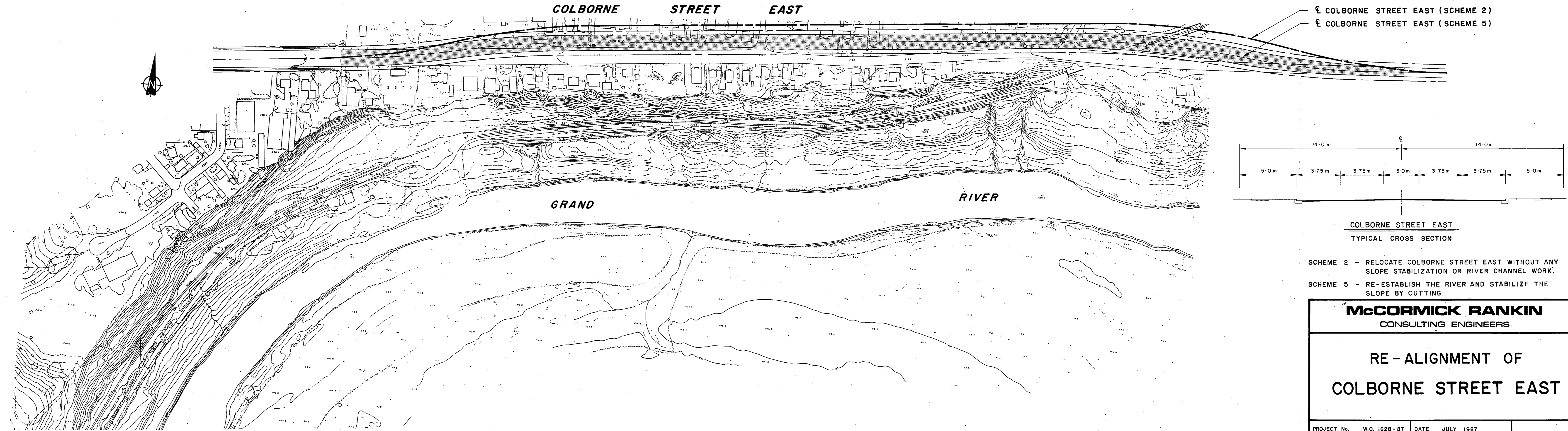
However, the cut only scheme (5) would not permit the railway to be re-established within its existing right-of-way if the existing rail gradient is to be maintained. From our analysis, we have determined that the railway line would have to be relocated approximately 30 metres to the north. This northward shift of the alignment would require the construction of a new road/rail grade separation structure at Colborne Street East and may require a new rail to rail grade separation structure at the Canadian National Railway line. The need for this structure has not been confirmed as it is outside our study area.



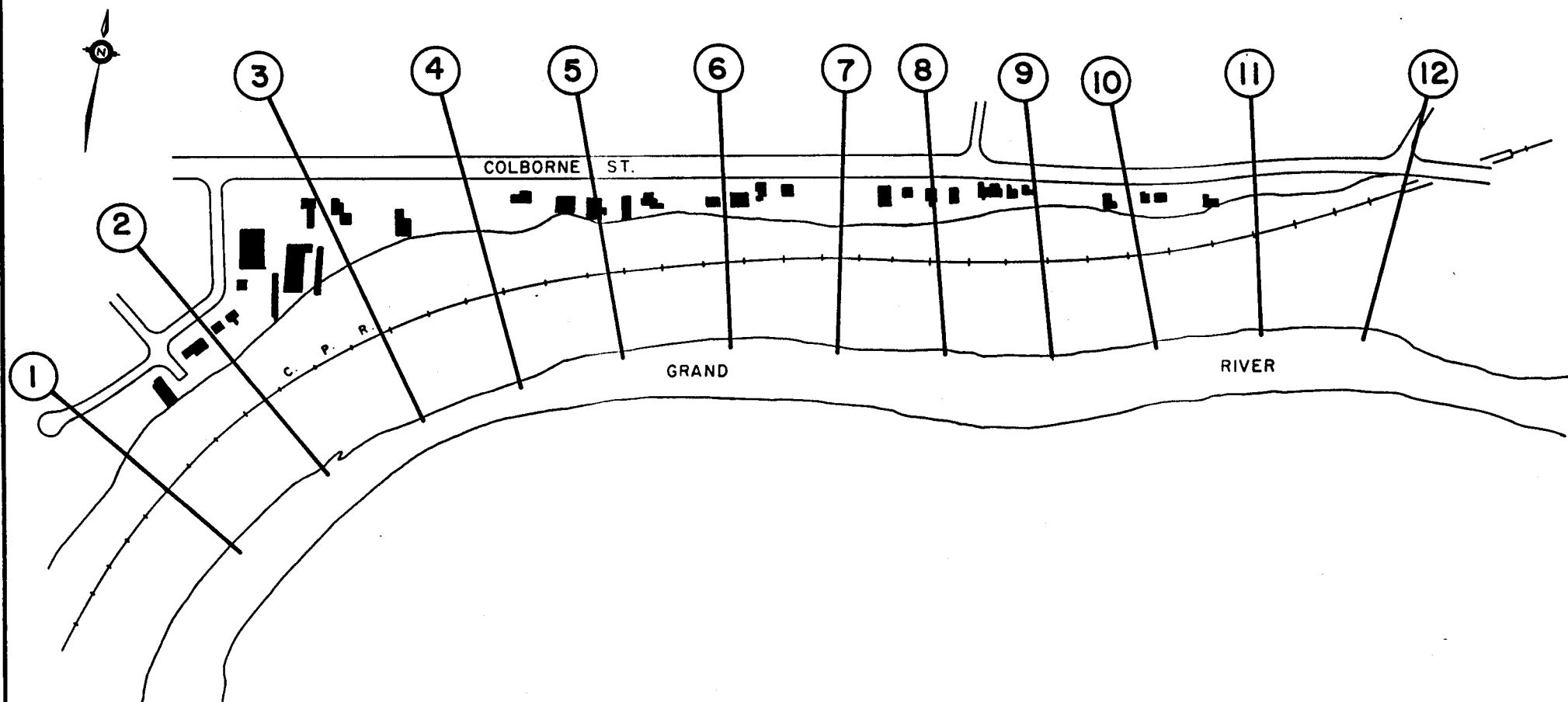
MCCORMICK RANKIN
CONSULTING ENGINEERS

ESTIMATED TOP OF SLOPE
AND
ENGINEERING SETBACK LINE
CUT ONLY SCHEME

FIGURE IV-1



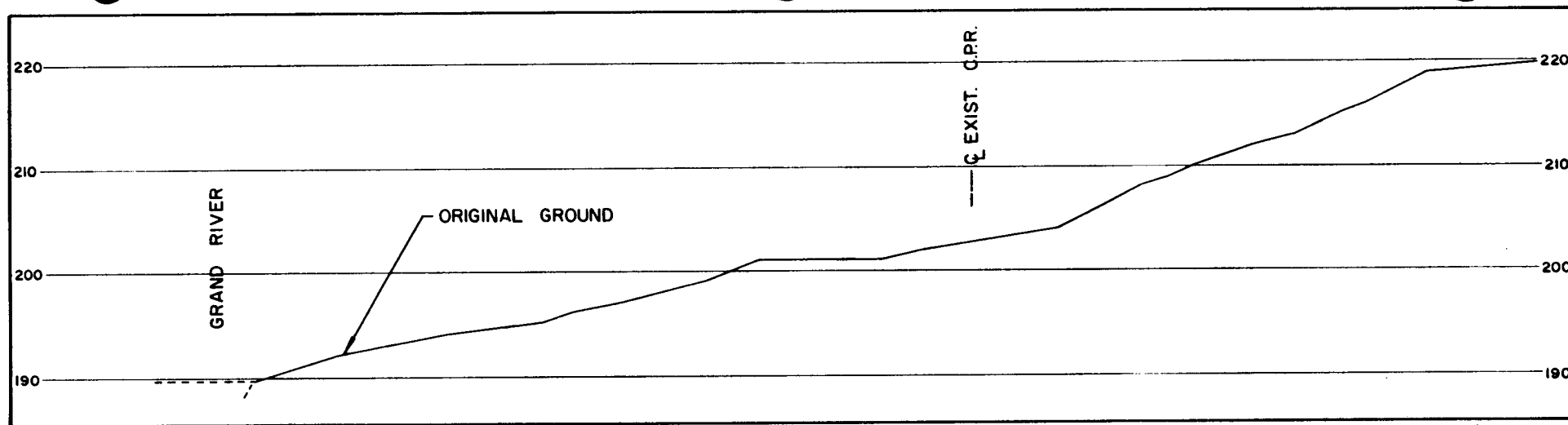
Note: TOPOGRAPHIC MAPPING PREPARED BY
NORTHWAY MAP TECHNOLOGY LIMITED
FOR CANADIAN PACIFIC



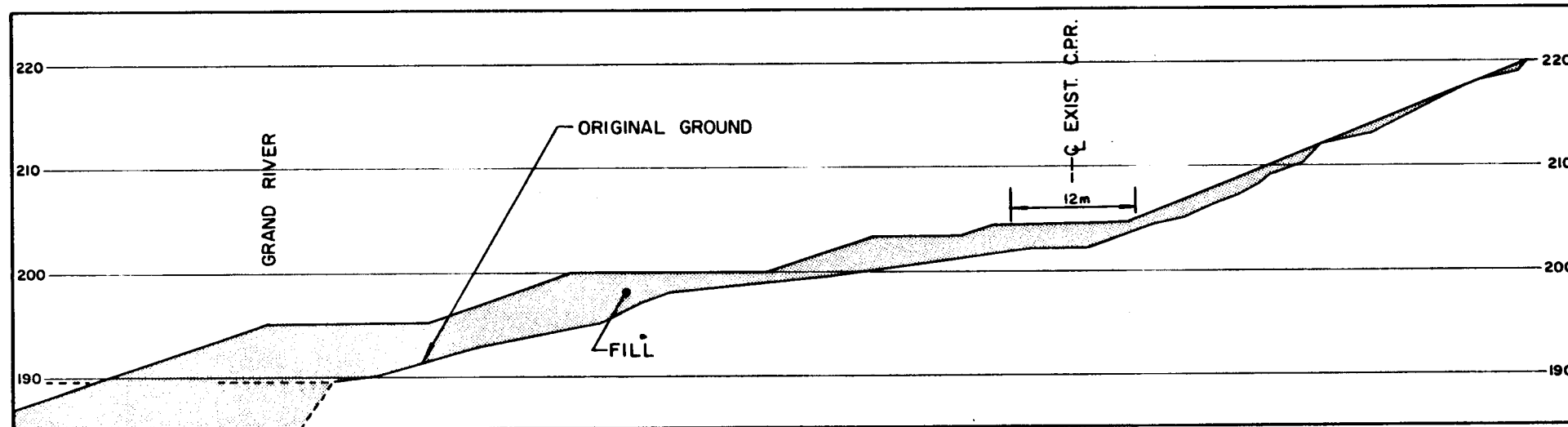
MCCORMICK RANKIN
CONSULTING ENGINEERS

CROSS SECTION LOCATIONS

FIGURE IV-3



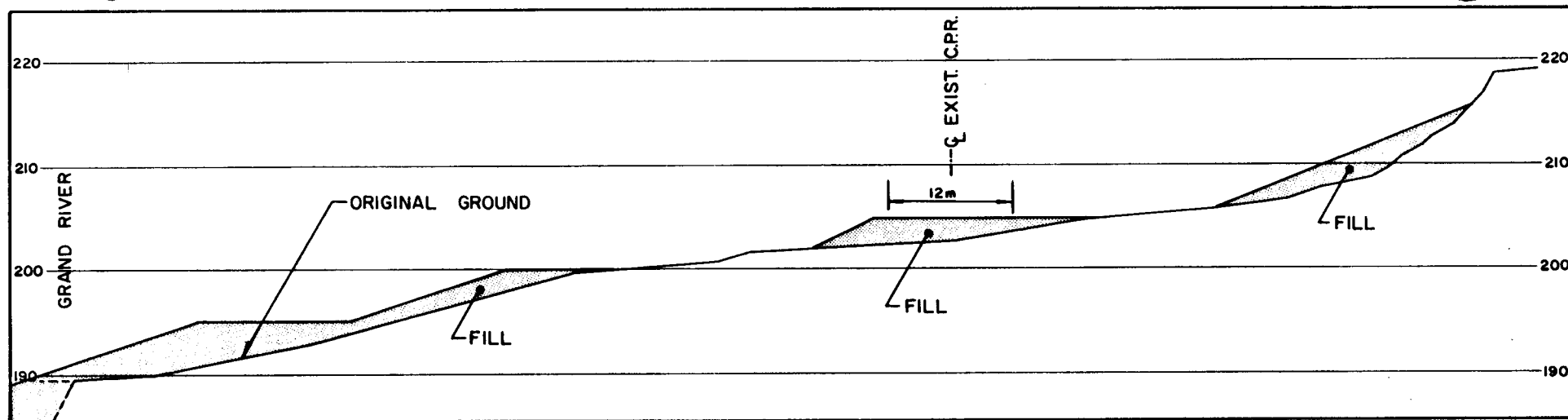
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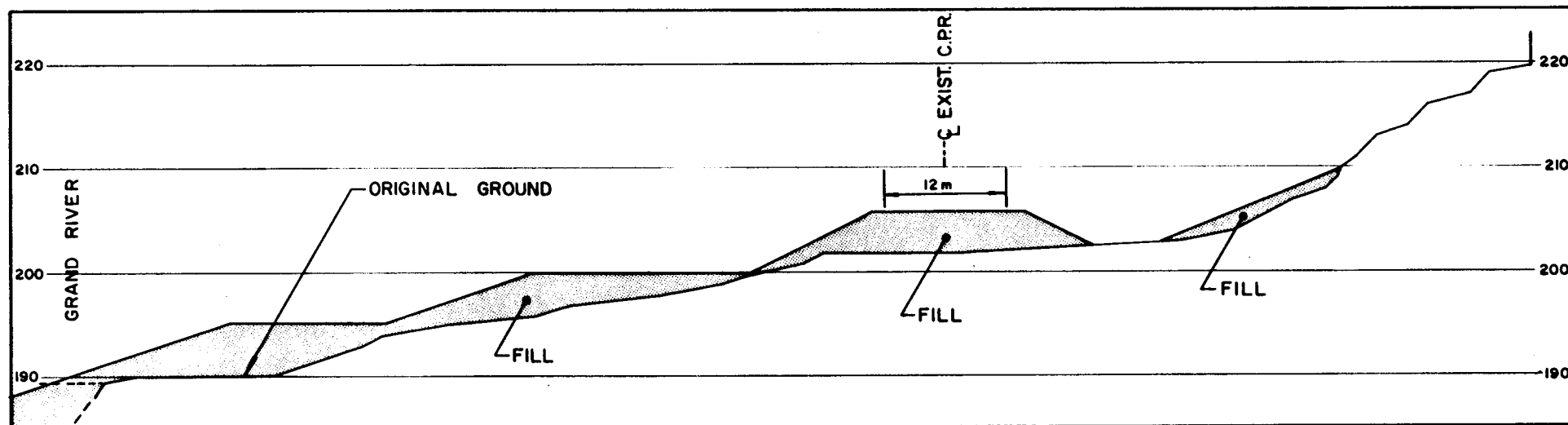
CROSS SECTION 2

CROSS SECTIONS FOR SCHEME 3
RECHANNEL THE RIVER AND STABILIZE SLOPE BY FILLING

FIGURE IV-4.1



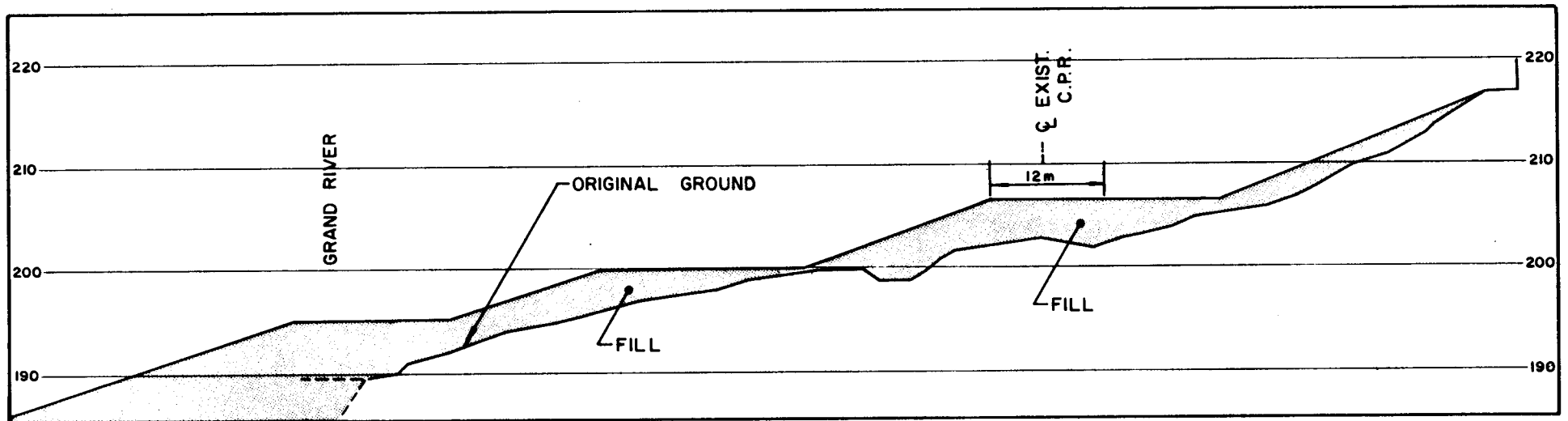
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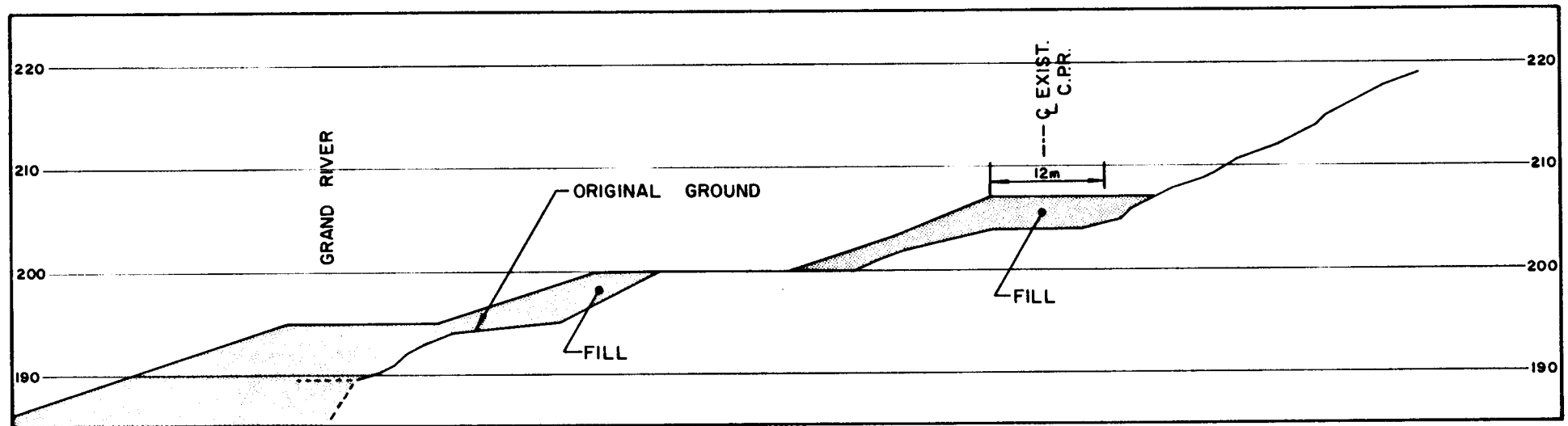
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CROSS SECTIONS FOR SCHEME 3
 RECHANNEL THE RIVER AND STABILIZE SLOPE BY FILLING

FIGURE IV - 4.2

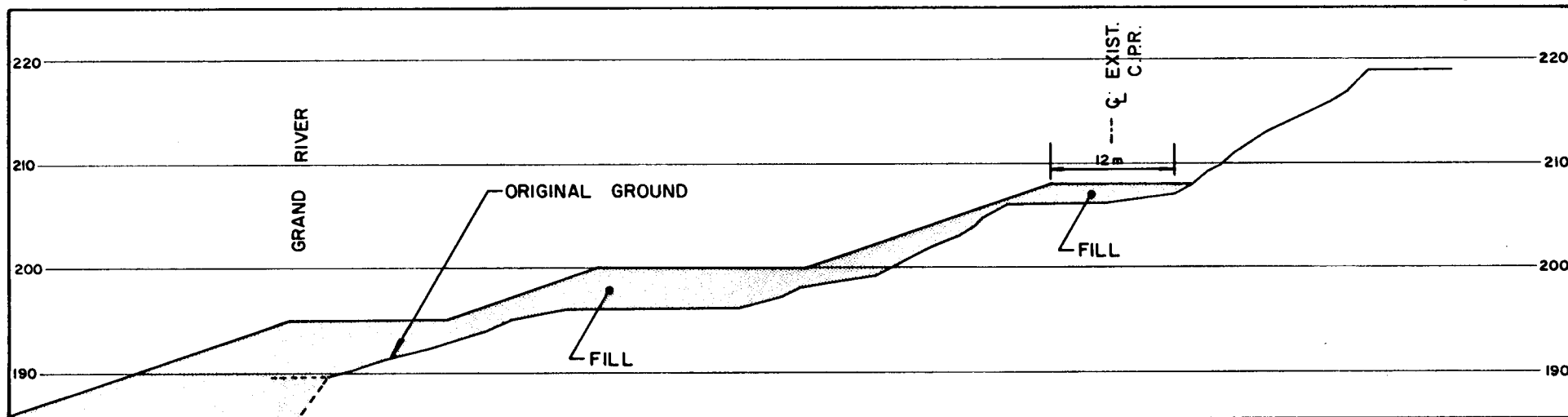


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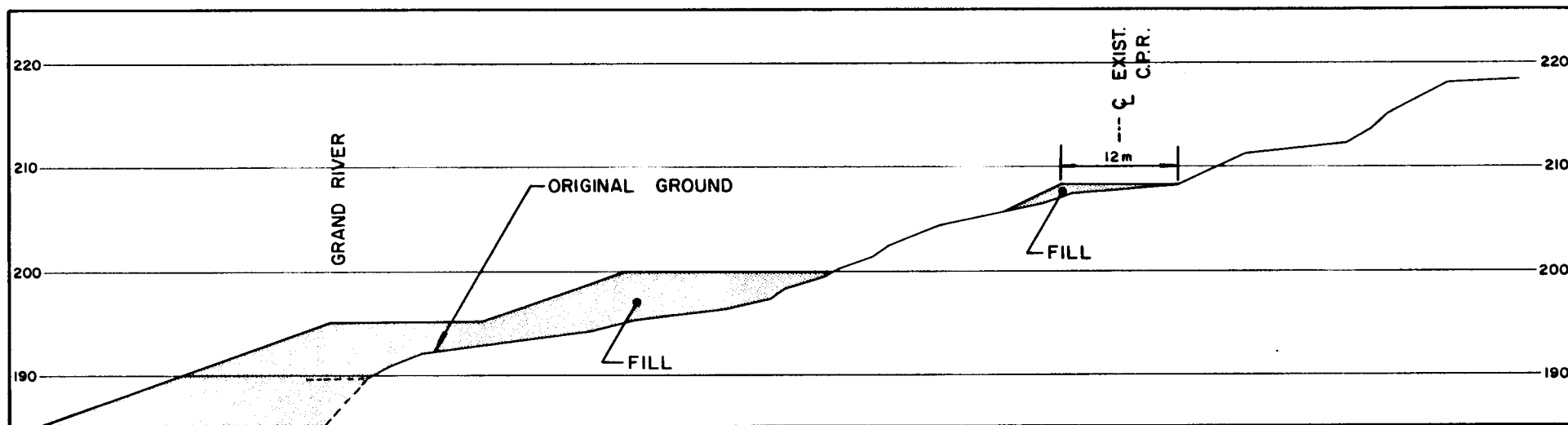


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CROSS SECTIONS FOR SCHEME 3
 RECHANNEL THE RIVER AND STABILIZE SLOPE BY FILLING



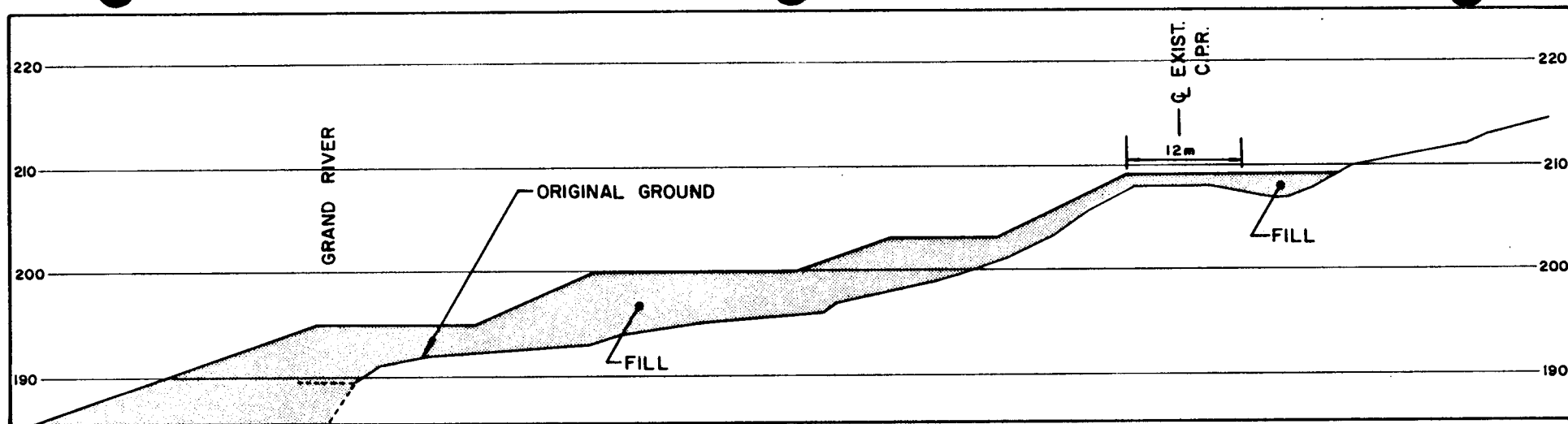
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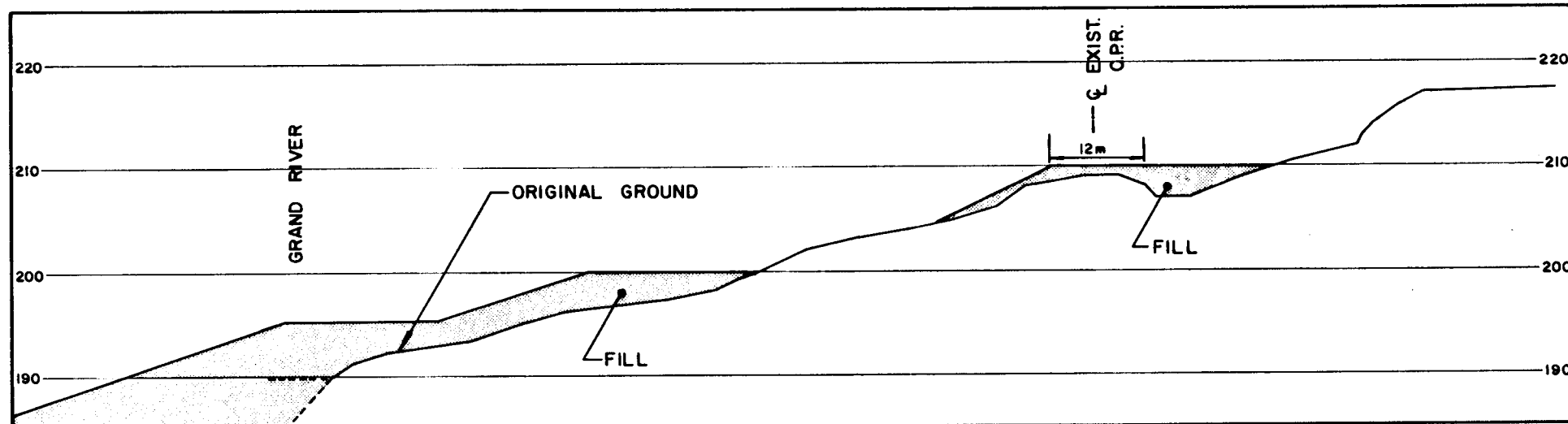
CROSS SECTION 8

CROSS SECTIONS FOR SCHEME 3
RECHANNEL THE RIVER AND STABILIZE SLOPE BY FILLING

FIGURE IV- 4.4



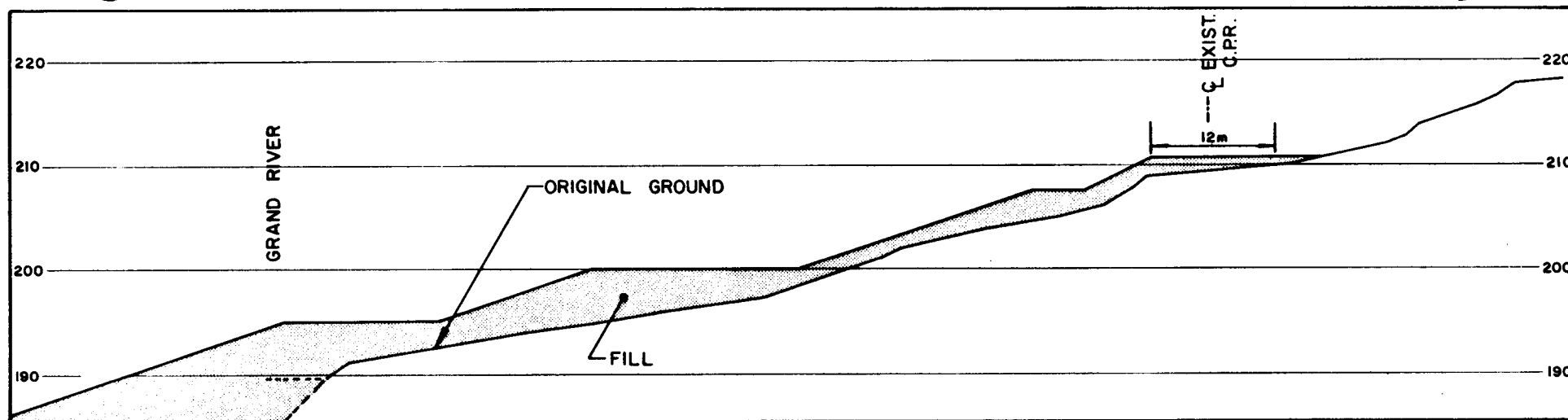
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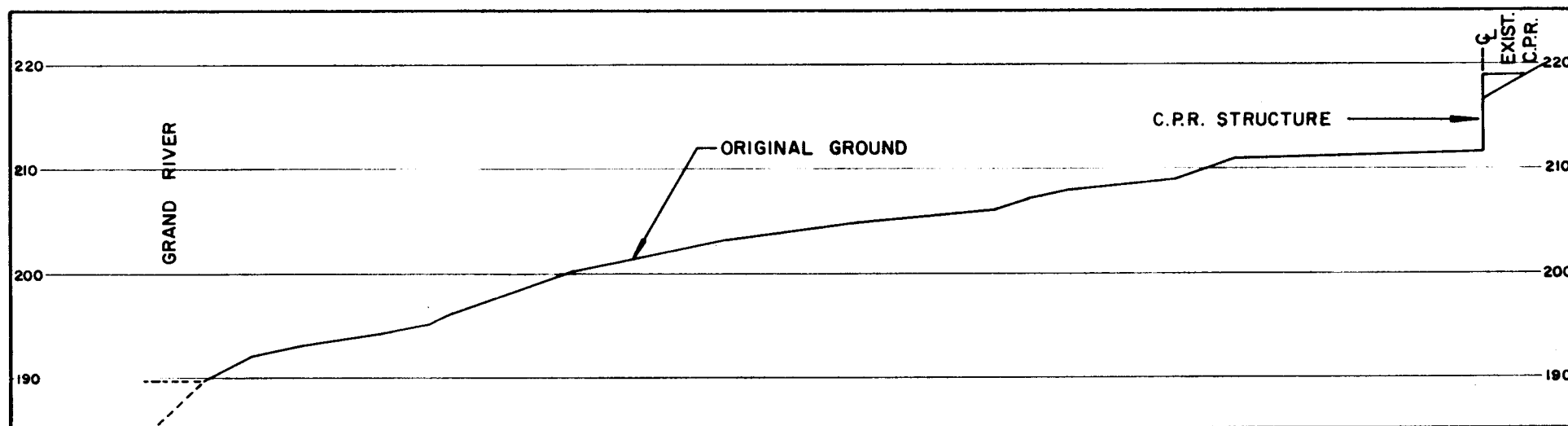
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CROSS SECTIONS FOR SCHEME 3
RECHANNEL THE RIVER AND STABILIZE SLOPE BY FILLING

FIGURE IV - 4.5



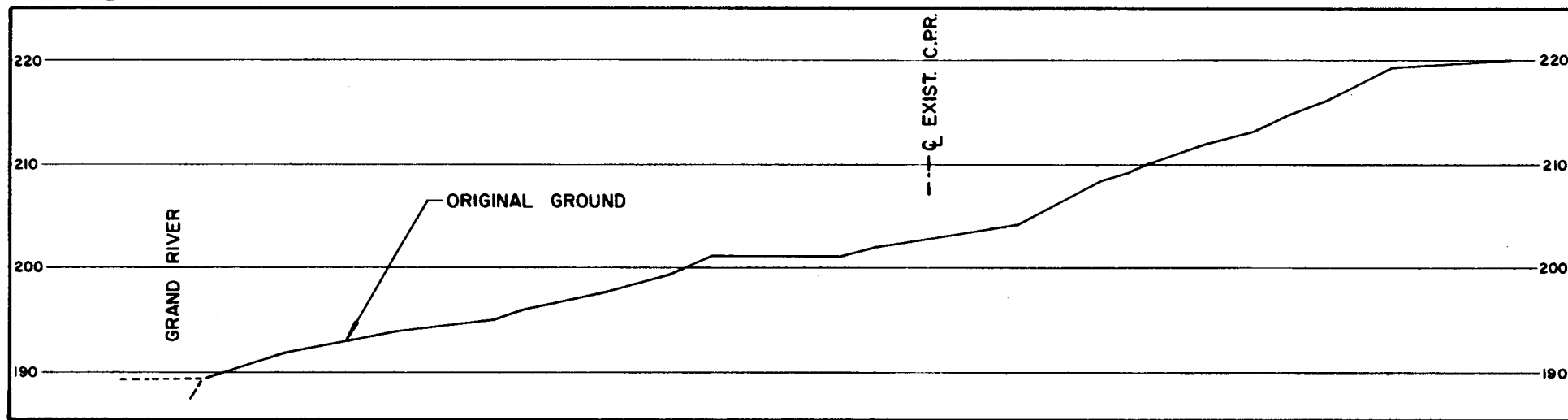
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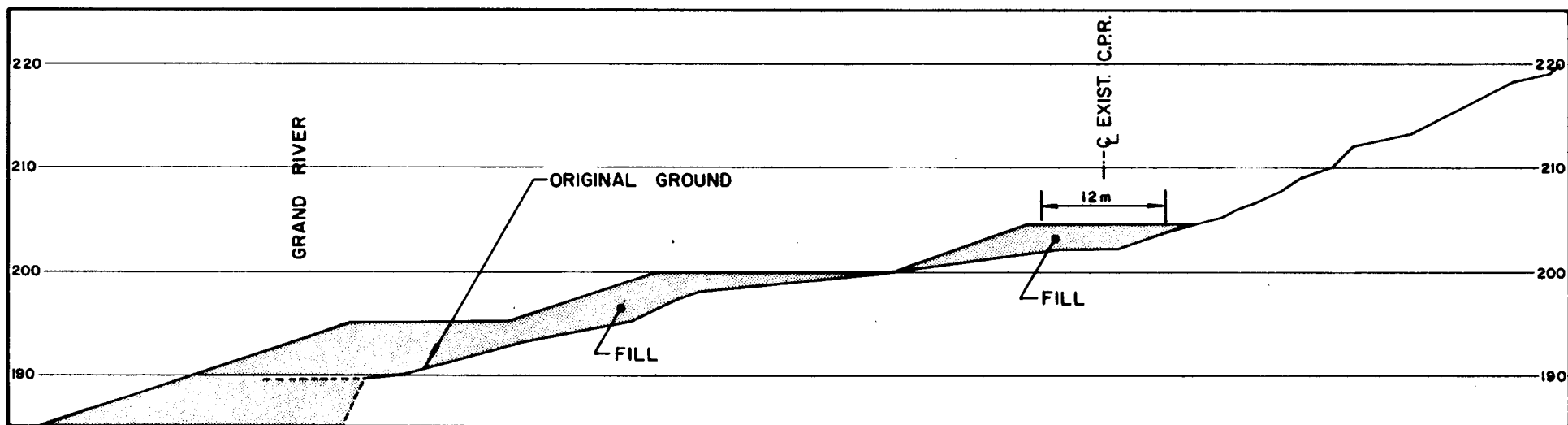
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**CROSS SECTIONS FOR SCHEME 3
RECHANNEL THE RIVER AND STABILIZE SLOPE BY FILLING**

FIGURE IV- 4.6

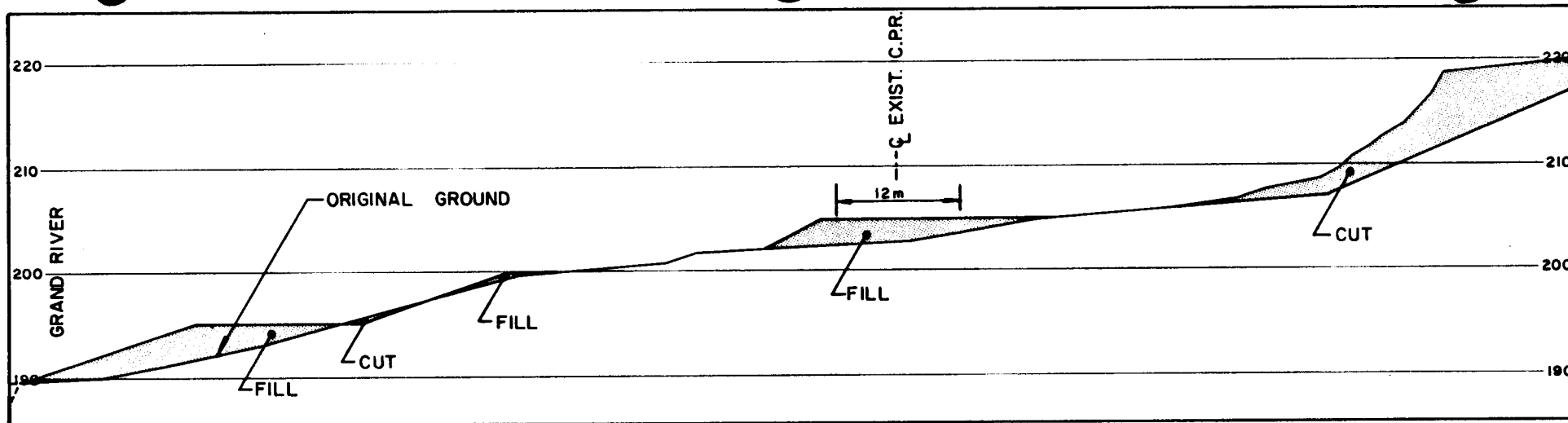


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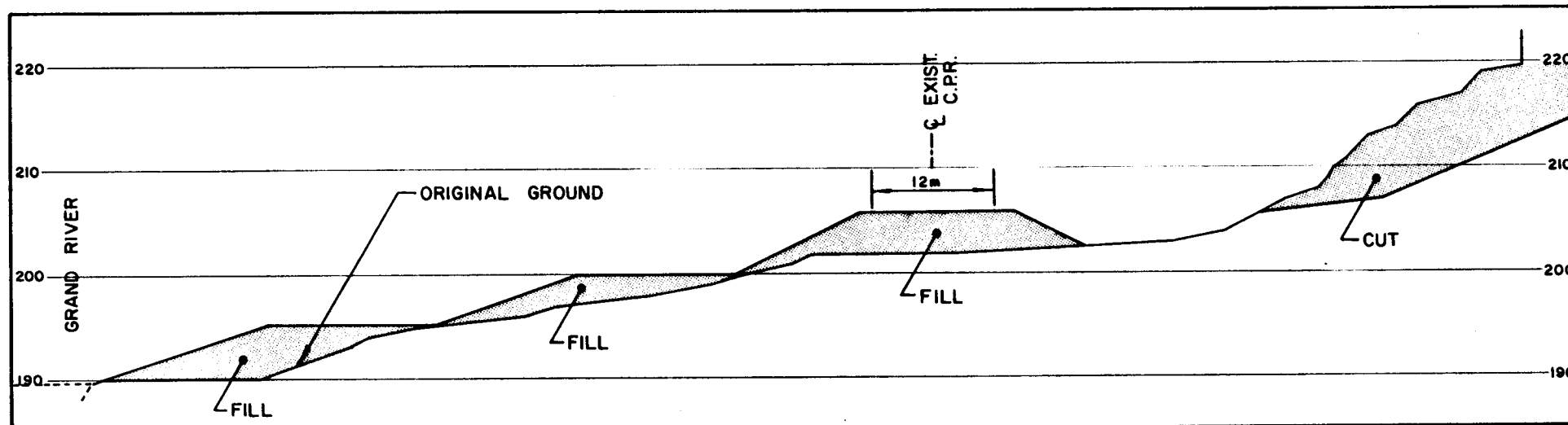


CROSS SECTION 2

**CROSS SECTIONS FOR SCHEME 4
RECHANNEL THE RIVER AND STABILIZE THE SLOPE BY
A COMBINATION OF CUTTING AND FILLING**

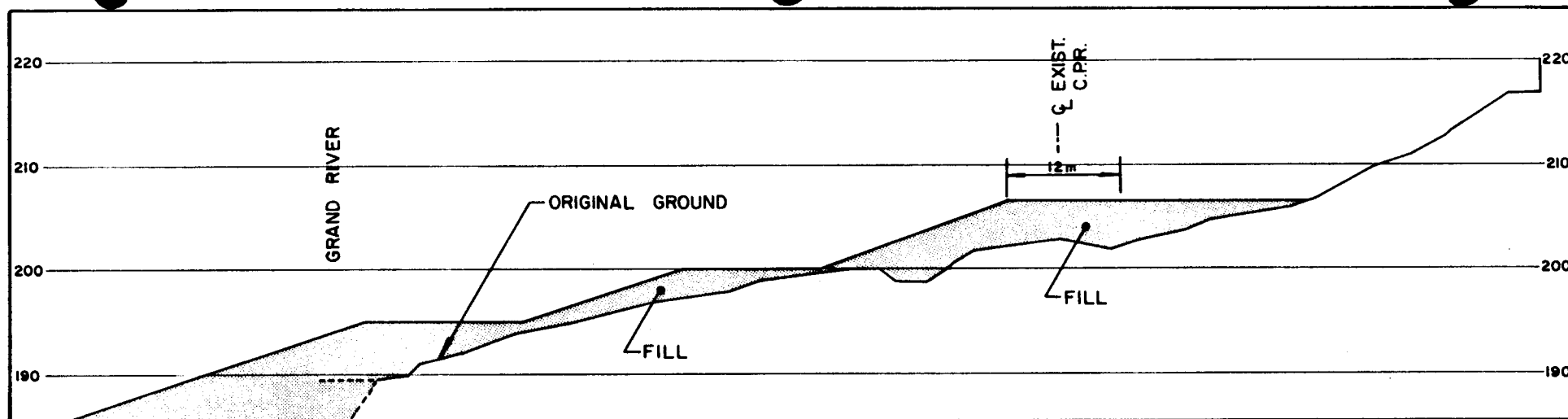


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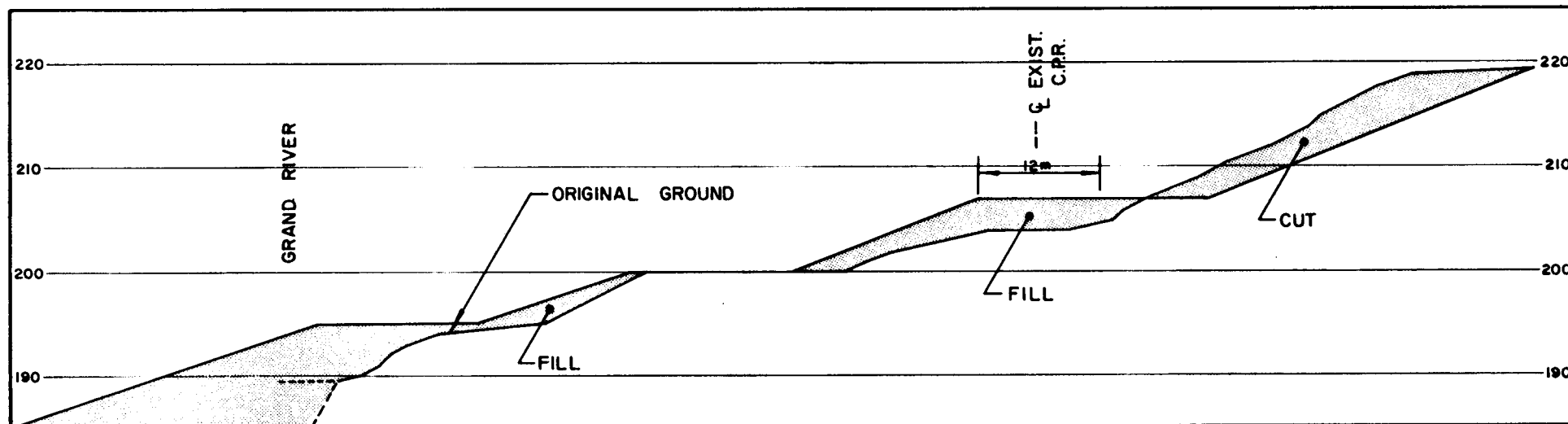


CROSS SECTION 4

**CROSS SECTIONS FOR SCHEME 4
RECHANNEL THE RIVER AND STABILIZE THE SLOPE BY
A COMBINATION OF CUTTING AND FILLING**



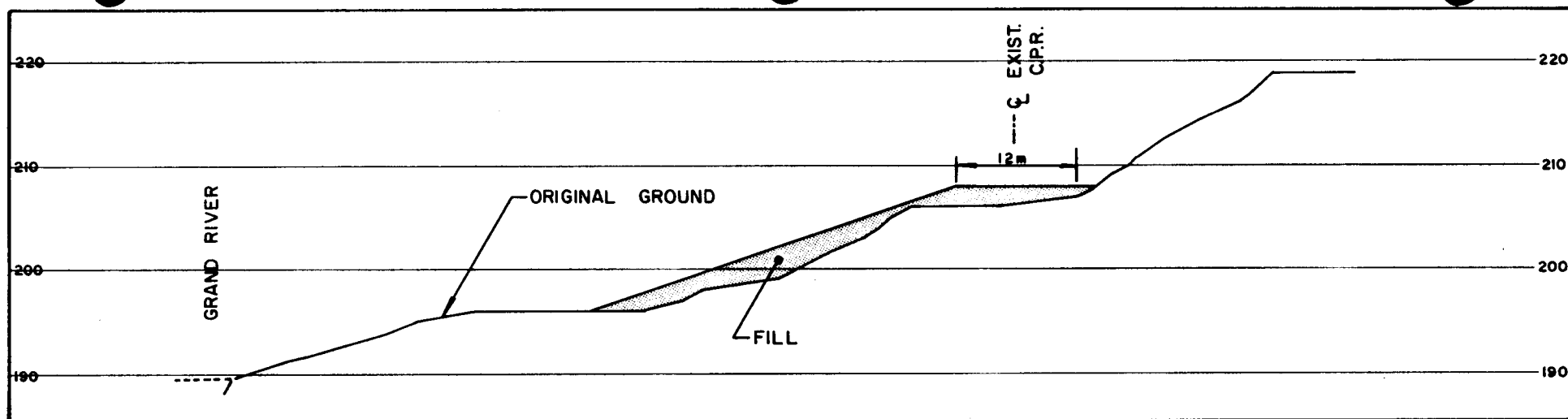
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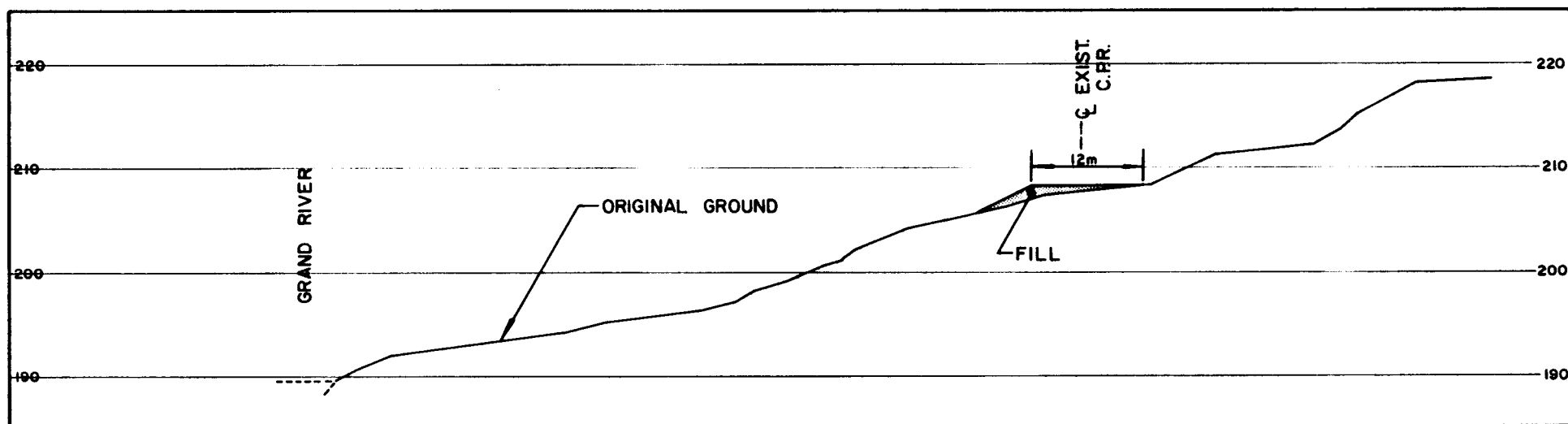
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**CROSS SECTIONS FOR SCHEME 4
RECHANNEL THE RIVER AND STABILIZE THE SLOPE BY
A COMBINATION OF CUTTING AND FILLING**

FIGURE IV-5.3



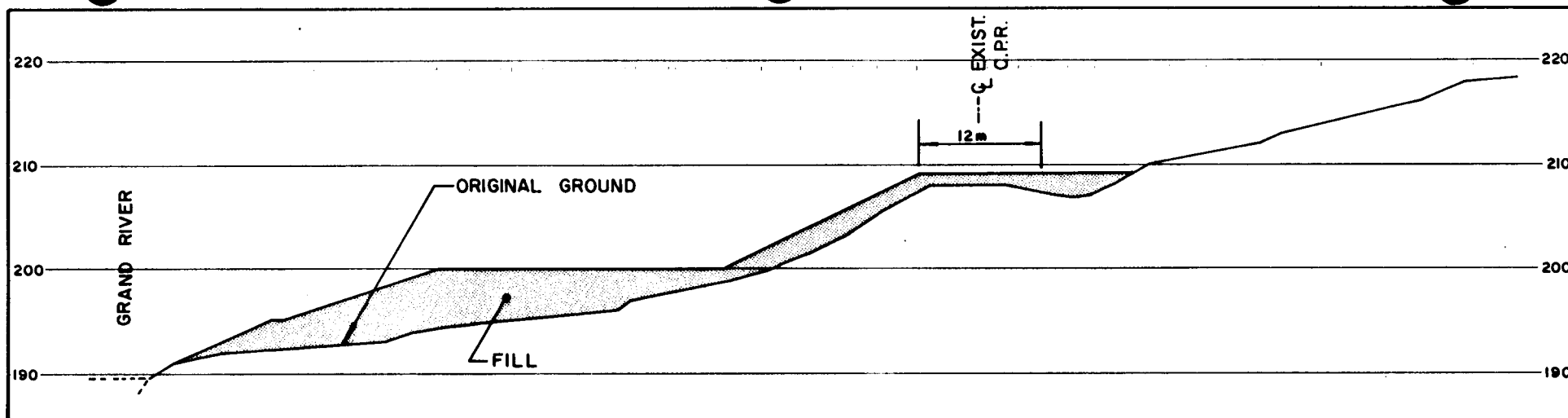
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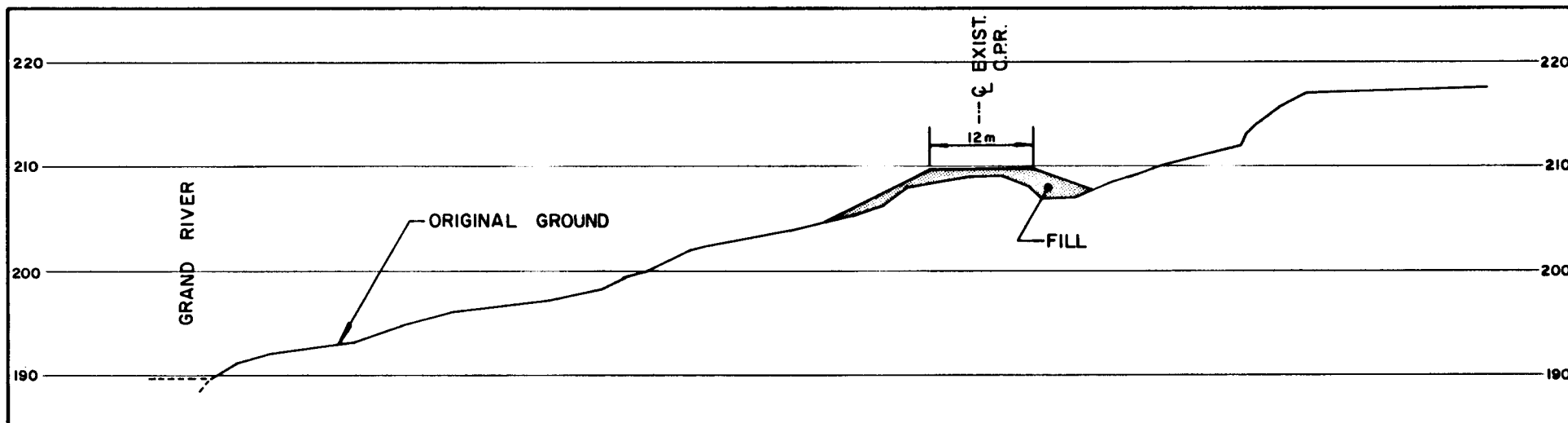
CROSS SECTION 8

**CROSS SECTIONS FOR SCHEME 4
RECHANNEL THE RIVER AND STABILIZE THE SLOPE BY
A COMBINATION OF CUTTING AND FILLING**

FIGURE IV - 5.4



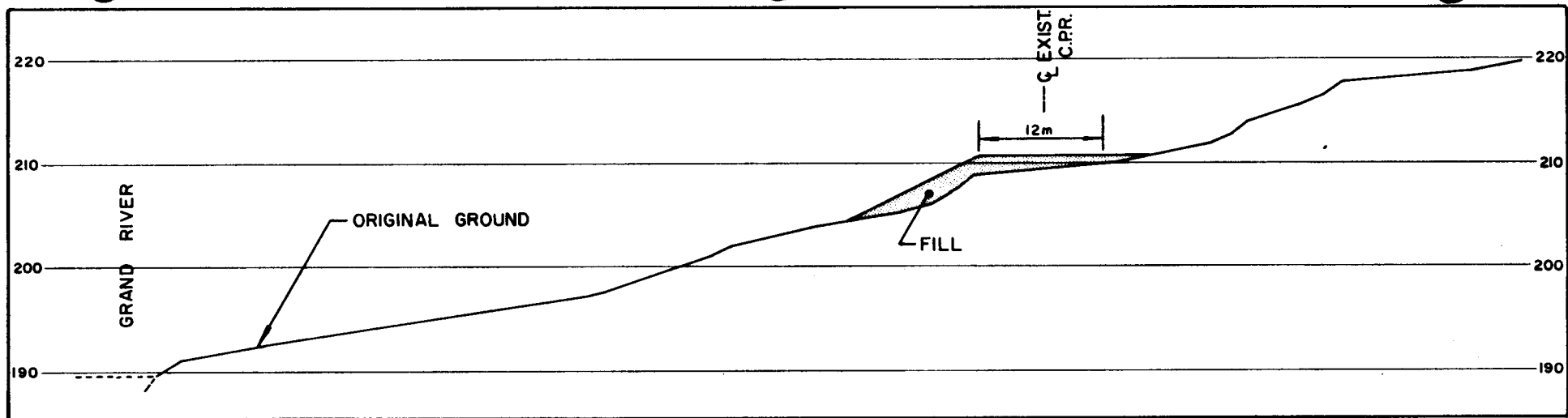
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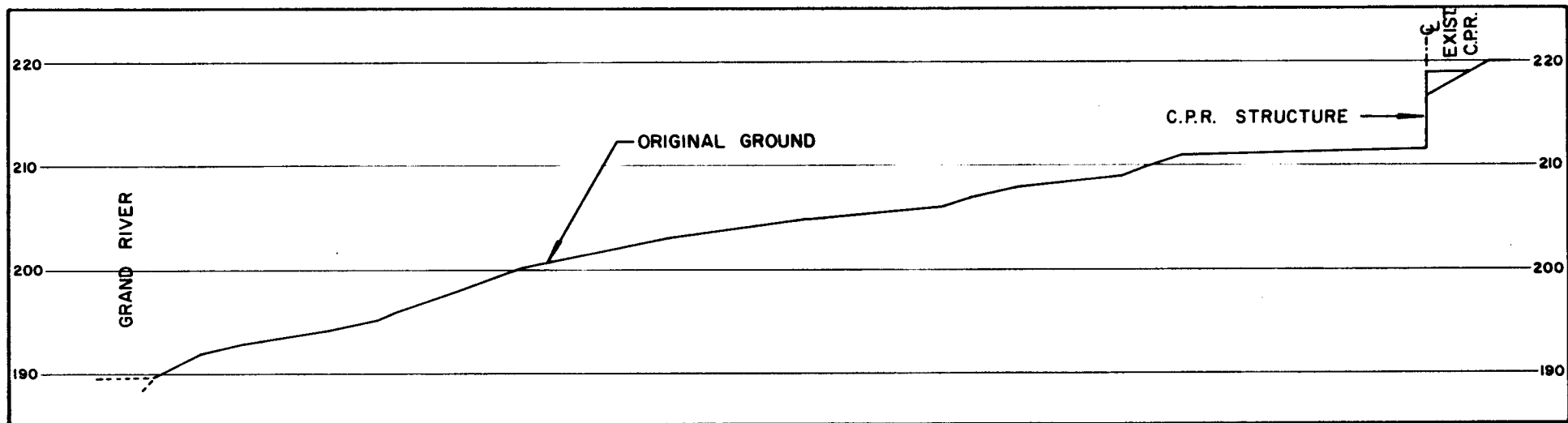
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**CROSS SECTIONS FOR SCHEME 4
RECHANNEL THE RIVER AND STABILIZE THE SLOPE BY
A COMBINATION OF CUTTING AND FILLING**

FIGURE IV - 5.5



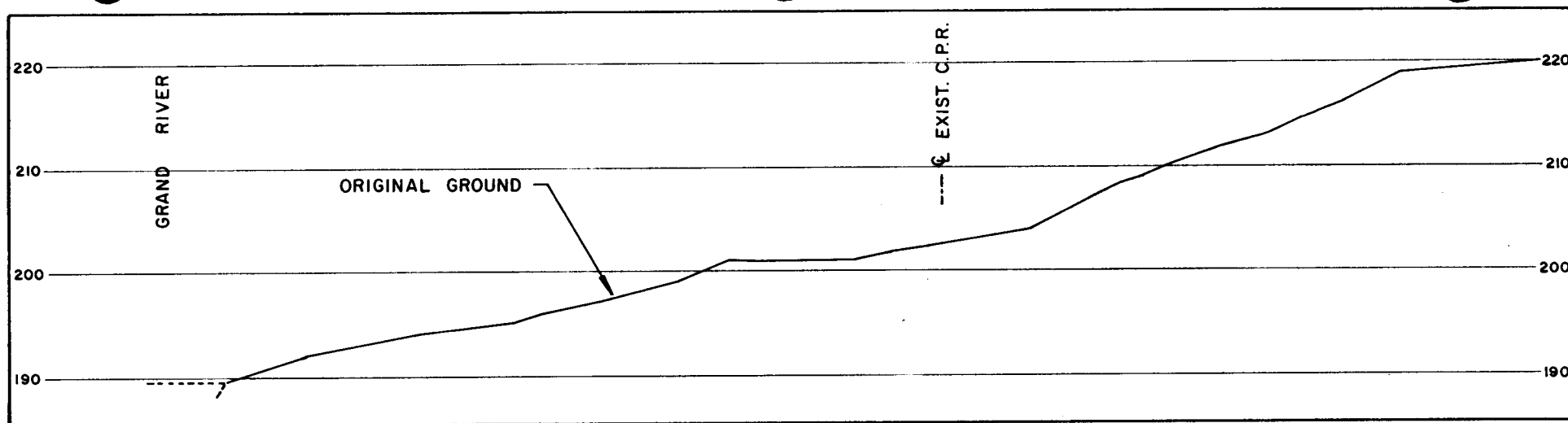
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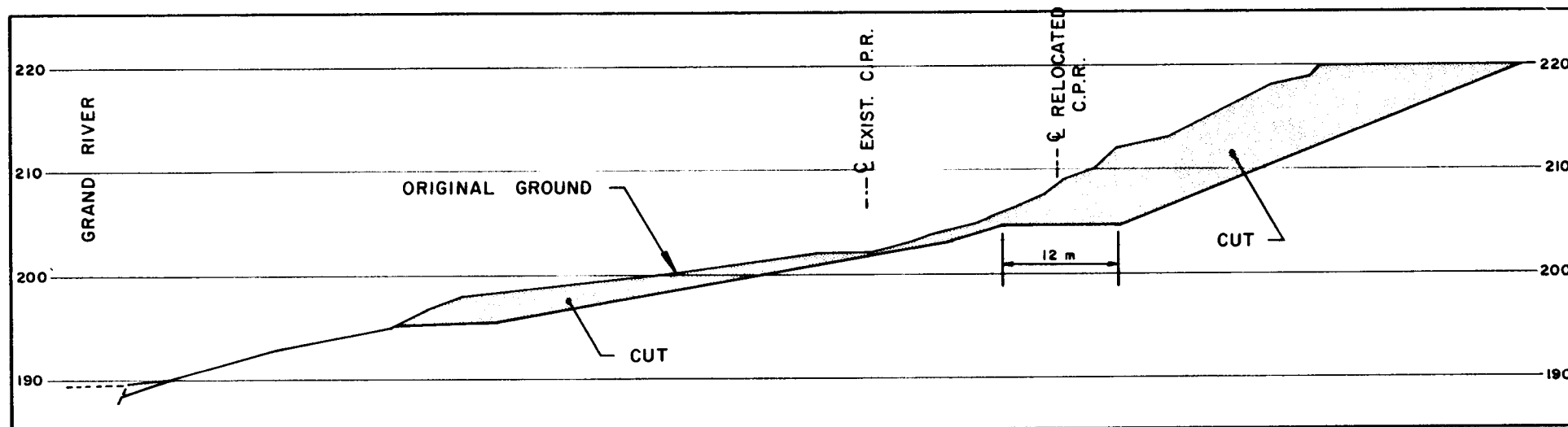
CROSS SECTION 12

**CROSS SECTIONS FOR SCHEME 4
RECHANNEL THE RIVER AND STABILIZE THE SLOPE BY
A COMBINATION OF CUTTING AND FILLING**

FIGURE IV-5.6



CROSS SECTION 1

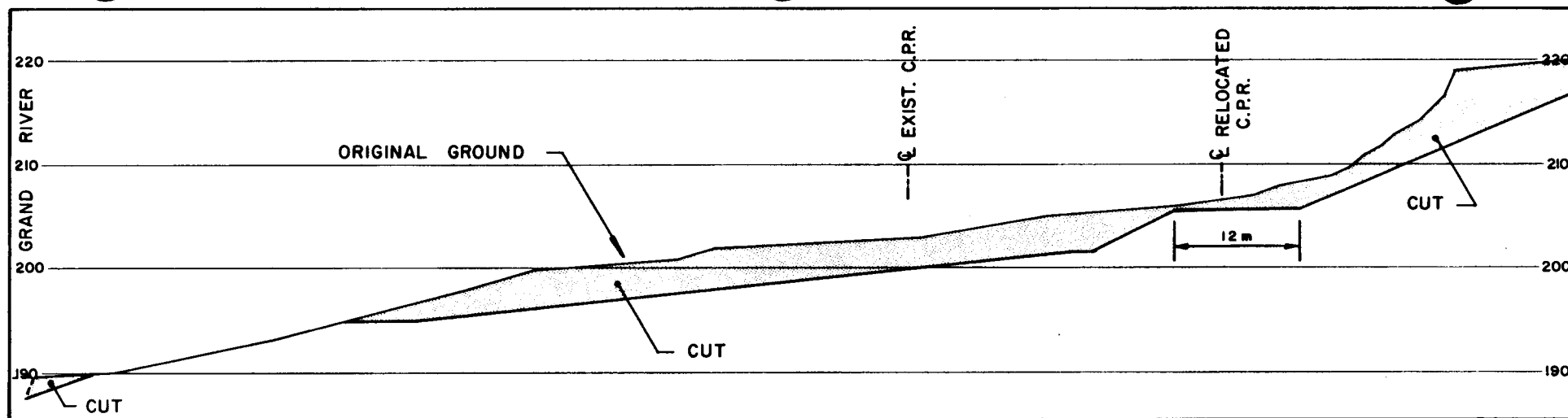


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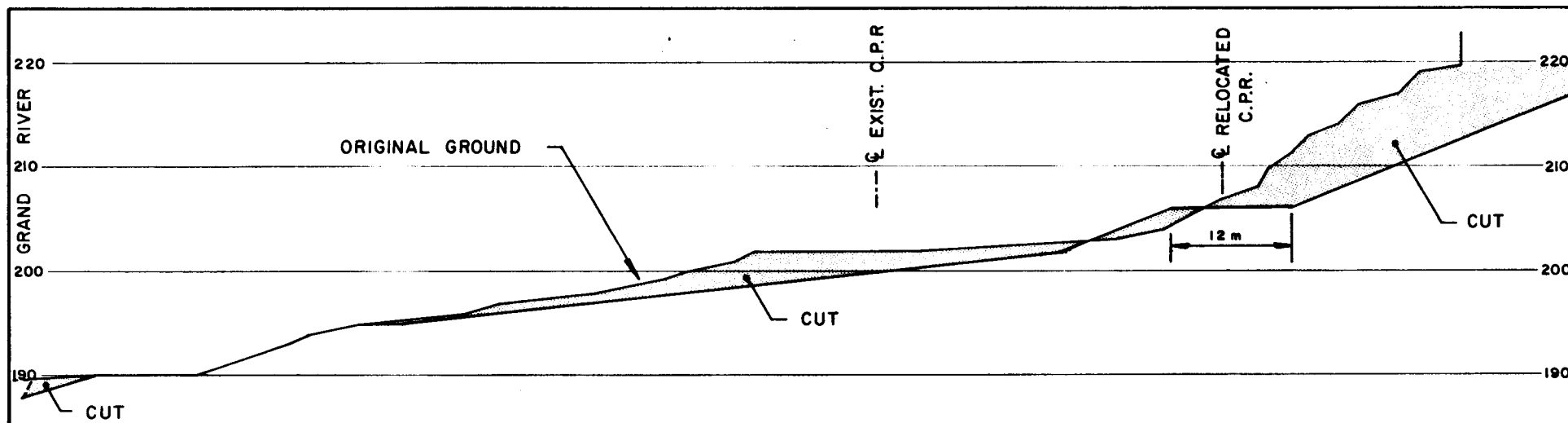
CROSS SECTIONS FOR SCHEME 5

RE-ESTABLISH THE RIVER AND STABILIZE THE SLOPE BY CUTTING

FIGURE IV - 6.1



CROSS SECTION 3

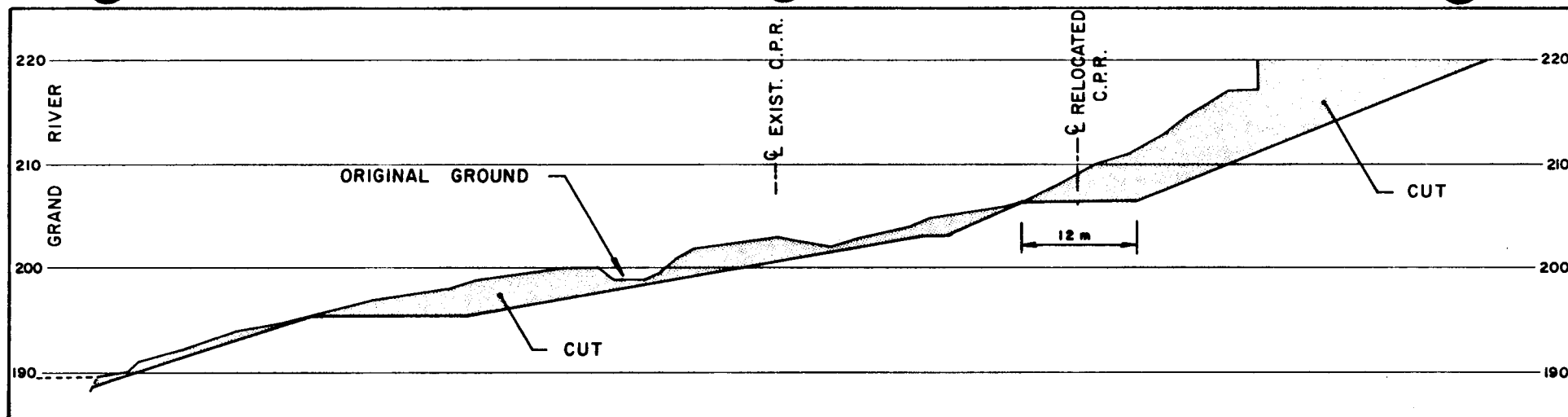


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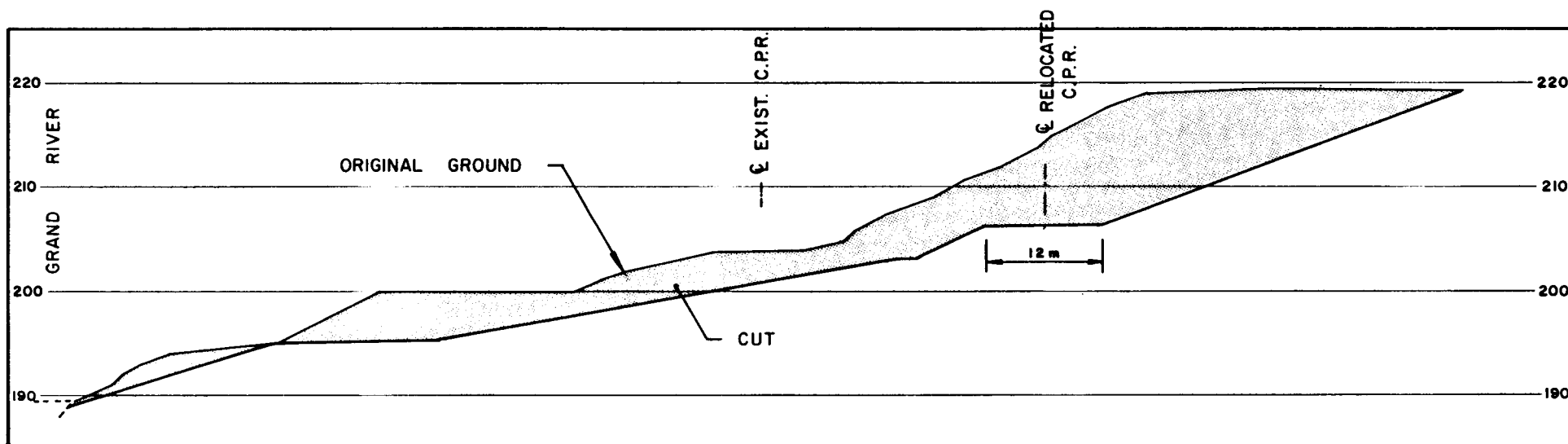
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RE-ESTABLISH THE RIVER AND STABILIZE THE SLOPE BY CUTTING

FIGURE IV- 6.2



CROSS SECTION 5

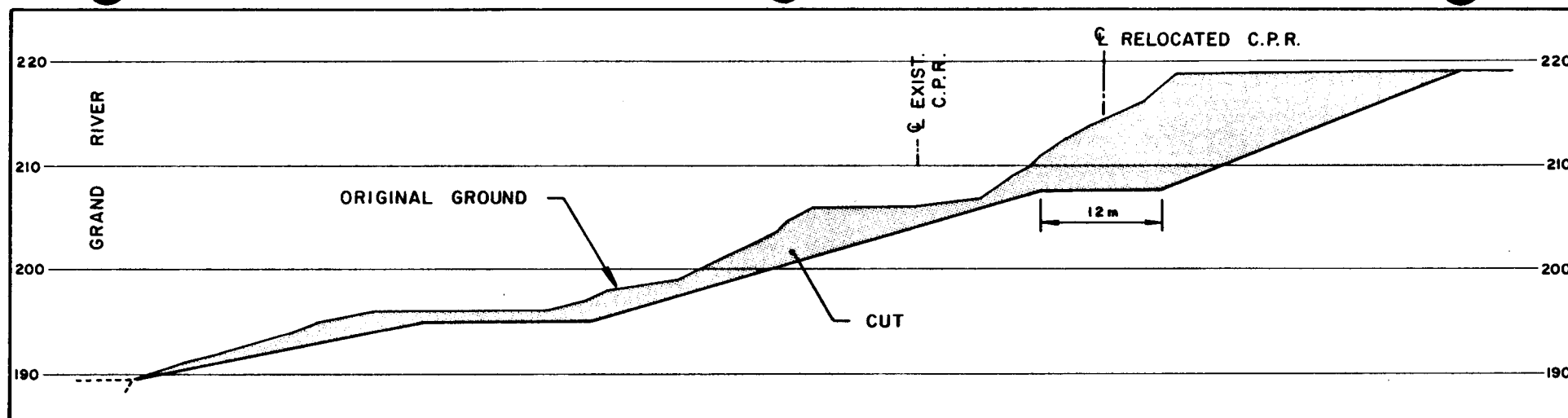


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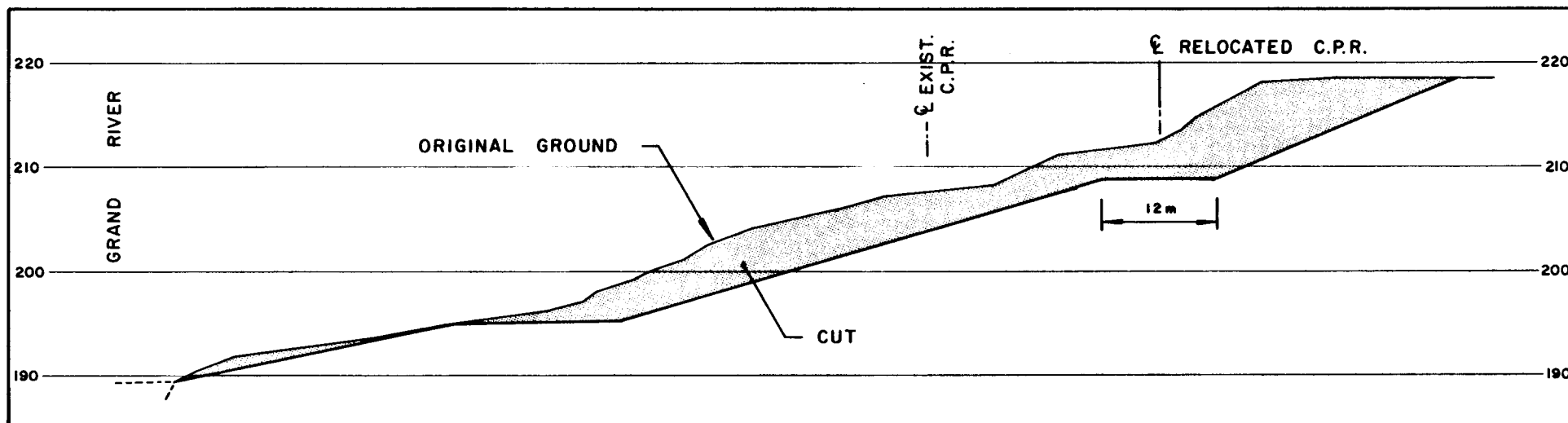
CROSS SECTIONS FOR SCHEME 5

RE-ESTABLISH THE RIVER AND STABILIZE THE SLOPE BY CUTTING

FIGURE IV-6.3



CROSS SECTION 7

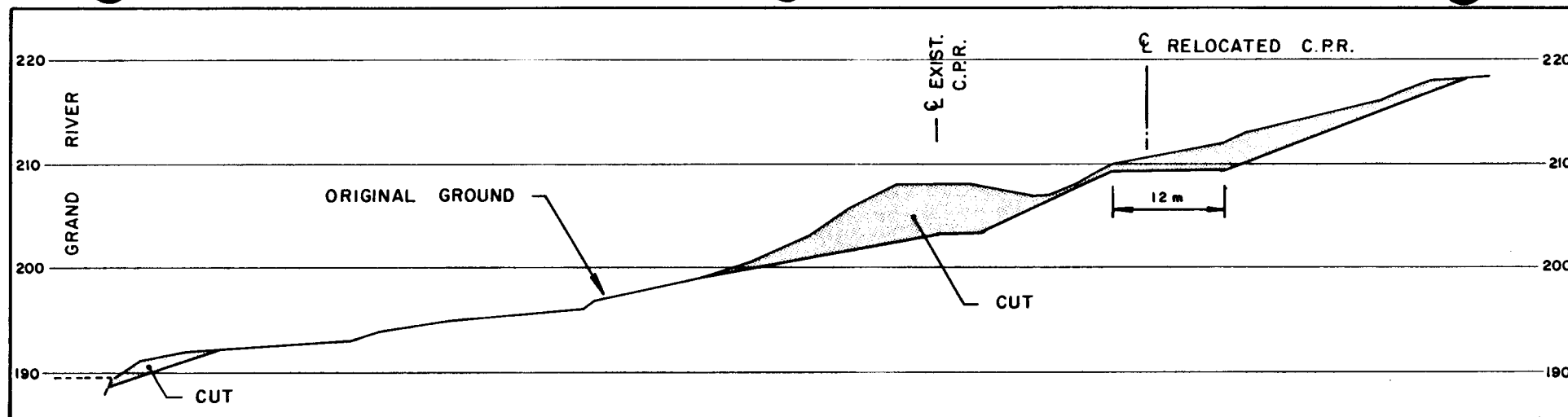


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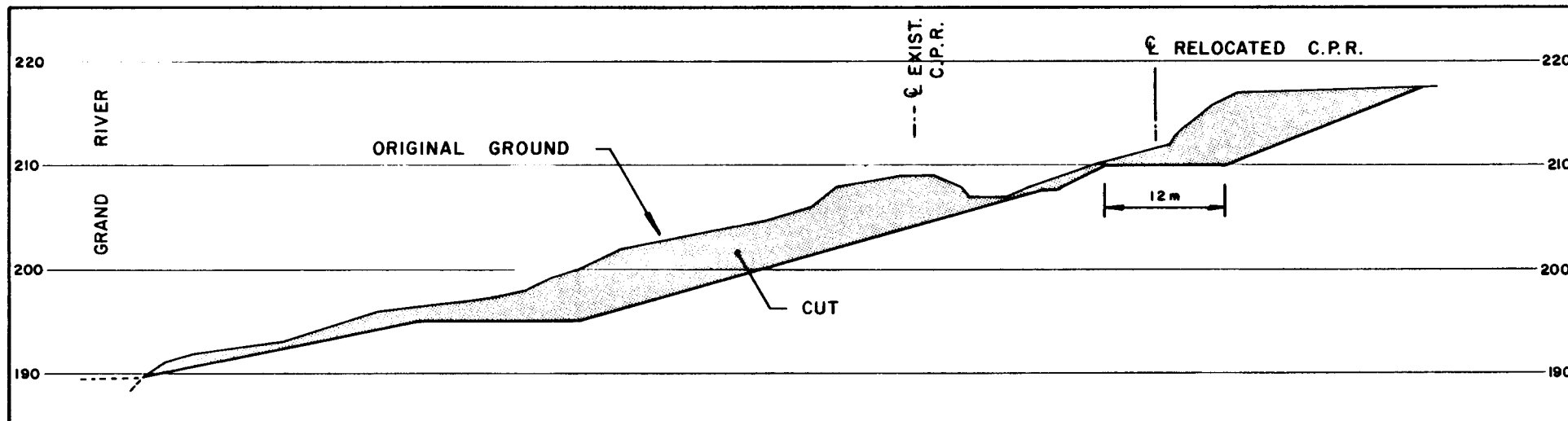
CROSS SECTIONS FOR SCHEME 5

RE-ESTABLISH THE RIVER AND STABILIZE THE SLOPE BY CUTTING

FIGURE IV-6.4



CROSS SECTION 9

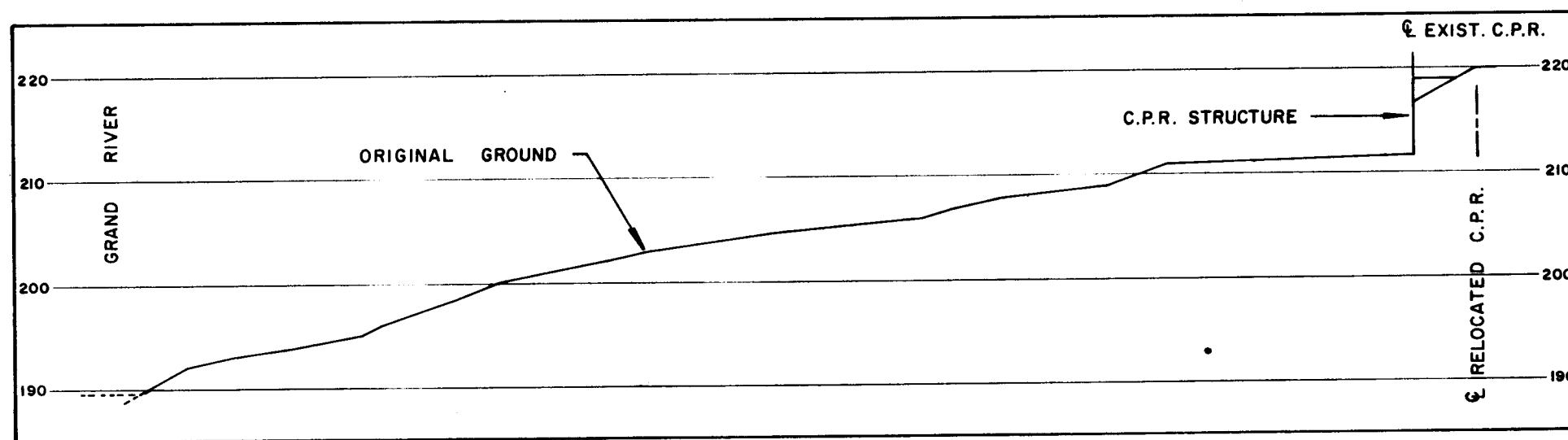
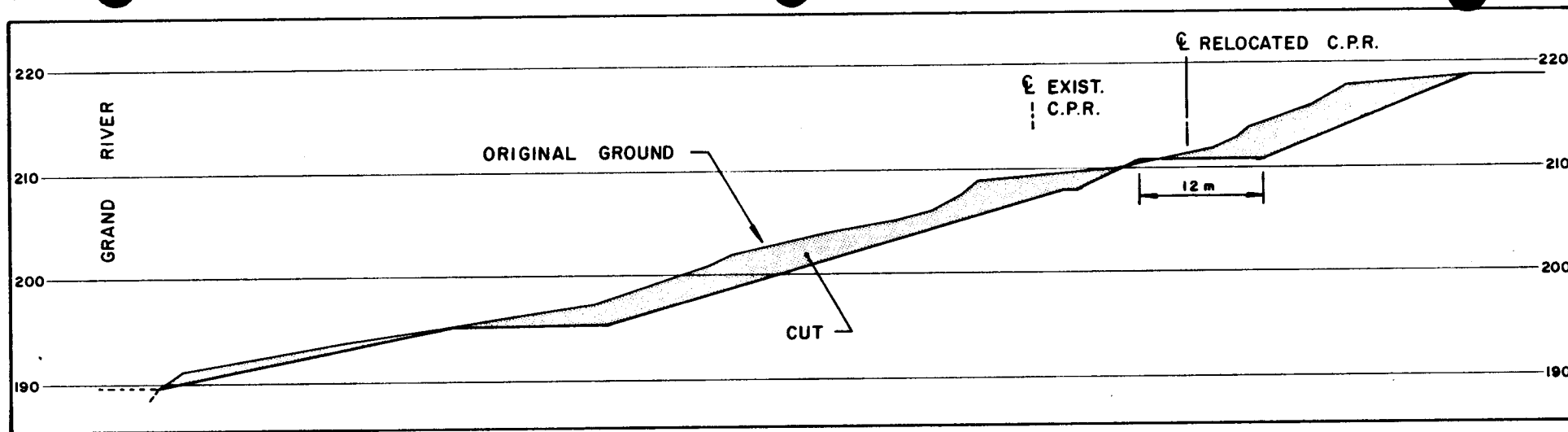


CROSS SECTION 10

CROSS SECTIONS FOR SCHEME 5

RE-ESTABLISH THE RIVER AND STABILIZE THE SLOPE BY CUTTING

FIGURE IV - 6.5



CROSS SECTIONS FOR SCHEME 5

RE-ESTABLISH THE RIVER AND STABILIZE THE SLOPE BY CUTTING

FIGURE IV- 6.6

APPENDIX V

THE NATURAL ENVIRONMENT

**PRELIMINARY ENGINEERING STUDY
GRAND RIVER VALLEY WALL SLOPE FAILURE
COLBORNE STREET EAST
BRANTFORD, ONTARIO**

TABLE OF CONTENTS

	<u>Page No.</u>
1.0 INTRODUCTION	V-1
2.0 TERRESTRIAL ENVIRONMENT	V-2
2.1 Vegetation	V-2
2.1.1 Communities Present	V-2
2.1.2 Plant Species	V-6
2.1.3 Significance of the Vegetation	V-6
2.2 Wildlife	V-7
2.3 Summary of the Terrestrial Environment	V-8
3.0 AQUATIC ENVIRONMENT	V-9
3.1 Summary of the Aquatic Environment	V-11
4.0 IMPACTS OF THE ALTERNATIVES OF THE NATURAL ENVIRONMENT	V-12
4.1 Do Nothing Alternative	V-12
4.2 Relocation of Colborne Street	V-12
4.3 Fill Only	V-12
4.4 Cut and Fill	V-13
4.5 Cut Only	V-13
4.6 River Diversion at the Cockshutt Bridge	V-13
5.0 EVALUATION OF THE ALTERNATIVES	V-14
6.0 MITIGATION	V-15
7.0 LITERATURE CITED	V-16

LIST OF FIGURES

Figure V-1: VEGETATION COMMUNITIES IN THE VICINITY OF THE SLOPE FAILURE	V-3
Figure V-2: VEGETATION TYPES - RIVER DIVERSION	V-5

LIST OF ATTACHMENTS

	<u>Page</u>
ATTACHMENT V-I: PLANTS OBSERVED	V-18
ATTACHMENT V-II: WILDLIFE OBSERVED	V-28

1.0 INTRODUCTION

This report describes the biological environment of the Grand Valley slope failure in the vicinity of Colborne Street in Brantford. Both terrestrial and aquatic biological resources are discussed and assessed, and the various alternatives for dealing with the problem are evaluated in terms of their potential impacts on the biological environment.

The terrestrial resources were examined on October 23 and 28, 1986. This entailed mapping vegetation communities and identifying all plant and wildlife species present.

No original information was collected on aquatic resources. The Grand River Conservation Authority extensively inventoried the fish populations in the Grand River. For the purposes of this study, their information was used to predict the species that are likely to occur in the vicinity of the slope failure.

The study and subsequent reporting of the results were designed to meet the requirements of the Class Environmental Assessment for Water Management Structures (Association of Conservation Authorities of Ontario 1986).

2.0 TERRESTRIAL ENVIRONMENT

2.1 Vegetation

The vegetative conditions on the slope failure site were examined on October 23. All communities were identified and mapped, and the study area was split into two areas: above and below the railway tracks. Within these two areas, all plant species observed were identified and listed. This approach was used as some of the alternatives might affect the top or toe of the slope differently.

On October 28, the area of the potential river diversion was examined. This included the area from the bend in the river upstream of the Cockshutt Bridge across to the river above the Newport Bridge.

October is not the optimum time to conduct a vegetation survey as some of the early spring species are not evident. However, most of the ephemeral species occur in woodlots with closed canopies. This type of habitat is not present in the vicinity of the slope failure, so it is unlikely that any significant species were overlooked there. The habitat at the proposed diversion area has the potential to have some early-flowering woodlot species.

2.1.1 Communities Present

Figure V-1 shows the vegetation communities in the vicinity of the slope failure. Above the railway tracks, there are six basic vegetation types: manicured areas, herbaceous meadow, mixed stands of oaks and black walnut, stands of pure walnut, stands of walnut and Manitoba maple, and stands of pure Manitoba maple.

The manicured area consists of the lawn around the school house and the associated planted trees. This also includes the back yards of some houses and some ornamental evergreens.

The meadow is dominated by goldenrods and other late succession herbs, and is being invaded by shrubs such as sumacs, raspberries, grapes and dogwoods.

In the extreme western portion of the study area, there is a stand dominated by red oak, white oak and black walnut. It also contains some specimens of shagbark hickory and sweet pignut hickory.

The pure walnut stand is also near the western extremity of the study area. The trees vary from 15 to 30 cm d.b.h. (diameter-at-breast-height) and are generally in good condition. The canopy is open and the understory is grassy and weedy.

Most of the area above the tracks is walnut mixed with Manitoba maple. Generally, the amount of walnut present declines to the east. Overall,

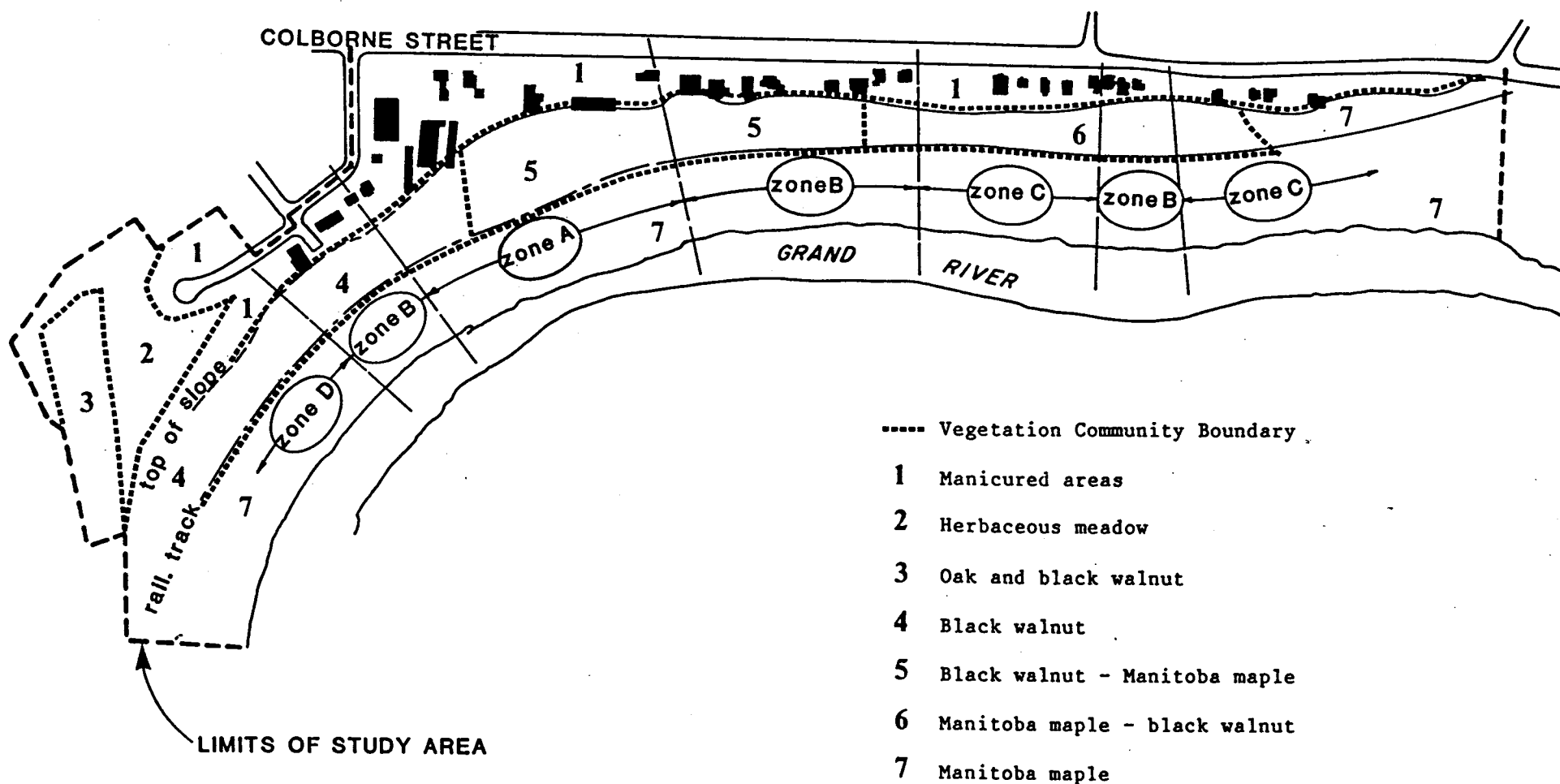


Figure V-1

VEGETATION COMMUNITIES

the canopy is open and the understory is weedy in aspect. There are pockets where there are few to no trees, particularly in the vicinity of the slope failure.

At the far east above the tracks, the forest cover is pure Manitoba maple. This canopy is also open with a weedy understory. Below the tracks, except for manicured areas around two buildings, the forest cover is dominated by Manitoba maple.

Figure V-2 shows the vegetation types found in the vicinity of the proposed river diversion. They are described very briefly below, with the numbers corresponding to those on the map.

1. An open stand of large red oak, young elm and Manitoba maple that is pastured.
2. Young elm and hawthorn that is pastured.
3. Young sugar maple mixed with large white pine (up to 50 cm d.b.h.), occasional black cherry.
4. A poorly stocked plantation of white pine, 2-3 m in height, understory primarily goldenrod.
5. White ash with some red oak, hophornbeam and shagbark hickory, understory garlic mustard or bare.
6. Plantation 25-30 years old of white, red and jack pine and black locust. Mostly white pine on the top of the hill and black locust down the slope.
7. A variable floodplain of bur and red oak, Manitoba maple and willow. Black walnut sparse throughout, understory weedy.
8. Mostly sugar maple with some white ash, red oak and black cherry, changing to young white ash in the west.
9. A small plantation of red pine.
10. Cattail fringe around pond, lots of floating green algae.
11. Red pine plantation 15-20 years old.
12. Floodplain primarily of Manitoba maple and white ash, with some white birch and hophornbeam. Common buckthorn abundant throughout.
13. Immature red oak, sugar maple and white oak, with buckthorn abundant in the understory.
14. Red pine plantation.

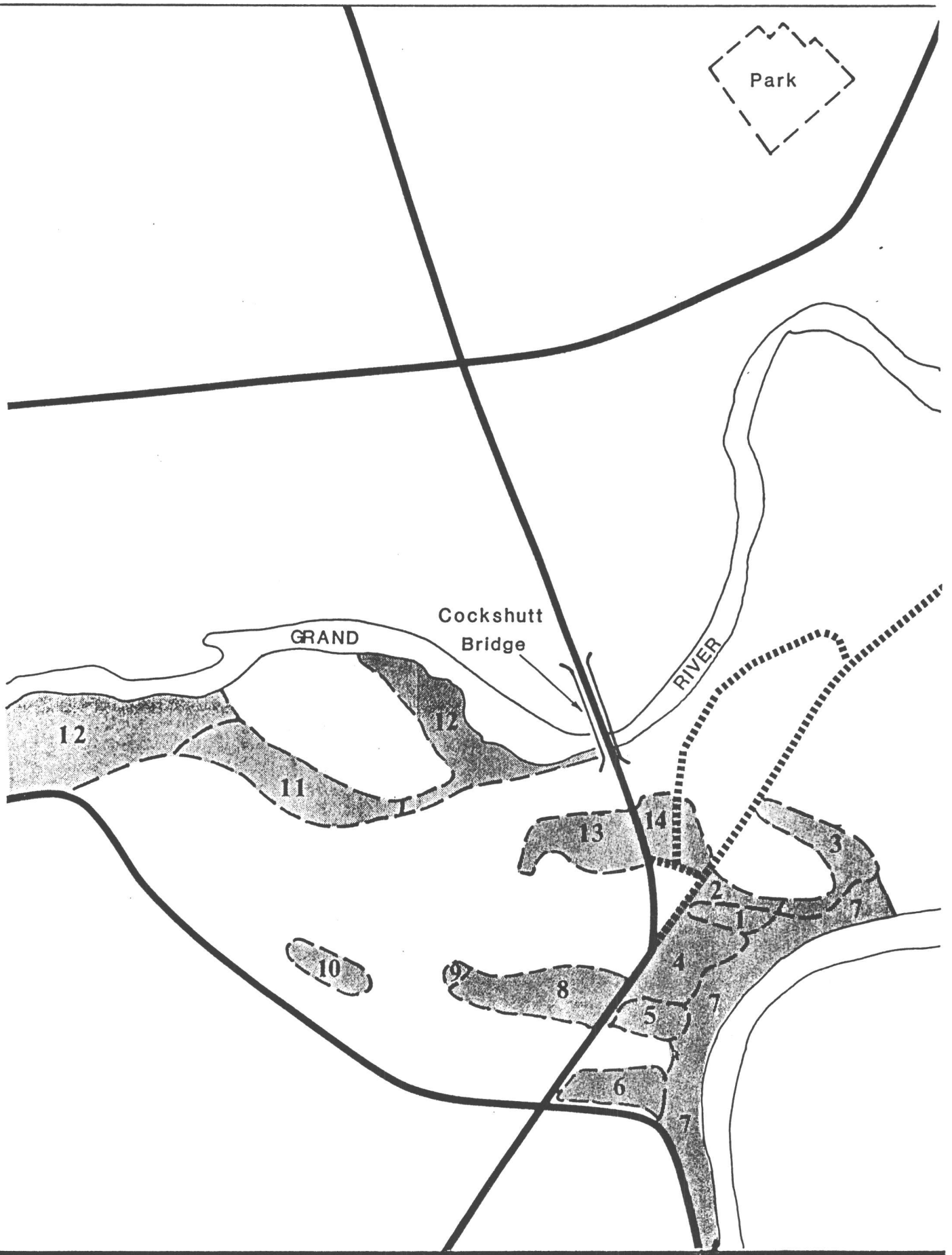


Figure V-2

VEGETATION TYPES - ALTERNATIVE 6

2.1.2 Plant Species

Attachment I lists all the plant species observed, using the order and nomenclature of Fernald (1950). Introduced species, which are usually considered to be weeds, are indicated with a plus sign.

A total of 230 species were observed, which is of moderate diversity for a study area of this size. Of these, 192 were found in the vicinity of the slope failure and 158 were present at the proposed diversion site.

2.1.3 Significance of the Vegetation

The percentage of native species present in a vegetation community is a good indication of its quality. Of all the plant species found in Ontario, 72.6% are native and the remainder are introduced. Urban areas in Toronto are typically comprised of about 50% native species (Kaiser 1983).

Urban areas with in excess of 60% native species and non-urban with more than 70% native species can be considered to be of high botanical quality. Sites with less than 50% native species are usually considered to be low quality and excessively disturbed.

The flora at the slope failure ranged from 53.6-56.0% native species, and can therefore be considered to be typical of an urban vegetation community. The proposed diversion area was slightly better than the failure, probably due to its being in a more agricultural area and having more mature woodlots. However, it also was only of moderate quality.

Black walnut is presently considered to be rare in Ontario (Argus and White 1977). The original work completed by Argus and White is presently being up-dated, but the walnut family has not yet been re-evaluated. Most likely, black walnut will be removed from the list of provincially rare plant species shortly in the future. Apparently, it was designated rare to protect large floodplain stands of pure walnut. Individual trees were considered to be of little significance. (Personal communication from John Ambrose, Ontario Rare Woody Plant Program, University of Guelph, 1982).

Black walnut is abundant in the Brantford area, being one of the most common shade trees in the city as well as occurring along the river. As such, it is of limited significance in a local and regional context.

In the study area, the pure black walnut stand to the west of the slope failure is the only one of any significance. In the remainder of the site, it is mixed with Manitoba maple or is a minor component of the tree composition.

Red mulberry is also considered to be provincially rare, and has yet to be re-evaluated (Argus and White 1977). This species frequently hybridizes

with the introduced white mulberry. It is possible that the red mulberries seen on the site were hybrids with characteristics more closely resembling red than white mulberry. White mulberry was common in the area, but only two red mulberries were seen, so hybridization is highly likely.

The two red mulberries were both small, being less than 3 m in height. One was on the railway right-of-way east of the slope failure and the other was in the western portion of the study area between the pure walnut stand and the mixed oak and walnut stand.

In summary, the vegetation in the study areas is typical of the local area. The only items of any significance are a stand of pure black walnut and two immature red mulberries. With the exception of one mulberry, these features are in an area where they will not be disturbed by future slope failures or by any of the proposed remedial measures.

2.2 Wildlife

As with the plants, all wildlife species observed were recorded. The 34 species seen are listed in Attachment II. This included one reptile, 26 birds and 7 mammals.

No amphibians were seen or heard. Earlier in the year, common species such as American toad and northern leopard frog would likely be present. Habitat for uncommon and rare species is lacking, and the woodlots are too open and disturbed to support salamanders.

The eastern garter snake was the only reptile observed. It is abundant throughout Ontario. Rare and uncommon reptile species are not likely to occur in the study area, although it is probable that some common species of turtles (Midland painted, snapping) inhabit the river. Natural nesting habitat for turtles appeared to be absent, although they might nest in the gravel on the railway right-of-way.

The majority of bird species found were fall migrants or permanent residents. All of them are common to abundant in Ontario at this time of year, as defined by James et al. (1976). They considered common species of birds to be those that a single observer could see 25-500 of in a day. One could expect to find over 500 of an abundant species.

Unfortunately, it was not possible to determine which species of birds nested in the area. In the vicinity of the slope failure, no rare nesting species would be expected due to the immaturity and types of woodlots present (Ecologistics Limited 1987). The proposed diversion area has a limited potential to support some rare species.

All the mammals recorded are abundant. Intensive field work and trapping might have revealed a few more species, but no rare or uncommon species would be anticipated due to the nature of the habitat.

In summary, all the wildlife species present are common to abundant, and are not even of local significance.

2.3 Summary of the Terrestrial Environment

Generally, the area is disturbed and only of moderate quality. Two specimens of red mulberry and a stand of black walnut are worthy of note. Only one mulberry would be affected by any of the proposed remedial measures. The wildlife populations are not of significance.

3.0 AQUATIC ENVIRONMENT

The Grand River Conservation Authority had adequately studied the aquatic resources of the Grand River in the Brantford area. Consequently, no original field work was conducted as a part of this study. In addition to the Grand River Conservation Authority's work, the status of certain species in the area has been studied by the National Museum of Canada.

No fisheries work has been done in the immediate vicinity of the study area, but fish populations in the Brantford area have been well documented. Using the habitat preferences of the fish species known from this region of the Grand River, it is possible to predict which species are likely to be present in the study area.

Near Colborne Street, the Grand River is approximately 50 m in width and averages 1-2 m in depth. The gradient is low, and flows are gentle to moderate. The substrate is primarily silt with occasional boulders.

The Ministry of the Environment (1981) analyzes water samples at regular intervals at the Cockshutt and Newport bridges. Results of their analyses indicate that the river is normally at or slightly above recommended concentrations for bacteria and moderately enriched with phosphorus and nitrogen. Turbidity levels are low to moderate on average, with occasional high levels, presumably during storm events. Overall, for a river of this size that has just passed through a major city, water quality can be considered moderate to good.

Mason (1976) reported the presence of several sports fish in the Grand River at Brantford. These include fall runs of coho salmon and rainbow trout plus northern pike, smallmouth bass, largemouth bass and walleye. In addition, there are a number of panfish present: black crappie, yellow perch and a variety of sunfish species.

The number of salmon and rainbow trout reaching Brantford each fall is unknown, but is generally thought to be fairly low. In the fall of 1977, the Grand River Conservation Authority (Hindley 1978) studied the salmonid populations in the lower Grand River at Dunnville and Caledonia. It was estimated that there were 38 salmon and 38 rainbow trout in the Sulphur Creek area at Dunnville, but it could not be determined what percentage of the total population this represented. It appeared as though most of these fish were spawning in this area, so it is unlikely that they would try to ascend the Dunnville dam and proceed further up the river. A hoop net was fished in the Grand River at Cayuga for 23 days during the spawning run, but failed to catch any salmon or trout. However, it was felt that the spawning run may have been earlier than normal due to cooler weather and higher river levels, so sampling may have been too late to catch the bulk of the fish. Normally, the spawning run for these species in the lower Great Lakes occurs from early September throughout October (Scott and Crossman 1973).

Some coho salmon and rainbow trout do pass through the study area, as they have been reported as far upstream as Paris. However, numbers are thought to be low, as the fish must ascend the Dunnville and Caledonia dams before having access to this stretch of the river. Spawning in the study area is extremely improbable, as both species prefer a gravelly substrate.

The northern pike prefers slow-flowing waters and beds of aquatic plants. Due to the time of year that field work has to be undertaken, the extent of aquatic macrophytes could not be determined. It is probably that there are pike in the study area, but unlikely that it is of significance for spawning.

Smallmouth bass prefer moderately flowing water with rocks and logs to provide cover. This species is probably relatively common in the study area, and some limited spawning may occur.

Largemouth bass are generally found in stiller water and areas with soft substrates and weed cover. It also is likely to be present in the study area, and some limited spawning may occur.

Walleye prefer large turbid lakes or large rivers that are turbid enough to provide shelter from the sun during the day. Spawning normally occurs over beds of cobblestones or large rocks in running water. Walleye are probably common in the study area, but there is no suitable spawning habitat.

Black crappies and yellow perch may be present in low numbers, while rock bass and sunfish are likely common.

The silver shiner has also been found in the Grand River at Brantford. It was not discovered in Canada until 1971, when it was found in the Grand at Elora and Brantford (Gruchy et al. 1973). Its known distribution in Canada and Ontario is restricted to the Grand River system (the Grand at Elora and Brantford, the Nith River at Ayr, and the Conestogo River at St. Jacobs) and the Thames River at London. Consequently, this species is considered to be rare in Ontario and Canada (Parker and McKee 1983a, McAllister et al. 1985).

Although it is rare, the silver shiner population appears to be stable or increasing. Where it occurs, it is often locally abundant. It inhabits medium to large streams with moderate to high gradients (0.5-1.9 m/km) and hard substrates. It is most often in areas of moderate current below dams, and is also present in the Elora gorge.

Because of the silver shiner's habitat preferences, it is unlikely to be present in the study area. The substrate is soft and the gradient is only 0.24 m/km.

The river redhorse is another provincially rare fish that has been found near Brantford. It was, however, in Fairchild Creek which empties into the Grand approximately 12 km below the study area. Five immatures were

caught in this creek in 1971, but it has not been seen since and may have become extirpated due to degraded water quality (Parker and McKee 1983b).

It apparently prefers larger rivers with gravel, rubble and bedrock bottoms where there is a minimum of silt. The river redhorse is intolerant of turbidity, and increased turbidity and siltation are usually followed by population declines (Jenkins 1970). Because of its habitat preferences and intolerance of turbidity, it is unlikely to occur in the study area. It is questionable whether this species is still present in the Grand River watershed.

3.2 Summary of the Aquatic Environment

Water quality in the study area is moderate to good for a large river draining an agricultural and urbanized watershed.

Two provincially and nationally rare fish species have been reported from the Brantford area, but neither are likely to occur in the study area.

There may be a limited number of coho salmon and rainbow trout pass through the area in September and October. The study area is unsuitable for salmonid spawning.

Northern pike, smallmouth bass, largemouth bass and walleye are probable inhabitants of the study area. Walleye may be the most common of these species. Walleye spawning is not likely to occur, but limited spawning by the other three species may take place.

4.0 IMPACTS OF THE ALTERNATIVES ON THE NATURAL ENVIRONMENT

Six potential alternatives to the undertaking have been identified:

- 1) do nothing
- 2) relocate Colborne Street
- 3) fill
- 4) cut and fill
- 5) cut
- 6) diverting the river at the Cockshutt bridge

These alternatives have been described in the main document.

In this section, the potential impacts of each of these alternatives is discussed and evaluated.

4.1 Do Nothing Alternative

It has been demonstrated that, in the absence of remedial actions, additional bank slumping will occur, particularly in Zones A and B. The impact of this on the terrestrial environment will be the loss of the vegetative cover on these slopes. The higher quality black walnut stands will not be affected, but one of the small red mulberries would likely be lost.

The bank failure would probably result in the introduction of silt into the river. Depending upon the time of year that this occurred and the amount of material, this could have adverse impacts on the spawning of fish and possibly on their movement patterns.

4.2 Relocation of Colborne Street

As this solution does not address the problem of future bank failure, all the impacts of doing nothing will still be experienced. In addition, some shade trees at the top of the bank will be lost due to the relocation.

4.3 Fill Only

With the fill only alternative, fill is added to the base and top of slope in Zones A and B. In Zone C, fill is required only at the base and no work is required in Zone D.

Depending upon the most practical methods of carrying out the construction, it is possible that a strip of natural vegetation will be left in the middle of Zones A and B and at the top of Zone C. The black walnut stand in Zone D will not be disturbed.

The addition of fill will result in the toe of the slope being extended further out into the present channel of the river. In order to accommodate flows, the river will have to be widened or a new channel cut.

Both alternatives have the potential to introduce large amount of sediments into the river. Cutting a new channel is preferable, as much of the work could be done under dry conditions, thereby minimizing siltation. With river widening, almost all the work would have to take place in the river, including the placing of fill and gabions at the toe of the slope.

Whether a new channel is cut or the existing one widened, some land on the other side of the river will be lost. Much of the area is vegetated with soft maple mixed with Manitoba maple. This is an abundant cover type along the Grand River and is of very limited biological significance.

4.4 Cut and Fill

The environmental ramifications are similar to the fill only, except that possibly less area in the middle of the slope will be disturbed.

4.5 Cut Only

The cut only will result in the total removal of vegetation from Zones A, B and C, plus removal of shade trees above the current top of bank. In the area of the failure, the material that has slumped into the river will have to be removed, and the base of the toe will have to be hardened. This may result in siltation in the river.

4.6 River Diversion at the Cockshutt Bridge

In order to accomplish this, a channel approximately 1.75 km in length would have to be cut. The depth of the cut would be in excess of 30 m in some places, so that it would have to be quite wide in order to have stable slopes. Although no rare communities or species were observed in this area, there would be a loss of terrestrial habitat.

The ramifications of this alternative on the aquatic environment could be extreme. By cutting off the oxbow, approximately 15 km of river will be lost and will no longer provide habitat for fish. If the diversion results in a change in flow downstream, this could affect the fish populations. The construction may also introduce sediments into the river. If the oxbow is not completely dried up, the water in it is likely to be stagnant and of poor quality.

The river diversion does not stabilize the bank at Colborne Street, so the bank will still fail resulting in a loss of vegetation on the slope.

5.0 EVALUATION OF THE ALTERNATIVES

The first five alternatives (do nothing, relocate Colborne Street, fill, cut and fill, and cut) do not pose significant adverse impacts to the natural environment. From a biological perspective, there is no reason why any of these could not be implemented.

Diverting the river at the Cockshutt bridge has the potential to cause significant adverse impacts upon the aquatic community and possibly upon terrestrial habitat. Considerably more research than was conducted during this study would be required to determine the potential ramifications of this alternative. Because of the uncertainties and the high potential for damage to the environment, this alternative is not recommended.

Of the remaining five viable alternatives, they are ranked below in order of preference. This is based on the discussion in Section 4, and considers biological factors only:

- 1) cut and fill
- 2) fill
- 3) cut
- 4) do nothing
- 5) relocate Colborne Street

The latter two do not necessarily do more damage to the environment than the first three. With the first three, however, sedimentation to the river can be controlled.

6.0 MITIGATION

The following comments on mitigation refer only to the fill, cut and fill, and cut alternatives. The river diversion at the Cockshutt bridge is not considered to be an acceptable alternative. The other two alternatives (do nothing, relocate Colborne Street) assume that nothing is being done to the bank and that nature will be allowed to take its course. This does not preclude the possibility that emergency remedial measures would not be required in future to remove material that constricts the channel of the river.

On the bank itself, once cutting or filling has been completed in an area, it should be seeded as soon as possible to prevent erosion and assist in retaining bank stabilization. As the site will still be relatively steep, a grass/legume mixture is recommended for binding the soil and improving conditions for long-term tree growth. The following mixture applied at a rate of 50 kg/ha should give good results provided fertilizer (10-10-10) at a rate of 300 kg/ha is added at the same time:

30%	Kentucky bluegrass
30%	Perennial ryegrass
20%	Birdsfoot trefoil
10%	Red clover
10%	White clover
<u>100%</u>	

A mulch or mulch mat may be required to ensure a good seed catch.

Planting of trees or shrubs on the slope is not considered necessary. Within a short time span (5-10 years), the site should become naturally treed with a mixture of black walnut and Manitoba maple.

If a new river channel is to be constructed, this should be done, if practical, prior to working on the slope stabilization. This will allow the work at the base of the slope to be done under dry conditions, thereby eliminating the potential for sedimentation from construction. The channel should also be constructed so that most of the material is removed and the walls hardened before the river has contact with it. This also will minimize sedimentation. Although sedimentation should be kept to a minimum at all times, the critical periods are late April and early May and mid June when walleye and bass are spawning.

With the construction of a new channel, there is the potential to create fish spawning habitat and improve conditions for aquatic invertebrates. This could be accomplished by dumping boulders on the floor of the new channel, thereby making the site suitable for walleye and smallmouth bass spawning. This, of course, is only a management option that is not essential.

If the existing channel is to be widened, areas in which construction is being undertaken should be de-watered or enclosed with a silt curtain. This will prevent delivery of sediments to the river.

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ATTACHMENT I
PLANTS OBSERVED

LEGEND

- 1 - Bank failure site, above tracks
- 2 - Bank failure site, below tracks
- 3 - Channel diversion area
- + - Introduced species

	<u>1</u>	<u>2</u>	<u>3</u>
<u>EQUISETACEAE</u>			
<u>HORSETAIL FAMILY</u>			
Equisetum arvense - Field Horsetail	X	X	X
+ E. hyemale - Common Scouring-Rush	X		X
<u>POLYPODIACEAE</u>			
<u>FERN FAMILY</u>			
Pteretis pensylvanica - Ostrich Fern		X	
Dryopteris spinulosa - Spinulose Woodfern			X
Athyrium filix-femina - Lady Fern	X		X
<u>PINACEAE</u>			
<u>PINE FAMILY</u>			
Abies balsamea - Balsam Fir			X
Tsuga canadensis - Hemlock	X		
+ Picea abies - Norway Spruce	X		X
P. glauca - White Spruce	X		X
+ Pinus banksiana - Jack Pine			X
+ P. resinosa - Red Pine			X
P. strobus - White Pine	X		X
+ P. sylvestris - Scotch Pine	X		X
Thuja occidentalis - White Cedar		X	X
Juniperus virginiana - Red Cedar			X
<u>TYPHACEAE</u>			
<u>CATTAIL FAMILY</u>			
Typha latifolia - Common Cattail	X		X
<u>GRAMINEAE</u>			
<u>GRASS FAMILY</u>			
+ Bromus inermis - Awnless Brome			X
+ Poa compressa - Canada Bluegrass	X		
P. pratensis - Kentucky Bluegrass	X		
+ Dactylis glomerata - Orchard Grass	X	X	X
+ Phragmites communis - Common Reed Grass	X		
+ Agropyron repens - Witch Grass	X		X
Elymus virginicus - Virginia Wild Rye	X	X	X
Hystrix patula - Bottle-brush Grass			X
+ Agrostis stolonifera - Redtop	X		
+ Phleum pratense - Timothy	X	X	X
Phalaris arundinaceae - Reed Canary-Grass		X	X
Panicum capillare - Old Witch Grass	X	X	X
+ Echinochloa crusgalli - Barnyard Grass	X	X	X
+ Setaria glauca - Yellow Foxtail	X		
+ S. viridis - Green Foxtail	X	X	X
+ Zea mays - Corn			X
<u>CYPERACEAE</u>			
<u>SEDGE FAMILY</u>			
Cyperus strigosus - Straw-coloured Cyperus		X	
Scirpus atrovirens - Dark Green Bulrush	X		

	<u>1</u>	<u>2</u>	<u>3</u>
<u>LEMNACEAE</u>			
<u>DUCKWEED FAMILY</u>			
Lemna minor - Lesser Duckweed	X	X	
<u>JUNCACEAE</u>			
<u>RUSH FAMILY</u>			
Juncus dudleyi - Dudley's Rush	X		
<u>LILIACEAE</u>			
<u>LILY FAMILY</u>			
+ Hemerocallis fulva - Day-Lily	X	X	
+ Asparagus officinalis - Asparagus	X		X
<u>IRIDACEAE</u>			
<u>IRIS FAMILY</u>			
Iris versicolor - Larger Blue Flag	X	X	
<u>ORCHIDACEAE</u>			
<u>ORCHIS FAMILY</u>			
+ Epipactis helleborine Helleborine			X
<u>SALICACEAE</u>			
<u>WILLOW FAMILY</u>			
+ Salix babylonica - Weeping Willow	X	X	
+ S. fragilis - Crack Willow	X	X	X
S. nigra - Black Willow	X	X	
+ Populus alba - White Poplar	X	X	
P. balsamifera - Balsam Poplar			X
P. deltoides - Cottonwood	X	X	X
P. grandidentata - Large-toothed Aspen	X		
P. tremuloides - Trembling Aspen	X		X
<u>JUGLANDACEAE</u>			
<u>WALNUT FAMILY</u>			
Juglans nigra - Black Walnut	X	X	X
Carya cordiformis - Bitternut Hickory	X		X
C. ovalis - Sweet Pignut Hickory	X		
C. ovata - Shagbark Hickory	X		X
<u>CORYLACEAE</u>			
<u>HAZEL FAMILY</u>			
Corylus cornuta - Beaked Hazel			X
Ostrya virginiana - Hophornbeam			X
Carpinus caroliniana - Blue Beech	X		X
Betula papyrifera - White Birch			X
+ Alnus glutinosa - Black Alder			X
A. rugosa - Speckled Alder			X
<u>FAGACEAE</u>			
<u>BEECH FAMILY</u>			
Quercus alba - White Oak	X	X	X
Q. macrocarpa - Bur Oak	X	X	X
Q. rubra - Red Oak	X		X
Q. velutina - Black Oak	X		X
<u>ULMACEAE</u>			
<u>ELM FAMILY</u>			
Ulmus americana - White Elm	X	X	X
U. rubra - Red Elm	X	X	X
Celtis occidentalis - Hackberry		X	X

	<u>1</u>	<u>2</u>	<u>3</u>
<u>MORACEAE</u> <u>MULBERRY FAMILY</u>			
+ <u>Morus alba</u> - White Mulberry	X	X	
<u>M. rubra</u> - Red Mulberry	X	X	
<u>URTICACEAE</u> <u>NETTLE FAMILY</u>			
<u>Urtica gracilis</u> - Slender Nettle		X	X
<u>ARISTOLOCHIACEAE</u> <u>BIRTHWORT FAMILY</u>			
<u>Asarum canadense</u> - Wild Ginger			X
<u>POLYGONACEAE</u> <u>BUCKWHEAT FAMILY</u>			
+ <u>Rumex crispus</u> - Curled Dock	X	X	X
+ <u>R. obtusifolius</u> - Broad Dock	X	X	X
+ <u>Polygonum aviculare</u> - Prostrate Knotweed	X		
<u>P. coccineum</u> - Swamp Smartweed	X		X
+ <u>P. cuspidatum</u> - Japanese Knotweed	X		
+ <u>P. persicaria</u> - Lady's-Thumb	X	X	
+ <u>P. scandens</u> - Climbing False Buckwheat	X	X	
<u>CHENOPODIACEAE</u> <u>GOOSEFOOT FAMILY</u>			
+ <u>Chenopodium album</u> - Lamb's-Quarters	X	X	X
<u>AMARANTHACEAE</u> <u>AMARANTH FAMILY</u>			
+ <u>Amaranthus graecizans</u> - Tumbleweed		X	
<u>PHYTOLACCACEAE</u> <u>POKEWEED FAMILY</u>			
<u>Phytolacca americana</u> - Pokeweed	X		
<u>CARYOPHYLLACEAE</u> <u>PINK FAMILY</u>			
+ <u>Silene noctiflora</u> - Night-flowering Catchfly	X		
<u>RANUNCULACEAE</u> <u>CROWFOOT FAMILY</u>			
+ <u>Ranunculus acris</u> - Common Buttercup		X	
<u>R. sceleratus</u> - Cursed Buttercup		X	
<u>Thalictrum dioicum</u> - Early Meadow-Rue	X		X
<u>T. polygamum</u> - Tall Meadow-Rue		X	X
<u>Anemone canadensis</u> - Canada Anemone	X	X	X
<u>A. riparia</u> - Thimbleweed		X	
<u>Clematis virginiana</u> - Virgin's-Bower	X	X	X
<u>Actaea pachypoda</u> - White Baneberry			X
<u>A. rubra</u> - Red Baneberry			X
<u>BERBERIDACEAE</u> <u>BARBERRY FAMILY</u>			
+ <u>Berberis thunbergii</u> - Japanese Barberry	X		X
<u>PAPAVERACEAE</u> <u>POPPY FAMILY</u>			
+ <u>Chelidonium majus</u> - Celandine	X	X	X

	<u>1</u>	<u>2</u>	<u>3</u>
<u>CRUCIFERAE</u>			
<u>MUSTARD FAMILY</u>			
+ Capsella bursa-pastoris - Shepherd's-Purse	X	X	
+ Brassica nigra - Black Mustard	X		
+ Allaria officinalis - Garlic Mustard	X	X	X
+ Sisymbrium officinale - Hedge Mustard	X		
+ Barbarea vulgaris - Yellow Rocket	X	X	
<u>SAXIFRAGACEAE</u>			
<u>SAXIFRAGE FAMILY</u>			
Ribes cynosbati - Pasture Gooseberry			X
+ R. sativum - Garden Red Currant	X	X	X
<u>ROSACEAE</u>			
<u>ROSE FAMILY</u>			
Physocarpus opulifolius - Ninebark			X
Spiraea alba - Narrow-leaved Meadowsweet		X	
Pyrus americana - American Mountain-Ash	X		
+ P. malus - Apple	X	X	X
Amelanchier laevis - Smooth Juneberry			X
Crataegus sp. - Hawthorn	X	X	X
Fragaria virginiana - Common Strawberry	X		X
+ Potentilla recta - Rough-fruited Cinquefoil	X		X
P. simplex - Common Cinquefoil	X		
+ Geum aleppicum - Yellow Avens	X	X	X
G. canadense - White Avens	X	X	X
Rubus allegheniensis - Blackberry	X	X	X
+ R. idaeus - Red Raspberry	X	X	X
R. occidentalis - Black Raspberry	X		X
R. odoratus - Purple-flowering Raspberry	X		
Agrimonia gryposepala - Agrimony	X		X
Rosa blanda - Smooth Rose	X		X
R. palustris - Swamp Rose		X	
Prunus pensylvanica - Pin Cherry			X
P. serotina - Black Cherry	X	X	X
P. virginiana - Chokecherry		X	
<u>LEGUMINOSAE</u>			
<u>PULSE FAMILY</u>			
+ Trifolium hybridum - Alsike Clover	X		
+ T. pratense - Red Clover	X	X	X
+ Melilotus alba - White Sweet Clover	X	X	X
+ Medicago sativa - Alfalfa	X	X	X
+ Robinia pseudo-acacia - Black Locust	X	X	X
+ Vicia cracca - Cow Vetch	X		
+ Glycine max - Soy-Bean			X
<u>OXALIDACEAE</u>			
<u>WOOD-SORREL FAMILY</u>			
+ Oxalis europaea - Yellow Wood-Sorrel	X		
O. stricta - Yellow Wood-Sorrel	X		
<u>GERANIACEAE</u>			
<u>GERANIUM FAMILY</u>			
Geranium robertianum - Herb-Robert			X

	<u>1</u>	<u>2</u>	<u>3</u>
<u>SIMARUBACEAE</u>			
+ <u>Ailanthus altissima</u> - Tree-of-Heaven	X		
<u>EUPHORBIACEAE</u>			
<u>Acalypha rhomboidea</u> - Three-seeded Mercury	X		
<u>ANACARDIACEAE</u>			
<u>Rhus glabra</u> - Smooth Sumac	X	X	X
<u>R. radicans</u> - Poison Ivy	X	X	X
<u>R. typhina</u> - Staghorn Sumac	X	X	X
<u>CELASTRACEAE</u>			
<u>Euonymus obovatus</u> - Running Strawberry-Bush			X
<u>ACERACEAE</u>			
<u>Acer negundo</u> - Manitoba Maple	X	X	X
+ <u>A. platinoides</u> - Norway Maple	X		
<u>A. rubrum</u> - Red Maple			X
<u>A. saccharinum</u> - Silver Maple	X	X	X
<u>A. saccharum</u> - Sugar Maple	X	X	X
<u>BALSAMIFERAE</u>			
<u>Impatiens capensis</u> - Spotted Touch-Me-Not		X	X
<u>RHAMNACEAE</u>			
+ <u>Rhamnus cathartica</u> - Common Buckthorn	X	X	X
<u>VITACEAE</u>			
<u>Parthenocissus inserta</u> - Thicket Creeper	X	X	X
<u>Vitis riparia</u> - Riverbank Grape	X	X	X
<u>TILIACEAE</u>			
<u>Tilia americana</u> - Basswood			X
<u>MALVACEAE</u>			
+ <u>Malva neglecta</u> - Cheeses	X		
<u>GUTTIFERAE</u>			
+ <u>Hypericum perforatum</u> - Common St. John's-Wort	X	X	X
<u>VIOLACEAE</u>			
<u>Viola sp.</u> - Violet	X	X	X
<u>LYTHRACEAE</u>			
+ <u>Lythrum salicaria</u> - Purple Loosestrife	X	X	X
<u>ONAGRACEAE</u>			
<u>Epilobium coloratum</u> - Northern Willow-herb	X	X	X
<u>Oenothera biennis</u> - Common Evening-Primrose	X	X	X
<u>Circaea quadrisulcata</u> - Enchanter's Nightshade	X		X

	<u>1</u>	<u>2</u>	<u>3</u>
<u>UMBELLIFERAE</u>			
<u>PARSLEY FAMILY</u>			
+ <i>Pastinaca sativa</i> - Wild Parsnip	X		
+ <i>Daucus carota</i> - Wild Carrot	X	X	X
<u>CORNACEAE</u>			
<u>DOGWOOD FAMILY</u>			
<i>Cornus alternifolia</i> - Alternate-leaved Dogwood			X
<i>C. racemosa</i> - Gray Dogwood	X	X	X
<i>C. stolonifera</i> - Red-osier Dogwood	X	X	X
<u>PYROLACEAE</u>			
<u>WINTERGREEN FAMILY</u>			
<i>Monotropa hypopithys</i> - Pinesap			X
<u>PRIMULACEAE</u>			
<u>PRIMROSE FAMILY</u>			
<i>Lysimachia ciliata</i> - Fringed Loosestrife		X	X
<u>OLEACEAE</u>			
<u>OLIVE FAMILY</u>			
<i>Fraxinus americana</i> - White Ash	X	X	X
+ <i>Syringa vulgaris</i> - Common Lilac	X	X	X
<u>APOCYNACEAE</u>			
<u>DOGBANE FAMILY</u>			
+ <i>Vinca minor</i> - Periwinkle	X		
<i>Apocynum androsaemifolium</i> - Spreading Dogbane	X		
<u>ASCELPIADACEAE</u>			
<u>MILKWEED FAMILY</u>			
<i>Asclepias syriaca</i> - Common Milkweed	X	X	X
<u>BORAGINACEAE</u>			
<u>BORAGE FAMILY</u>			
+ <i>Echium vulgare</i> - Viper's Bugloss			X
<u>VERBENACEAE</u>			
<u>VERVAIN FAMILY</u>			
<i>Verbena urticifolia</i> - White Vervain	X	X	X
<u>LABIATAE</u>			
<u>MINT FAMILY</u>			
+ <i>Nepeta cataria</i> - Catnip	X	X	X
+ <i>Glechoma hederacea</i> - Gill-over-the-Ground	X		X
+ <i>Prunella vulgaris</i> - Heal-All	X	X	X
+ <i>Leonurus cardiaca</i> - Motherwort	X	X	X
<i>Monarda fistulosa</i> - Wild Bergamot		X	
<i>Lycopus americanus</i> - Cut-leaf Water-Horehound		X	X
<u>SOLANACEAE</u>			
<u>NIGHTSHADE FAMILY</u>			
+ <i>Solanum dulcamara</i> - Bittersweet Nightshade	X	X	X
<u>SCROPHULARIACEAE</u>			
<u>FIGWORT FAMILY</u>			
+ <i>Verbascum thapsus</i> - Common Mullein	X		X
+ <i>Linaria vulgaris</i> - Butter-and-Eggs	X	X	X
<i>Scrophularia marilandica</i> - Carpenter's-Square	X	X	
<i>Chelone glabra</i> - Turtlehead	X		
+ <i>Veronica officinalis</i> - Common Speedwell		X	X

	<u>1</u>	<u>2</u>	<u>3</u>
<u>PLANTAGINACEAE</u> <u>PLANTAIN FAMILY</u>			
+ <i>Plantago lanceolata</i> - English Plantain	X		
+ <i>P. major</i> - Common Plantain	X	X	X
<u>RUBIACEAE</u> <u>MADDER FAMILY</u>			
<i>Galium asprellum</i> - Rough Bedstraw			X
+ <i>G. mollugo</i> - Wild Madder		X	X
<u>CAPRIFOLIACEAE</u> <u>HONEYSUCKLE FAMILY</u>			
+ <i>Lonicera tatarica</i> - Tartarian Honeysuckle	X	X	X
<i>Viburnum lentago</i> - Nannyberry			X
+ <i>V. opulus</i> - Guelder-Rose	X	X	X
<i>V. rafinesquianum</i> - Downy Arrow-Wood	X		X
<i>V. trilobum</i> - Highbush Cranberry	X		
<i>Sambucus canadensis</i> - Common Elderberry	X		X
<i>S. pubens</i> - Red Elderberry	X		X
<u>DIPSACACEAE</u> <u>TEASEL FAMILY</u>			
+ <i>Dipsacus sylvestris</i> - Teasel	X	X	X
<u>CUCURBITACEAE</u> <u>GOURD FAMILY</u>			
<i>Sicyos angulatus</i> - Bur-Cucumber		X	X
<i>Echinocystis lobata</i> - Wild Cucumber	X	X	X
<u>COMPOSITAE</u> <u>COMPOSITE FAMILY</u>			
<i>Eupatorium maculatum</i> - Joe-Pye-Weed	X		
<i>E. rugosum</i> - White Snakeroot		X	X
<i>Solidago caesia</i> - Blue-stemmed Goldenrod			X
<i>S. canadensis</i> - Canada Goldenrod	X	X	X
<i>S. flexicaulis</i> - Zig-zag Goldenrod			X
<i>S. graminifolia</i> - Lance-leaved Goldenrod	X	X	X
<i>S. nemoralis</i> - Gray Goldenrod		X	X
<i>Aster cordifolius</i> - Heart-leaf Aster			X
<i>A. lanceolatus</i> - Panicked Aster	X	X	X
<i>A. lateriflorus</i> - Calico Aster	X	X	X
<i>A. novae-angliae</i> - New England Aster	X	X	X
<i>Erigeron annuus</i> - Daisy Fleabane		X	
<i>E. canadensis</i> - Horsetweed	X	X	
<i>E. strigosus</i> - Rough Daisy Fleabane	X	X	
<i>Ambrosia artemisiifolia</i> - Common Ragweed	X	X	X
<i>A. trifida</i> - Great Ragweed	X	X	X
<i>Xanthium chinense</i> - Clotbur	X	X	X
+ <i>Rudbeckia serotina</i> - Black-eyed Susan	X	X	
+ <i>R. triloba</i> - Thin-leaved Coneflower		X	
<i>Helianthus decapetalus</i> - Thin-leaved Sunflower		X	
<i>H. tuberosus</i> - Jerusalem Artichoke	X		
<i>Bidens cernua</i> - Bur-Marigold	X	X	
<i>B. frondosa</i> - Beggar's Ticks	X		
+ <i>Achillea millefolium</i> - Yarrow			X
+ <i>Chrysanthemum leucanthemum</i> - Ox-eye Daisy	X		

	<u>1</u>	<u>2</u>	<u>3</u>
<u>COMPOSITAE (continued)</u> <u>COMPOSITE FAMILY</u>			
+ <i>Tanacetum vulgare</i> - Common Tansy	X	X	X
<i>Artemisia biennis</i> - Biennial Wormwood	X		
+ <i>Tussilago farfara</i> - Coltsfoot	X	X	X
+ <i>Arctium lappa</i> - Great Burdock	X		
+ <i>A. minus</i> - Common Burdock	X	X	X
+ <i>Carduus nutans</i> - Nodding Thistle		X	
+ <i>Cirsium arvense</i> - Canada Thistle	X	X	X
+ <i>C. vulgare</i> - Bull Thistle	X	X	X
+ <i>Cichorium intybus</i> - Chicory	X	X	X
+ <i>Taraxacum officinale</i> - Common Dandelion	X	X	X
+ <i>Sonchus oleraceus</i> - Common Sow-Thistle		X	
<i>Lactuca canadensis</i> - Wild Lettuce	X		X
<i>L. hirsuta</i> - Hairy Lettuce	X	X	
Number of species -	166	125	158
Number of native species -	89	70	100
Percent native species -	53.6	56.0	63.3
Total number of species -	230		

ATTACHMENT II
WILDLIFE OBSERVED

LEGEND

- 1 - Bank failure site, above tracks
- 2 - Bank failure site, below tracks
- 3 - Channel diversion area
- + - Introduced species

	<u>1</u>	<u>2</u>	<u>3</u>
A. <u>REPTILES</u>			
Eastern Garter Snake	X		
No. of Species	<u>1</u>	<u>0</u>	<u>0</u>
B. <u>BIRDS</u>			
Great Blue Heron		X	
Wood Duck		X	
Sharp-shinned Hawk		X	
Red-tailed Hawk			X
Rock Dove			X
Mourning Dove	X	X	
Great Horned Owl			X
Downy Woodpecker	X	X	X
Northern Flicker	X		
Cliff Swallow (old nests)			X
Blue Jay	X	X	X
American Crow	X		
Black-capped Chickadee		X	X
White-breasted Nuthatch	X	X	X
Red-breasted Nuthatch			X
Golden-crowned Kinglet			X
American Robin	X	X	X
Cedar Waxwing	X	X	X
+ European Starling	X		
Northern Cardinal	X	X	X
White-throated Sparrow	X		X
Dark-eyed Junco	X	X	X
Red-winged Blackbird	X		
Purple Finch		X	X
American Goldfinch	X	X	X
+ House Sparrow	X		
No. of species	<u>15</u>	<u>14</u>	<u>17</u>
C. <u>MAMMALS</u>			
Eastern Cottontail	X		
Eastern Chipmunk	X		X
Woodchuck		X	X
Grey Squirrel	X	X	X
Meadow Vole			X
Raccoon			X
White-tailed Deer		X	X
No. of species	<u>3</u>	<u>3</u>	<u>6</u>
Total no. of species	19	17	23

Grand total - 34



**Philips
Planning
+ Engineering
Limited**

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**APPENDIX VI
PROPERTY VALUATIONS**

**PRELIMINARY ENGINEERING STUDY
GRAND RIVER VALLEY WALL SLOPE FAILURE
COLBORNE STREET EAST
BRANTFORD, ONTARIO**

July 1987

Project: 36105

TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1
2.0 ZONING	3
2.1 Area "A"	3
2.2 Area "B"	4
2.3 Area "C"	5
2.4 Area "D"	6
2.5 Area "E"	7
2.6 Area "F"	7
2.7 Area "G"	8
3.0 SITE DESCRIPTION	9
4.0 APPRAISAL PROBLEMS	10
5.0 DESCRIPTION OF IMPROVEMENTS	12
6.0 CONTINGENT OR LIMITING CONDITIONS	13
7.0 SUMMARY	14

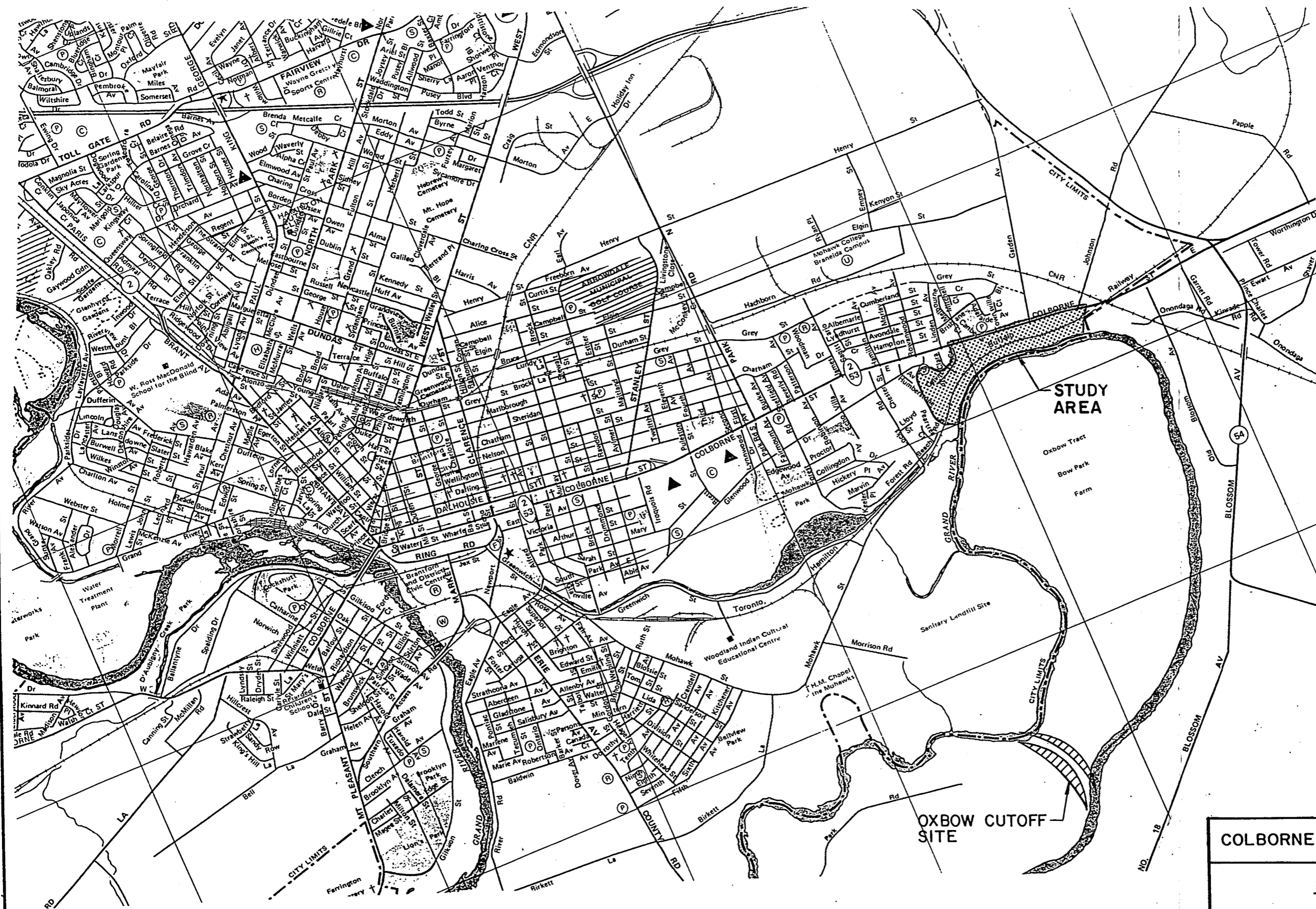
LIST OF FIGURES

Figure No.	Description	Page
VI-1	Key Plan	2
VI-2	Zoning Areas	8
VI-3	Property Valuation Summary	15

1.0 INTRODUCTION

In accordance with the Terms of Reference, Philips Planning and Engineering Limited retained the services of Louis A. Emsley, Professional Real Estate Appraiser, to carry out a preliminary appraisal of all properties within the study area. This report presents the finishing of these appraisals in a format consistent with the intent of this investigation. As per the Terms of Reference¹, visual inspection was carried out on the exterior of properties located on the north and south sides of Colborne Street, from the easterly leg of Clara Crescent to the Toronto, Hamilton and Buffalo right-of-way, properties fronting on the east and south sides of Clara Crescent, and properties located on the easterly portion of Beach Road, for the purpose of providing a preliminary estimate of the value of the properties required for the various proposals currently under review. The area of study is shown in Figure VI-1.

Since the report is for estimation purposes only, in order to evaluate the various schemes and proposals to be studied and reviewed, none of the properties were measured or inspected, which would be the normal approach to estimate a supportable and defensible market value. It is understood that a detailed report will be required on each individual property deemed to be required based on the final scheme chosen.



COLBORNE STREET SLOPE FAILURE

KEY MAP OF AREA



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86105

FIGURE NO.

VI-1

2.0 ZONING

Under By-law 3649, being a by-law to prohibit certain uses of land, buildings and structures, and to regulate the height, bulk, location, space, character and use of buildings and structures in the City of Brantford, the lands are zoned as follows:

2.1 Area "A"

Calvin Street and south side of Clara Crescent to a point in the easterly limit of the easterly leg of Clara Crescent, 282 feet south of Colborne Street.

Zoned Single Family Two (SF2).

Permitted Uses:

1. Single family residence;
2. Municipal use;
3. Open space;
4. Farm use;
5. Private greenhouse;
6. Accessory buildings;
7. Two boarders;
8. Church;
9. Physician's office in dwelling;
10. Public highway or registered lane;
11. Signs;
12. Day nursery;
13. One operator beauty parlour in dwelling.

Use 13 was added by By-law 155-74, amending By-law 3649.

2.2 Area "B"

South side of Colborne Street from east side of Clara Crescent to the production southerly of the east limit of Garden Avenue, and extending southerly to the right-of-way of the Toronto, Hamilton and Buffalo Railway.

Zoned General Business (GB) under By-law 3649.

Permitted Uses:

1. Single family residence;
2. Municipal use;
3. Open space;
4. Farm use;
5. Private greenhouse;
6. Accessory buildings;
7. Two boarders;
8. Church;
9. Physician's office in dwelling;
10. Public highway or registered lane;
11. Signs;
12. Day nursery;
13. One operator beauty Parlour in dwelling;
14. Up to three boarders;
15. Bank;
16. Motor vehicle storage garage related to a business;
17. Hotel, motel;
18. Funeral home;
19. Business or professional office;
20. Retail stores;
21. Places of amusement;
22. Signs for business or profession;
23. Commercial greenhouse;
24. Any light industry not encroaching within 40 feet of street line;
25. Public places of amusement or assembly;
26. Field advertising or billboards;
27. Public utilities;

28. Public garage or service station;
29. Newspaper printing or publishing;
30. Institution or club;
31. Warehouse;
32. Laundry or dry cleaning;
33. Tavern;
34. Repair shop;
35. Car sales lot;
36. Manual or automatic car washes.

Uses are as amended under By-law 155-74.

2.3 Area "C"

South side of Colborne Street from projection of the centre line of Garden Avenue to the south limit of the Toronto, Hamilton and Buffalo Railway, and extending to the intersection of the railway right-of-way and Colborne Street.

Zoned under By-law 11-83 Multi-Family

Permitted Uses:

1. Single family residence;
2. Municipal use;
3. Open space;
4. Farm use;
5. Private greenhouse;
6. Accessory buildings;
7. Two boarders;
8. Church;
9. Physician's office in dwelling;
10. Public highway or registered lane;
11. Signs;
12. Day nursery;
13. One operator beauty parlour in dwelling;
14. Two-family dwelling, semi-detached, duplex, double duplex, back-to-back quadruplex;
15. Up to four boarders;

16. Multiple dwelling;
17. Rooming house or tourist home;
18. Private club;
19. Private garage;
20. Private hospital or nursing home;
21. Two operator beauty parlour in dwelling;
22. Two chair barbershop;
23. Signs.

Uses from 16 to 23 inclusive were added by By-law 155-74, being an amendment to By-law 3649.

By-law 11-83 also states under Section 3:

- 3.1 Notwithstanding the provisions of Section 8.3 of By-law 3649, no multiple dwelling hereafter erected on the lands in said Schedule "E", and shown on said Schedule "L", shall exceed three storeys in height.
- 3.2 The provisions of Section 8.5(C) and 8.5(D) of By-law 3649 shall not apply to the lands described in said Schedule "E", and shown on said Schedule "L". (Sections 8.5(C) and 8.5(D) limit the lot coverage and floor area.)
- 3.3 Any development hereafter established on any lot located in the lands described in said Schedule "E", and shown on said Schedule "L", shall not exceed a density of 40 dwellings per gross hectare.
- 3.4 Notwithstanding any provision of By-law Number 3649, any building for human occupancy hereafter erected on the lands described in said Schedule "E", and shown on Schedule "L", shall be connected to the municipal water supply system, and municipal sanitary sewer system, connected to the municipal water pollution control facility.

2.4 Area "D"

Located directly south and abutting Area "C". The northerly portion of Area "D" is zoned Hazard Land, and the southerly portion is zoned Conservatin (zoned under By-law 11-83).

2.5 Area "E"

North side of Colborne Street, commencing at 950 Colborne Street, and extending easterly to the centre line of Garden Avenue.

Zoned General Business, with the same permitted uses as Area "B" (zoned under By-law 3649).

2.6 Area "F"

North-east intersection of Colborne Street and Garden Avenue, and extending approximately 144 ft. easterly.

Zoned General Business (GB) under By-law 11-83, which permits the following land uses:

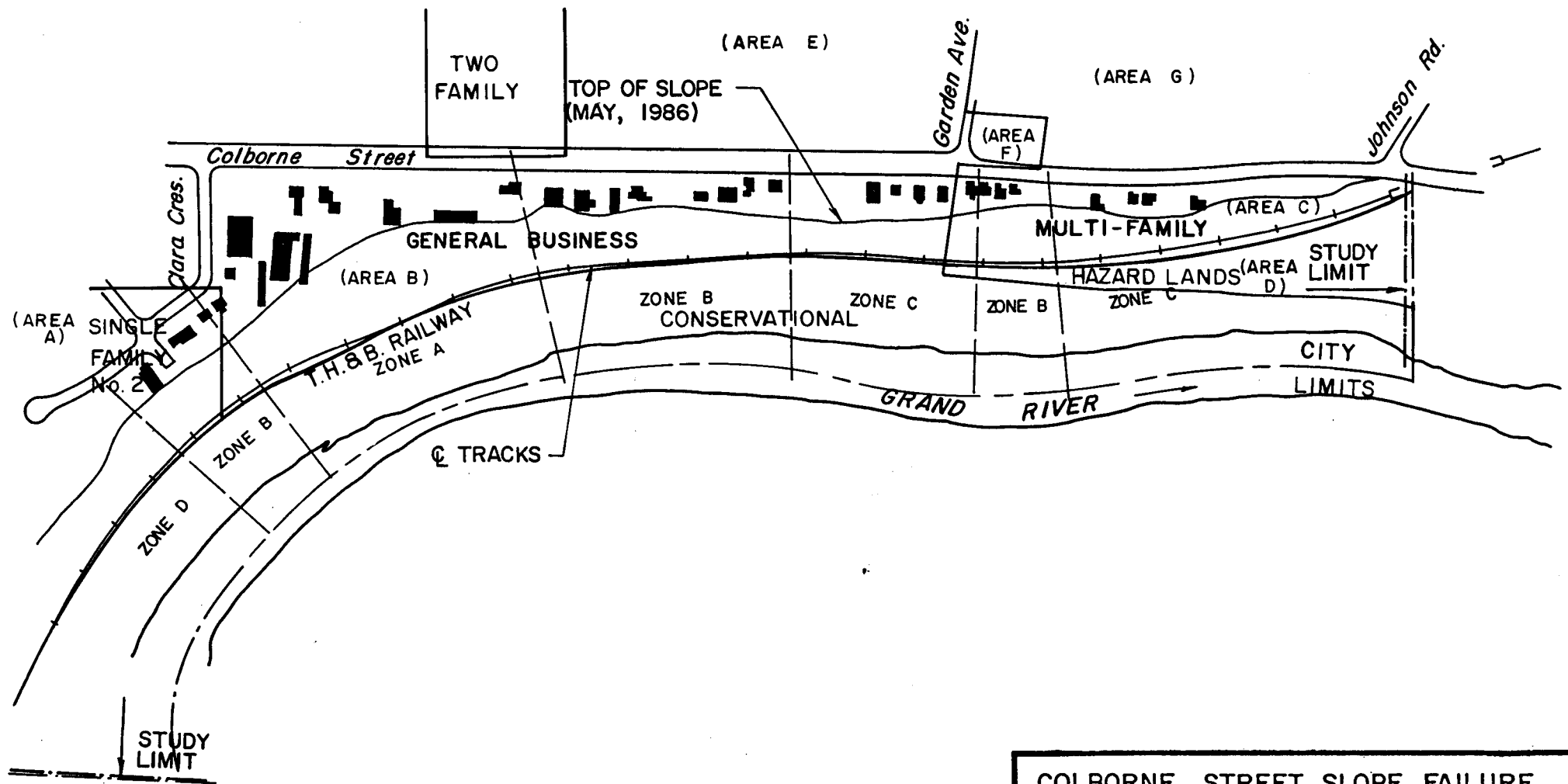
1. automotive rental establishment;
2. automotive sales established with or without repair facilities;
3. agricultural and industrial equipment sales and service establishment;
4. recreational vehicle sales and service establishment;
5. gasoline service station;
6. public garage;
7. a retail store limited to the sale of automotive accessories;
8. car washing facility;
9. a retail store limited to the sale of building supplies;
10. a private club;
11. a racquet facility;
12. a roller rink;
13. a veterinary clinic with or without kennels;
14. a market gardening facility;
15. buildings, structures and uses accessory to a principal use.

2.7 Area "G"

Located on the north side of Colborne Street, commencing 144 ft. east of the centre line of Garden Avenue, and extending to Johnson Road.

Zoned Mult-Family (zoned under By-law 11-83). Uses permitted are the same as Area "C".

Each of the zoning areas described above are noted on Figure VI-2.



COLBORNE STREET SLOPE FAILURE

EXISTING ZONING



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FIGURE Nº
VI-2

SOURCE : ZONING BY-LAW No.3649

3.0 SITE DESCRIPTION

Clara Crescent is a two lane, paved, residential street, south of Colborne Street and, with the exception of sidewalks, is fully serviced with storm and sanitary sewers, municipal water supply, natural gas, hydro, street lighting and telephone service. With the exception of a restaurant fronting on Colborne Street, and a retail lumber yard with access from the easterly leg of the street there are no land uses considered to create economic obsolescence with respect to residential use.

Colborne Street, from Clara Crescent to Garden Avenue, is a four lane, paved, arterial road, with centre turning land, which is a major access from the east to the city, and is the connecting link within the city limits of Highways #2 and #53. As a result, the road is heavily trafficked, but is, to some extent, relieved of some through traffic by the Highway #403 connection with Highway #2 east of the city limit. The properties fronting this section are fully serviced with storm and sanitary sewers, curb and gutter, municipal water supply, natural gas, hydro, street lighting, and telephone service. The north side has a sidewalk the full length of the street, while the sidewalk on the south side extends to 973 Colborne Street.

The easterly section, from Garden Avenue easterly, is a two lane, paved street, albeit a relatively wide two lane, which leads into the four lane section of Colborne Street, and is also heavily used. Since the area was annexed to the City of Brantford, effective January 1st. 1981, the area is not serviced with municipal storm and sanitary sewers.

Beach Road is a relatively narrow road, extending easterly from Locks Road, which deteriorates to a virtual laneway after the crossing of the T.H. and B. Railway right-of-way. The easterly section parallels the railway, and subject lands are located between the road and the Grand River. The properties are isolated, and without municipal services.

4.0 APPRAISAL PROBLEMS

1. Since this report is prepared for the purpose of estimating the land acquisition cost, to be incorporated with other costs of various schemes and proposals related with respect to the remedial work to be undertaken in the Colborne Street landslide area, the properties were not measured or inspected on an individual basis.
2. The estimates are based on information gathered from sources believed to be reliable and "windshield" inspections. The market values, as estimated, are based on the market value of the properties prior to the landslide, and based on the following definition of "value":

"For the purpose of this report, market value is defined as being the highest price estimated in terms of money which a property would bring, if exposed for sale on the open market, by a willing seller, allowing a reasonable length of time to find a purchaser who buys with full knowledge of all uses of which it is capable of being adapted, and for which it is capable of being used."

3. The definition of market value states "all uses to which it is capable of being adapted". In other words, the highest and best use, which is defined as follows: The value of the property results from the use to which it is put, and varies with the profitability of that use: the present and prospective, actual and anticipated. There is no pecuniary value aside from that which results from such use. The amount and profitable character of such use determines the value.

The criteria for determining highest and best use include:

- (1) The use must be within the realm of possibility: a likely one, not speculative or conjectural.
- (2) A demand for such use must exist.
- (3) The use must be profitable.
- (4) The use must provide the highest net return to the land.
- (5) The use must produce the return for the longest possible time.

For the purpose of the preliminary land acquisition costs, the present use of the property is considered the highest and best use.

5.0 DESCRIPTION OF IMPROVEMENTS

A basic description of each property has been prepared which provides a photograph, legal description and land size, assessment and zoning. In addition, any sale of the property during the last five years is provided; however, due to recent increases in the real estate market, the sale will unlikely be of any assistance in estimating current value.

These individual appraisal reports are in our files.

6.0 CONTINGENT OR LIMITING CONDITIONS

1. The legal description, and land frontage, depth and area are based on information contained on the assessment rolls available at the City Clerk's office in City Hall.
2. The estimates are not based on a detailed personal inspection of individual properties, and are considered valid only for preliminary estimating purposes of the proposed project.
3. No responsibility is assumed for matters legal in character nor is there any opinion rendered as to title which is assumed to be good. All existing liens and encumbrances have been disregarded, and the property is appraised as though free and clear, under responsible ownership and competent management.
4. The figures in this report are included to assist the reader in visualizing the property. A survey of the property has not been made as a component of this investigation and there is no assumed responsibility in connection with such matters.
5. The information identified in this report as furnished by others, is believed to be reliable but no responsibility for its accuracy is assumed.
6. Possession of this report, or copy thereof, does not carry with it the right of publication, nor may it be used for any purpose other than the purpose for which it was prepared without the previously written consent of the appraiser and, in any event, only with proper qualification.
7. This report is only considered valid under present market conditions and prevailing interest rates.

7.0 SUMMARY

As a precursor to determining the costs associated with each alternative and to analyze the cost-effectiveness of each of the alternative remedial works, it was necessary to carry out a preliminary property valuation to determine the land costs and benefits associated with carrying out each scheme. In order to determine the market value of a property, it is necessary to obtain information on the sales history of the property, or of similar properties. Unfortunately, the south side of Colborne Street through the study area is unique, since there is no base data to determine the market value of the properties following the May, 1986 slope failure. Therefore the Pre-slide Market Value was determined. A Professional Real Estate Appraiser was retained by the project team to undertake individual, preliminary, pre-slide market value appraisals of each property within the study area. The results of this appraisal are summarized in Figure VI-2 for each of the Alternative rehabilitation schemes. The results are also presented below.

Estimated Land Acquisition Costs

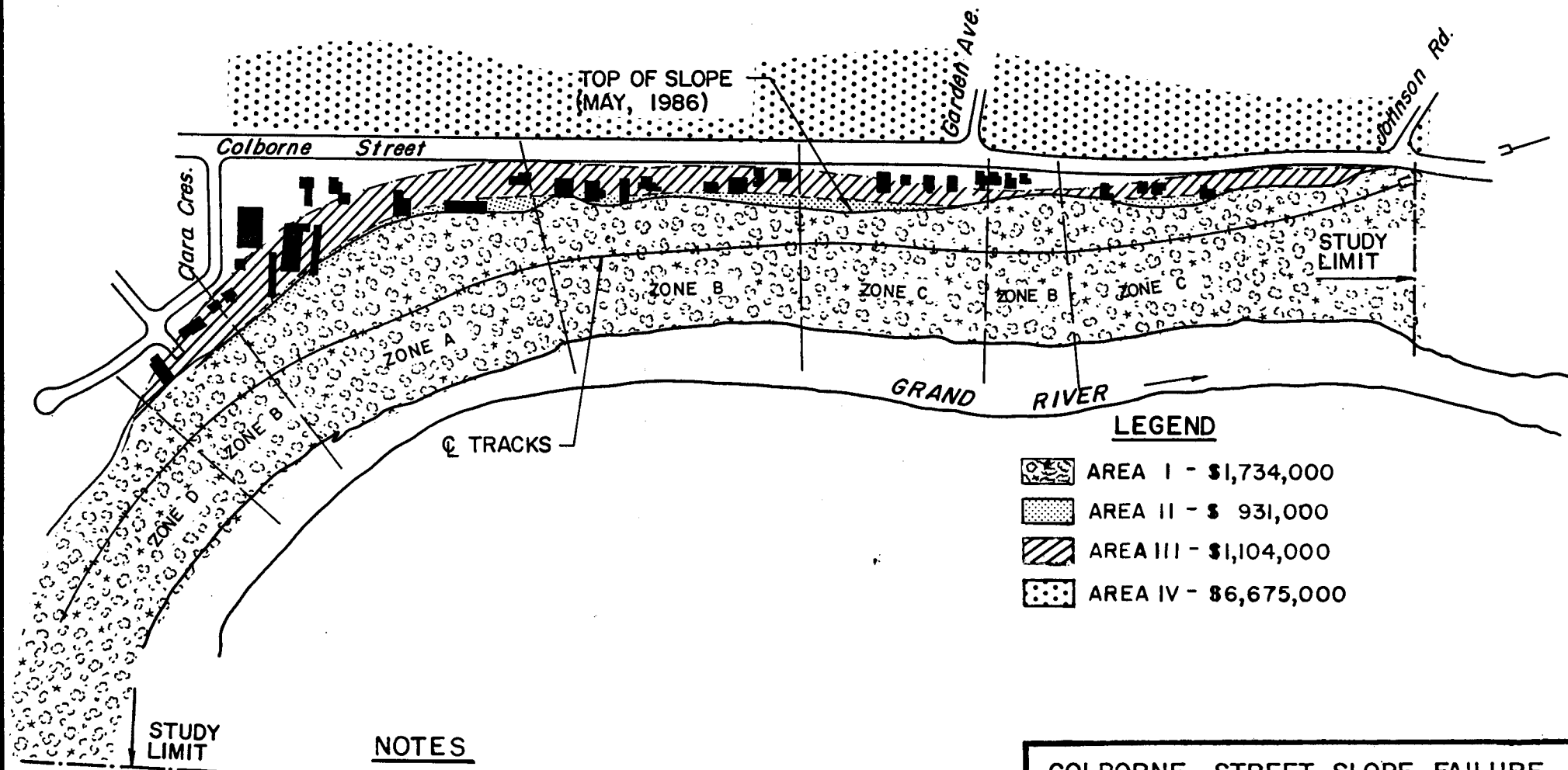
Scheme 1 - Cut Only

South Colborne Street	\$ 3,769,000.
North Colborne Street	<u>\$ 6,675,000.</u>
Total	\$10,444,000.

Scheme 2 - Combined Cut & Fill \$ 2,665,000.

Scheme 3 - Total Fill \$ 1,734,000.

Land South of the River \$ 4,000./acre



LEGEND

	AREA I - \$1,734,000
	AREA II - \$ 931,000
	AREA III - \$1,104,000
	AREA IV - \$6,675,000

NOTES

TOTAL CUT OPTION	= I + II + III	= \$ 3,769,000
PARTIAL FILL OPTION	= I + II	= \$ 2,665,000
TOTAL FILL OPTION	= I	= \$ 1,734,000
NORTH OF COLBORNE STREET		= \$ 6,675,000

COLBORNE STREET SLOPE FAILURE

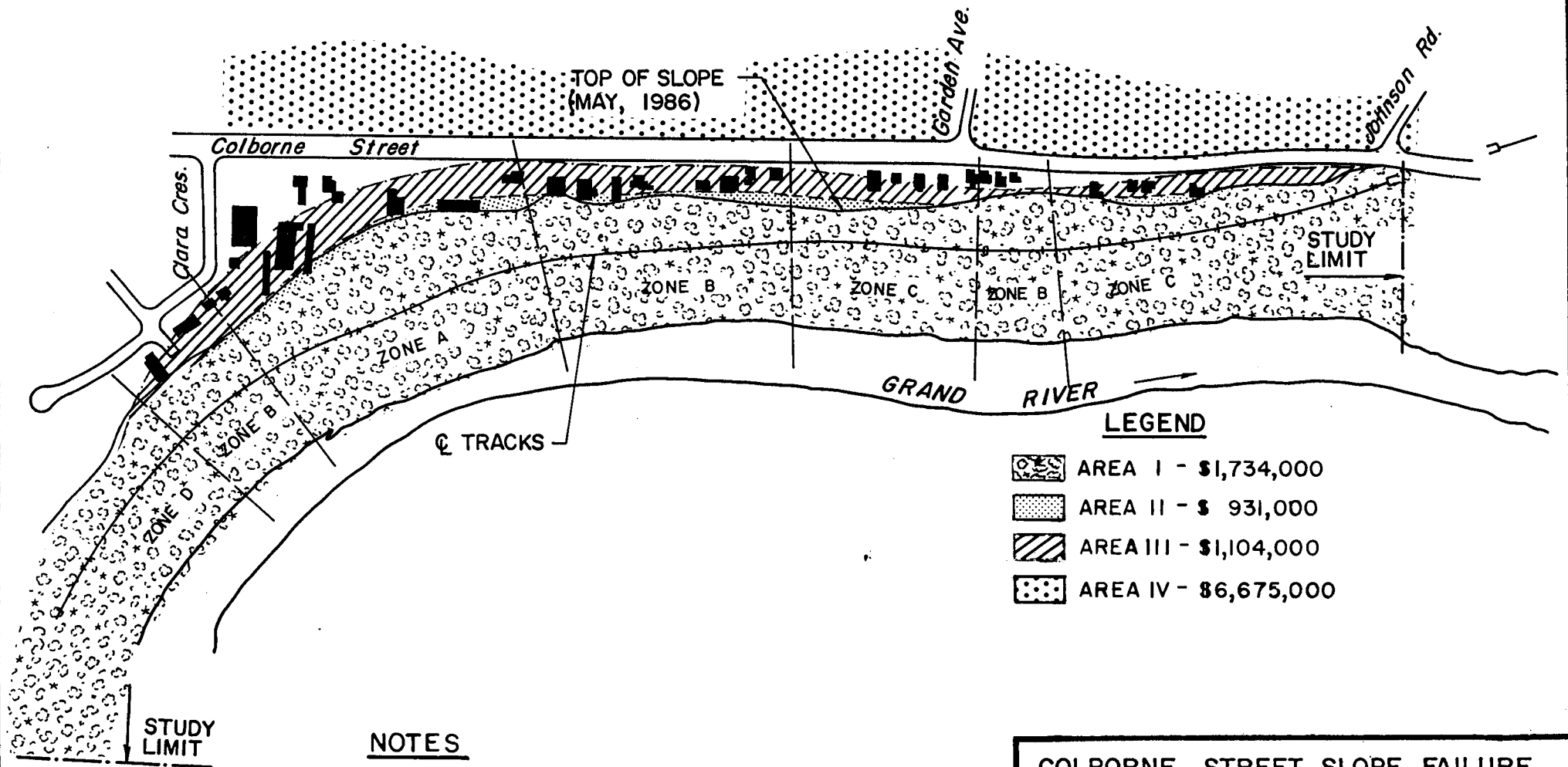
PROPERTY VALUATION SUMMARY



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PROJECT N^o
86105

FIGURE N^o
VI-3



NOTES

TOTAL CUT OPTION	= I + II + III	= \$ 3,769,000
PARTIAL FILL OPTION	= I + II	= \$ 2,665,000
TOTAL FILL OPTION	= I	= \$ 1,734,000
NORTH OF COLBORNE STREET		= \$ 6,675,000

COLBORNE STREET SLOPE FAILURE

PROPERTY VALUATION SUMMARY



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86105

FIGURE Nº
VI-3



**Philips
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Limited**

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Box 220, Burlington,
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416 335 2353
416 525 5981

**APPENDIX VII
ECONOMICS/BENEFIT VERSUS
COST ANALYSIS**

**PRELIMINARY ENGINEERING STUDY
GRAND RIVER VALLEY WALL SLOPE FAILURE
COLBORNE STREET EAST
BRANTFORD, ONTARIO**

July 1987

Project: 86105

TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1
FIGURE VII-1	2
2.0 METHODOLOGY	3
3.0 SUMMARY OF IMPACTS CONSIDERED	9
3.1 Tangible Costs	9
3.1.1 River Training	9
3.1.2 Bank Stabilization	10
3.1.3 Environmental Protection	10
3.1.4 Road Reinstatment	11
3.1.5 Storm Sewer Repairs	11
3.1.6 Railway Reinstatement	11
3.1.7 Services Relocation	11
3.1.8 Engineering and Supervisory	12
3.1.9 Property Acquisition	12
3.1.10 Legal	12
3.1.11 Planning and Approvals	12
3.1.12 Normal Project Maintenance	13
3.1.13 Major Project Maintenance	13
3.2 Tangible Benefits	14
3.2.1 Flood Hazard	14
3.2.2 Railway Maintenance	14
3.2.3 Railway Operating Costs	15
3.2.4 Storm Sewer Maintenance	15
3.2.5 Road Maintenance	16
3.2.6 Increased Property Values	16
3.3 Intangible Costs	16
3.3.1 Loss of Business Income	17
3.3.2 Personal Disruption	17
3.3.3 Relocation Costs	17
3.3.4 Construction Noise, Dust etc.	17
3.3.5 Disruption to the Community	18
3.3.6 Disruption of Services	18
3.3.7 Terrestrial Environmental Impact	18
3.3.8 Aquatic Environmental Impact	18
3.3.9 Traffic Disruption	19

TABLE OF CONTENTS (continued)

	Page
3.4 Intangible Benefits	19
3.4.1 Flow Velocity Maintenance Immediately Downstream	19
3.4.2 Fiscal Planning	19
3.4.3 Reduced Risk to Life and Limb	20
3.4.4 Economic Benefits During Construction	20
4.0 ALTERNATIVES FOR CONSIDERATION	21
5.0 ANALYSIS RESULTS	23
5.1 General	23
5.2 Sensitivity Analysis	23
5.3 Impacts of Phasing on the Benefit-Cost Analysis	24
6.0 CONCLUSIONS	37
7.0 LIST OF REFERENCES	39

LIST OF TABLES

Table No.	Description	Page
VII-1	Benefit Versus Cost - Economic Parameters	7
VII-2	Present Value Calculations for Tangible Benefits and Costs	26
VII-3	Tangible Data Summary	27
VII-4	Intangible Data Summary	28
VII-5	Statistical Evaluations	29
VII-6.1	Evaluation Matrices Page 1 of 4	30
VII-6.2	Evaluation Matrices Page 2 of 4	31
VII-6.3	Evaluation Matrices Page 3 of 4	32
VII-6.4	Evaluation Matrices Page 4 of 4	33
VII-7	Benefit Versus Cost Analysis Summary	34
VII-8	Sensitivity Analysis - May, 1986 Conditions	35
VII-9	Sensitivity Analysis - Recent Developments as of March, 1987	36

1.0 INTRODUCTION

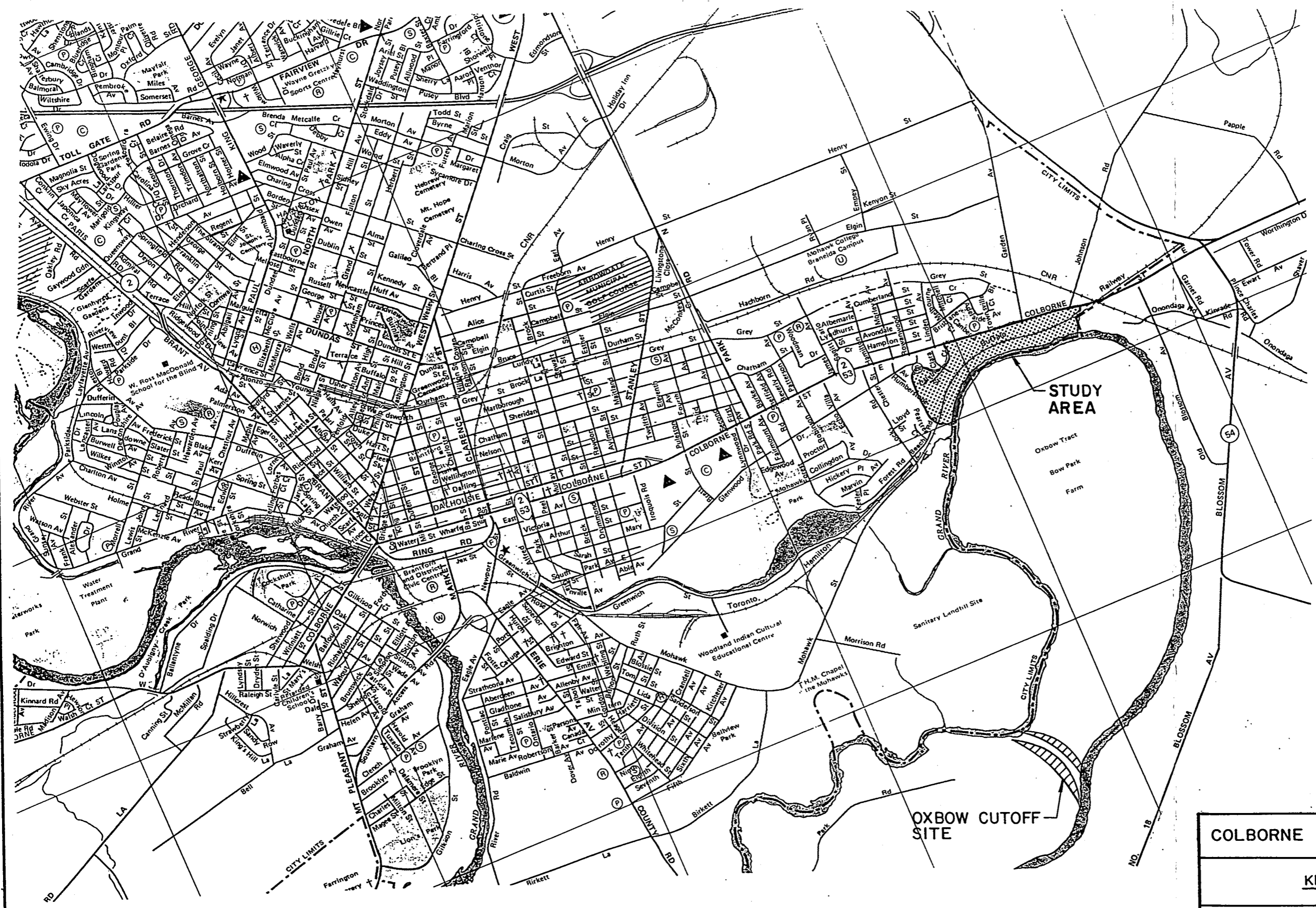
An investigation into the nature and extent of the May, 1986 slope failure adjacent to Colborne Street in Brantford yielded a number of alternative solutions to mitigate the impacts of the defined slope instability. Specific reports have been produced which deal with the following aspects related to the slope failure.


1. Geotechnical Details concerning the failure. (Appendix II)
2. Impacts of the failure on the River Regime. (Appendix III)
3. Potential impacts on transportation facilities and services. (Appendix IV)
4. The formulation of alternative remedial measures for consideration.

Each of these reports provides insight into the problem area (Figure VII-1) and yields information which is required to establish the most desirable alternative for implementation.

In order to determine effectively which of the formulated alternatives is the most desirable to implement, all factors relating to the impacts of each scheme on its surroundings must be considered systematically. In an intention to define the most desirable alternative for slope stabilization, a benefit versus cost and economic analysis is suggested in the Terms of Reference¹.

Philips Planning + Engineering Limited with the co-operation of Ecologistics Limited were retained to develop a benefit versus cost model and to carry out an economic/benefit versus cost analysis to yield the preferred scheme(s) for further consideration.



COLBORNE STREET SLOPE FAILURE		
KEY MAP OF AREA		
	PROJECT NO.	FIGURE NO.
	86105	VI-1

2.0 METHODOLOGY

The benefit versus cost analysis has been undertaken following guidelines documented by the Ministry of Natural Resources². The methods employed and the parameters defined for the analysis strictly follow the methods and suggestions of the Ministry of Natural Resources guidelines.

Assumptions made and values assigned to the various economic parameters are summarized below and in Table VII-1.

- 1) All costs are evaluated in terms of constant 1987 dollar values. A real (non-inflationary) discount rate of 7% is assumed for a base case evaluation, and rates of 5% and 10% are used for sensitivity analysis.
- 2) A time horizon of 50 years is used for all major engineering works. Construction costs are assumed to be incurred within the first year of this period while certain other costs arise within the first two to three years, or are assumed to recur periodically (e.g. project maintenance).
- 3) All costs and benefits are discounted back to year one. The present value of costs and benefits are then adjusted to a base year of 1988 using an assumed inflation rate of 4%. This is done to reflect an assumed 1988 start-up for major construction works.
- 4) Present values are provided for tangible benefits and costs. Costs include all construction capital costs for the alternative mitigative measures, as well as such costs as legal and planning costs, property acquisition costs and costs associated with utilities, transportation, municipal services and water management. A complete estimate of project costs is therefore provided (see Section 3.0 and Table VII-2).

- 5) All preliminary construction costs reflect the current economics of the construction industry as well as the availability of key materials in Brantford.
- 6) Preliminary construction costs are provided for major project components. Other components such as engineering fees, environmental protection costs, project maintenance costs and legal fees are estimated using representative factors.
- 7) Property values are based on formal appraisals of property (Appendix VI) value and reflect property value prior to the slide. In areas at risk south of Colborne St., properties were judged by the land appraiser to be unsalable now and thus to have no current value. Property owners therefore benefit if they receive full value from expropriation proceedings or if remedial work returns their properties to a marketable condition.
- 8) Where possible, project benefits are assigned a dollar for the purposes of economic analysis. There are other benefits such as the protection of life and limb to which a specific dollar value cannot be assigned, and project benefits are not therefore completely covered in the benefit-cost calculations. The present value of costs and benefits are summarized as a net benefit figure for each alternative project (Table VII-3). Benefit-cost ratios are not calculated since these could be misleading when benefits are only partially measured in the quantitative analysis.
- 9) The partial recovery of property acquisition costs at the completion of the project by its resale is a logical way of reducing the cost of the work for the proponent. Obviously the amount recovered would differ for the TOTAL FILL and the CUT/FILL options. An assumption of zero salvage value has been selected, since this value cannot be estimated to any degree of certainty.

To assist in the overall evaluation of alternative projects, a number of costs and benefits that could not be given a dollar value were identified. These "intangible" benefits and costs are evaluated using more qualitative indices that rate the degree of adverse or beneficial impact on a scale from zero to one or minus one to zero (Table VII-4). Where possible the rating is assigned on the basis of available information describing the nature of anticipated impacts (e.g. the number of households or businesses affected). In other cases the rating is based on professional judgement.

Net present value data and rating data for intangible benefits and costs are combined in a summary table of impact data (Table VII-5). This table provides a basis for an overall evaluation of the alternative projects.

All data in Table VII-5 are scaled from zero to one (positive impact) or from minus one to zero (negative impact). Rating data for intangibles were generated in this form from the outset, while the net benefit dollar values were re-scaled from zero to one if positive (net benefit) and from minus one to zero if negative (net cost). Ratings related to costs or adverse impacts are entered as negative values while benefits and beneficial impacts appear as positive values.

The table of impact data (Table VII-5) are provided as a convenient means of summarizing study findings. To help structure a comparison of alternatives, two screening methodologies have been applied to the data to generate an overall ranking of alternatives. With these methods, ratings for each type of impact are combined with assigned weights that measure the relative importance of these impacts.

Values to weight impacts are assigned based on professional judgement and reflect an interpretation of the importance of each benefit and cost in terms of the study objectives. In this sense they are somewhat more subjective than ratings which are meant to reflect technical data on the degree of impact for each alternative. For a given type of impact, the ratings will vary from one alternative to the next. However, weightings do not vary across alternatives but only across impacts. For example, ratings will indicate whether a project cost is high relative to other alternatives but the weight assigned to cost will

indicate how important cost is relative to say risk to life in the overall ranking of projects. Weights assigned to impacts should reflect the priorities of the agencies involved in a planning exercise. These are likely to be variable and not necessarily clearly established. Consequently, it is important to repeat the screening analysis using alternative sets of weights in order to determine if the overall ranking of alternative undertakings is sensitive to different sets of priorities. A sensitivity analysis has been conducted using weighting data assigned by members of the consulting team.

The two screening methodologies that have been applied to the impact data reflect different assumptions about how impact data can be manipulated and aggregated. Their use here constitutes another form of sensitivity analysis in the screening exercise.

In the first method, the rating data for an alternative are multiplied by the weights for each impact and the resulting products are summed to give an overall score for the alternative. High scores correspond to better overall performance.

The second method relies on the performance of each alternative in pair-wise comparisons with other alternatives (Tables VII-6.1 to VII-6.4). The overall ranking of an alternative is based on the frequency with which it outperforms other alternatives. The principal difference between this and the previous method is that ratings for the disparate types of impacts are no longer added together. Performance scores are added only after the rating data for alternatives are compared for each type of impact separately (Table VII-7).

The screening analysis has been programmed using spreadsheet software so that all assumptions regarding ratings or weights can be readily revised and the analysis repeated.

TABLE VII-1
BENEFIT/COST - ECONOMIC PARAMETERS

- * Base Year (Start of Implementation) is 1988.
- * Project Phasing (Number of Years to complete) is 3 years.
- * Inflation Rate is 4 percent (1987 to 1988 only).
- * Real Discount Rate (Interest Rate adjusted for Inflation) is 7 percent.
- * Assumed Project Life is 50 years.
- * Dominance Criterion (Minimum difference Between Ratings in the impact table Considered to be Significant) is 0.05.
- * Colborne Street Failure assumed to occur in the 10th year.
- * Normal Project Maintenance considered to occur on an annual basis.
- * Major Project Maintenance assumed to occur once in every 5 year period.
- * River Training and Property Acquisition occurs in year one.
- * Slope Stabilization and Storm Sewer replacement occurs in year two.
- * Railway Reinstatement occurs in year three.
- * Environmental Protection measures require an annual expenditure over the phasing period.
- * Property Acquisition for Colborne Street Relocation occurs in year 10.
- * Legal Costs represent an annual expenditure over a period equal to twice that of the phasing period.
- * Planning & Approvals require an annual expenditure over a period equal to the phasing period.
- * Savings in Railway Maintenance and Railway Operating Costs are realized annually over the project life beginning following Railway Reinstatement.
- * Savings in Storm Sewer Maintenance are realized annually over the project life beginning following Storm Sewer Replacement.
- * A reduction in Road Maintenance occurs annually from year 5 up to the time when Colborne Street is Relocated (year 10).
- * An increase in property values occurs immediately following project completion.
- * Business Loss, Personal Disruption, Relocation Costs and Disruption to the Community are estimated based upon the number of properties acquired in the interest of project implementation.

TABLE VII-1 (continued)

- * Traffic Disruption, Construction Noise, Dust, Etc., Economic Benefits During Construction and Fiscal Planning are related to the magnitude of the undertaking in terms of tangible costs.

All other factors related to the Benefit Versus Cost Analysis have been estimated by members of the Project Team based upon their individual areas of expertise.

3.0 SUMMARY OF IMPACTS CONSIDERED

3.1 Tangible Costs

The nature of the slide problem and the required remedial works enable the construction activities to be categorized as follows:

3.1.1 River Training

River Training involves the realignment, widening, relocation and/or hardening of the Grand River through the study area. Preliminary estimates of construction costs for the various alternative River works have been developed (Appendix III). These alternatives are:

- **Channel Reinstatement** involves excavating slide material from the river to re-establish the pre-slide channel. Erosion Protection is also required to harden the river thus mitigating the impacts of on-going river bank erosion in the slide area. The costs outlined for this item reflect the work required for excavation and to line the existing river through the study area. This option is only valid for the Cut only slope stabilization scheme.
- **Widening the Existing Channel** is the minimum requirement for either of the Fill only or Cut/Fill rehabilitation schemes due to the need to extend the existing toe of the slope into the river. The cost provided for this includes stream bank erosion protection.
- **Relocation of the River** away from the embankment is similar in its intent to the river widening. It involves creating a new, second flow channel away from the toe of slope, thus providing two flow paths. The advantage of this item is a substantial decrease in flow velocities downstream. This is an important factor as the flow velocity is a primary factor in the erosion process.

- **Oxbow Relocation** is a special case of channel relocation and requires the complete cutoff of river flows from the bank - effectively creating an artificial oxbow. This alternative involves extensive channelization due to the depth of cut required to match grades. In addition, Stilling facilities would be required to maintain acceptable velocities in the downstream flow regime. The primary benefit of this alternative is realized in terms of future savings in toe erosion protection which may ultimately be required in other areas along the banks of the oxbow.

3.1.2 Bank Stabilization

The stabilization of the slope through the study area may be accomplished using a cut, fill or combination cut/fill schemes. The costs identified for each scheme includes all costs associated with importation or disposal of fill materials and the complete reinstatement of the bank with a suitable vegetative cover.

3.1.3. Environmental Protection

In order to minimize the impact of construction activities on the natural environment, certain environmental construction controls will be specified. These controls may include fencing off sensitive areas, siltation control, dust and noise control, etc. These controls have costs associated with them as provided. Estimates are based on the materials and labour costs to implement the required measures.

3.1.4 Road Reinstatement

If nothing is done to stabilize the existing bank, it is predicted that on-going, regressive bank instability will eventually result in the abandonment of the existing Colborne Street. Assuming that this road continues to be a primary traffic route, the road would require re-establishment or replacement with another road system in some alternative location or alignment. For the purposes of this analysis, the road has been valued based upon an engineering estimate for its relocation.

3.1.5 Storm Sewer Repairs

An existing Storm Sewer along Colborne Street drains to the Grand River through the recent slope failure site. The sewer requires extensive repairs which would be carried out in conjunction with any of the proposed proactive alternatives.

3.1.6 Railway Reinstatement

Immediately following the stabilization of the embankment, the T. H. & B. railway line would be reinstated at the expense of the railway. With a cut only stabilization scheme, the Colborne Street railway grade separation would require replacement (see Appendix IV).

3.1.7 Services Relocation

With the unpredictability of failures along Colborne Street adjacent to the embankment, services such as hydro, sewer, water, telephone and natural gas would have to be relocated. For the most part, each of these services is the responsibility of an independent agency or corporation and the assessment of risk to an individual service would be the responsibility of the corresponding organization using their own set of criteria. Services relocation would be incurred in conjunction with the reconstruction of Colborne Street.

3.1.8 Engineering and Supervisory

For estimation purposes, engineering and supervisory fees for design and contract administration may be based on a percentage of the construction costs. A 10% engineering and supervisory fee percentage has therefore been applied to each construction category. An exception to this rate, is the Oxbow Relocation, where the percentage was reduced to 3% based on the magnitude of the assignment. These costs are incorporated in the individual construction cost estimates.

3.1.9 Property Acquisition

Properties are required in order to construct the required stabilization and river training works. Only those properties which cannot safely accommodate a building are assumed to be permanently acquired. Permanent Easements and Temporary Easements will be acquired to enable ease of construction and maintenance.

3.1.10 Legal

Legal costs will be incurred in several areas relating to project planning and initiation. For instance, property acquisition will require the preparation and execution of appropriate easement and fee simple agreements.

3.1.11 Planning and Approvals

Many other costs are incurred prior to project initiation. Some of these costs are incurred in obtaining approvals from various agencies and in establishing land use planning for the site.

3.1.12 Normal Project Maintenance

To ensure that a particular engineering solution continues to perform to its potential, routine day-to-day maintenance may be required. These maintenance activities would typically be carried out on an annual basis and may consist of:

- grass cutting & trimming
- weed control
- minor grade maintenance (rills and gulleys)
- inspection of erosion protection
- slope monitoring.

An annual expenditure is suggested appropriate to cover the costs of undertaking such a maintenance program.

3.1.13 Major Project Maintenance

In addition to a routine day-to-day maintenance program, a major maintenance program is recommended to take care of any major problems affecting the project's integrity. Possible sources of major maintenance may include:

- Rip-rap replacement
- Gabion Basket Re-wiring
- Repairs to un-checked gulley erosion
- large tree removal

It is difficult to identify the financial requirements of a major maintenance program since the expenditures are generally unknown and depend on the effectiveness of the routine annual maintenance program. However, for the purposes of the benefit versus cost analysis, equal expenditures at five (5) year intervals have been assumed over the projected life of the remedial works.

3.2 Tangible Benefits

For each of the alternatives identified, certain benefits will result if they are implemented. Many of these benefits may be quantified as follows:

3.2.1. Flood Hazard

An impact analysis of the slide on upstream flood levels has been carried out as a component of this investigation. The analysis indicated a minor increase in upstream flood levels as a result of a decrease in flood storage at the slide site. Furthermore, a sensitivity analysis indicates that additional failures of a similar magnitude would further increase upstream flood levels. To compensate for these increases, upstream flood protection measures would require reinforcement and heightening to ensure full flood protection to their original design requirements. The cost of improving existing upstream flood protection works and the increased costs of proposed, subsequent phases of the Brantford Flood Control Program have been estimated and form the basis of this tangible benefit. Another method which could be used to quantify the degree of flood hazard is to measure the damages associated with increased flooding. This method was not considered practical due to the difficulties associated with obtaining damage data for analysis.

3.2.2 Railway Maintenance

If the railway were reinstated on the existing unstable slope, the railway would incur on-going maintenance costs resulting from additional slope failures. The maintenance "cost" would be incurred on an irregular basis. Thus the benefits associated with bank stabilization would be a savings associated with these maintenance activities. For the purposes of this analysis, a series of maintenance expenditures in each five (5) year period over the planning period has been assumed.

3.2.3 Railway Operating Costs

At the present time, the railway is incurring additional costs in utilizing alternative rail routes over and above those that would be incurred if the line in question were reinstated. These costs result from a number of factors:

- increased haul distance.
- line rental costs in excess of the operating costs for the line in question.
- costs related to re-routing traffic to the alternate line.

These costs, which may be summarized as series of annual costs, would not be incurred if the line were reinstated on a stable slope.

3.2.4 Storm Sewer Maintenance

Any of the proposed pro-active slope stabilization techniques would provide a stable environment for the existing storm sewer outfall. If nothing is done to the slope, this outfall would suffer from continuing, unpredictable deterioration as a result of on-going slumping and erosion. As a result, there is a perceived savings in major maintenance of the storm sewer outfall. This benefit has been expressed in terms of a series of cash savings in each five (5) year period over the life of the project.

3.2.5 Road Maintenance

Prior to failure of Colborne Street under a do-nothing alternative, certain road maintenance items would be required in the short term to ensure a safe transportation route. These maintenance requirements would take the form of:

- repairs to the south shoulder
- guard rail installation and maintenance
- drainage

It has been assumed that such maintenance would occur on an irregular basis and equal expenditures in each five (5) year period prior to anticipated abandonment/relocation.

3.2.6 Increased Property Values

For each of the slope stabilization schemes, a benefit would be incurred as a result of appreciated land values resulting from a safer and more stable slope. The degree of increase is commensurate on the revised top of bank as established by the various slope stabilization alternatives.

3.3 Intangible Costs

In carrying out any of the proposed schemes, certain costs will be incurred which cannot be estimated to any degree of certainty. These costs must be included in the assessment of alternatives since they may be significant.

3.3.1 Loss of Business Income

In cases where a business or a component of a business is to be acquired to effect the repairs to the embankment, the business may suffer a business loss over the short term. This impact is applicable to this project since several businesses and farms will be potentially affected by the various alternatives.

3.3.2 Personal Disruption

A disruption in the domestic status of individuals involved in property acquisition for construction results in impacts on the personal incomes of those individuals.

3.3.3 Relocation Costs

Over and above those costs directly recovered by the landowner via the property agreements, relocation costs will be incurred by the landowner. These costs include:

- moving expenses
- alternative purchase costs (legal, etc.)
- mortgage discharge penalties

These costs, although not measureable at this stage, do represent an impact commensurate with the number of homes and businesses affected.

3.3.4 Construction Noise, Dust etc.

These "costs" are related to the actual construction of the desired scheme and are generally thought of in terms of unquantifiable aggravation to the public.

3.3.5 Disruption to the Community

Many businesses and public facilities adjacent to the slide site owe their existence to use by the local residents. An increase in the number of displaced residents will impact on the use of facilities such as schools, churches, playground and convenience stores. These impacts must be considered.

3.3.6 Disruption of Services

Each alternative will have an impact in terms of a disruption to key services in the area, such as water, sewer, telephone, hydro and natural gas. The impacts to these services considered under this item represent inconvenience related to temporary service disruption during the construction period or during the relocation or removal of services.

3.3.7 Terrestrial Environmental Impact

The slopes and river flood plain areas contain many species of flora and fauna which will be subject to impacts by the alternatives outlined. These impacts relate to the removal of key species of flora and fauna and the ability to reinstate the terrestrial environment.

3.3.8 Aquatic Environmental Impact

The Grand River provides habitat and spawning ground for a wide variety of Aquatic species. Unchecked, each of the specified alternatives will impact these species. These impacts represent a negative benefit in terms of any of the specified alternatives.

3.3.9 Traffic Disruption

Many of the alternatives involve the transport of large quantities of construction materials. The magnitude of the hauls involved will generate an impact on traffic along the proposed haul routes. Conversely, if nothing is done, Colborne Street will eventually be lost, causing major traffic impacts in the area and on adjacent roads.

3.4 Intangible Benefits

As with costs, there are many benefits attributable to each alternative which cannot be effectively quantified. However, many important benefits are included in this category and must be considered if the analysis is to truly represent the impact of each alternative.

3.4.1 Flow Velocity Maintenance Immediately Downstream

At the present time, river velocities immediately downstream of the slide have been increased. These increased velocities will increase toe erosion rates on adjacent slopes downstream of the study site. The ability of an alternative to effectively reduce these velocities is a key consideration in the evaluation of alternatives.

3.4.2 Fiscal Planning

A benefit of any pro-active scheme is the ability to plan expenditures for remedial works. This ability to forecast expenditures enables the impact of the expenditures on other programs of the funding agency(s) to be minimized and ensures the orderly allocation of benefits and costs.

3.4.3 Reduced Risk to Life and Limb

Perhaps the most significant benefit realized in a pro-active solution to the bank instability is the opportunity to save lives and property. For this project, it is of particular significance due to the unpredictability of the slides in the area and the catastrophic manner of failure.

3.4.4 Economic Benefits During Construction

Although of minor significance in the current economic environment, the construction project will provide economic benefits to a number of private sector suppliers and contractors during the construction period and in terms of on-going maintenance.

4.0 ALTERNATIVES FOR CONSIDERATION

A total of six alternatives have been identified which, to varying degrees, fulfill the objectives of this investigation. These alternatives are provided as follows:

1. Do-nothing
2. Do-nothing, but relocate Colborne Street
3. Cut Only - Channel Reinstatement
4. Cut/Fill - Channel Widening
 - Channel Relocation
5. Fill Only - Channel Widening
 - Channel Relocation
6. Oxbow Cutoff

In order to effectively evaluate these alternatives from a benefit versus cost perspective, it is necessary to ensure that each scheme provides a full solution in terms of the objectives of the study. In the case of Alternative # 6; the Oxbow Cutoff, no slope stabilization option has been proposed. The Oxbow Cutoff must be implemented in conjunction with either the Cut Only, the Cut/Fill or the Fill Only slope stabilization scheme in order to fulfill the intent of the proposed works. In reality, the Oxbow Cutoff becomes a special river training alternative, which does not provide a slope stabilization effect. Therefore, in the interest of consistency, the Oxbow Cutoff (Alternative # 6) has been considered a special case of the Cut Only, Cut/Fill and Fill Only Schemes (Alternatives # 3, 4 and 5 respectively). Similarly, the Do-nothing-Relocate Colborne Street Scheme (Alternative # 2) is a special case of the Do-nothing Scheme (Alternative #1).

A revised list of alternatives considered in the benefit versus cost and economic analysis is therefore prepared as follows:

- 1a) Do-nothing
- b) Do-nothing but relocate Colborne Street
- 2a) Cut Only - Channel Reinstatement
- b) Cut Only - Oxbow Cutoff
- 3a) Cut/Fill - Channel Widening
- b) Cut/Fill - Channel Relocation
- c) Cut/Fill - Oxbow Cutoff
- 4a) Fill Only - Channel Widening
- b) Fill Only - Channel Relocation
- c) Fill Only - Oxbow Cutoff

The numbering and description of each alternative used throughout the benefit versus cost analysis is consistent with the above list.

The tangible and intangible costs and benefits associated with each alternative have been compiled from information made available through the course of this investigation by the various members of the project team and are reflected in Tables VII-2 and VII-4.

5.0 ANALYSIS RESULTS

5.1 General

The detailed benefit versus cost analysis was carried out for each of the derived alternatives assuming the conditions following the May, 1986 slope failure, using the spreadsheet analysis system implemented on Philips Planning + Engineering's in-house computing facilities. The analysis considers all benefits and costs described in detail in Section 3.0 and provides a technological approach to the assessment of alternatives in accordance with Ministry of Natural Resources Guidelines². The results indicate that the most economic solution involves a TOTAL FILL scheme for slope stabilization with CHANNEL WIDENING as the preferred river training alternative.

A net tangible benefit of \$6.7 million was calculated for this project and is indicative of a benefit versus cost ratio of greater than unity. In addition, certain social and environmental intangibles are considered least affected by this alternative remedial project.

The assumptions used to reach this conclusion are consistent with the objectives of this investigation and are in agreement with the objective judgements of the Project Team. These parameters used in the analysis are listed on Table VII-1. The detailed reports produced in the benefit versus cost analysis are provided as Tables VII-2 to VII-7.

5.2 Sensitivity Analysis

The benefit versus cost analysis presented in Section 4.1 is a very specific analysis based on the parameters listed in Table VII-1. Many of these parameters have an associated variance, which may be related to the uncertainty of the estimation, their variance with time or their subjectivity.

To analyze all alternatives on an unbiased basis, it is necessary to vary each of the parameters subject to variance by their respective levels of uncertainty and to re-do the benefit-cost analysis. If the rankings of the alternatives vary when a parameter is modified, it can be said to be "sensitive" to that parameter. Conversely, if variances of a parameter have little or no impact on the rankings of alternatives, the result is insensitive and the parameter itself has little impact on the final selection of an alternative.

A sensitivity analysis of this nature was carried out for each of the parameters listed in Table VII-1. The results of the sensitivity analysis are shown on Table VII-8.

The results of the sensitivity analysis showed that the ranking of the alternatives is relatively insensitive to reasonable changes in the parameters. When categorized, it is apparent that the selection of an alternative is insensitive to changes in the "economic" parameters (tangible benefits and costs). While there is only minor sensitivity in terms of the intangible benefits and costs. However, the definitive selection of a preferred alternative is still evident, despite this minor sensitivity.

5.3 Impacts of Phasing on the Benefit-Cost Analysis

Several developments have occurred throughout the study period which have a significant affect on the benefit-versus cost analysis. A property acquisition scheme has recently been established³ which would see the acquisition of virtually all properties south of Colborne Street within the study area. Therefore, the property acquisition costs for both the TOTAL FILL option and the CUT/FILL option become equivalent when the salvage value of properties after completion of the remedial works are considered to be nil. Similarly, the intangible social impacts which are related to the number of properties affected, become equal.

Potential fiscal constraints on the part of the proponents have also been made apparent to the study team. As a result, a phased implementation has been suggested. This phased implementation involves river training to be followed by slope stabilization in a series of vertical strips over a period of years. Unfortunately, the phased construction of slope stabilization works leaves portions of the slope in a marginally stable state. Therefore, the erosion protection implemented in conjunction with a river widening scheme, would be at risk of failure until such time as the entire slope was made safe. This situation favours a channel relocation which enables erosion protection of the north river bank to be delayed until project completion or be phased in conjunction with the vertical strip slope stabilization.

The initial analysis of alternatives has been considered relative to the slope conditions of May, 1986 (immediately after the slope failure). Subsequent slope movements as recent as March of 1987, have significantly modified the slope conditions which, impacts on the viability of the selected slope stabilization alternative. Specifically, the costs associated with the FILL ONLY scheme become much higher, since more fill is required to reinstate the slope to the degree required. The CUT/FILL scheme however, is not subject to the same degree of impact.

With these potential impacts in mind, a modified benefit versus cost analysis has been undertaken with the appropriate modifications made to reflect these recent developments.

The analysis indicates that the CUT/FILL-CHANNEL WIDENING is the favoured alternative. A sensitivity analysis, similar to the analysis described in Section 4.2, suggests a sensitivity to project phasing. The results of this modified sensitivity analysis are presented in Table VII-9.

This sensitivity indicates that the longer the phasing period, the more favourable a channel relocation river training alternative becomes. This is primarily due to the reduced risk of further channel constriction as a result of continued potential slope failure during the phased construction period.

TABLE VII-2

PRESENT VALUE CALCULATIONS FOR TANGIBLE COSTS						
CONSTRUCTION PERIOD (Years) = 3			Base Year = 1986		Discount Rate = .07	
PROJECT LIFE (Years) = 50					Inflation Rate = .04	
	Time Span	Rate of Payment	Estimated Cost	1987 Present Worth	PV of Periodic Expense	Base Year Value
CONSTRUCTION:						
RIVER TRAINING: River Reinstatement -			\$2,200,000	\$2,200,000		\$2,290,000
Channel Widening -			\$4,200,000	\$4,200,000		\$4,370,000
Channel Relocation -			\$5,900,000	\$5,900,000		\$6,140,000
Oxbow Cutoff -			\$50,000,000	\$50,000,000		\$52,000,000
SLOPE STABILIZATION: Cut Bank -	2		\$5,200,000	\$4,698,159		\$4,890,000
Fill Bank -	2		\$4,200,000	\$3,794,667		\$3,950,000
Fill Bank -	2		\$6,000,000	\$5,420,952		\$5,640,000
OTHER: Relocate Colborne Street -	10		\$4,500,000	\$2,287,572		\$2,380,000
Repair Storm Sewer Outfall -			\$165,000	\$165,000		\$170,000
Environmental Protection -	3	1		\$140,401	\$50,000	\$150,000
Railway Reinstatement -	3		\$550,000	\$448,964		\$470,000
Services Relocation -	10		\$500,000	\$254,175		\$260,000
PROPERTY ACQUISITION:						
North River Bank -			\$120,000	\$120,000		\$120,000
Properties At Risk -			\$780,000	\$780,000		\$810,000
South Side of Colborne St (Blk "A") -			\$834,500	\$834,500		\$870,000
(Blk "B") -			\$931,500	\$931,500		\$970,000
(Blk "C") -			\$1,104,000	\$1,104,000		\$1,150,000
North Side of Colborne Street -	10		\$6,675,000	\$3,393,232		\$3,530,000
South of River (Widening) -			\$20,000	\$20,000		\$20,000
(Relocation) -			\$60,000	\$60,000		\$60,000
(Oxbow Cutoff) -			\$100,000	\$100,000		\$100,000
OTHER EXPENSES:						
Legal -	6	1		\$51,002	\$10,000	\$60,000
Planning & Approvals -	3	1		\$28,080	\$10,000	\$30,000
Normal Project Maintenance -	50	1		\$29,534	\$2,000	\$30,000
(Grass Cutting, Slope Maint., etc.)						
Major Project Maintenance -	50	5		\$25,678	\$10,000	\$30,000
(Gabion, Rip Rap Replacement, etc.)						

PRESENT VALUE CALCULATIONS FOR TANGIBLE BENEFITS						
CONSTRUCTION PERIOD (Years) = 3			Base Year = 1988		Discount Rate = .07	
PROJECT LIFE (Years) = 50					Inflation Rate = .04	
	Time Span	Rate of Payment	Estimated Benefit	1987 Present Worth	PV of Periodic Expense	Base Year Value
Flood Hazard -			\$1,500,000	\$1,500,000		\$1,560,000
Railway Maintenance -	50	3	1	\$897,345	\$50,000	\$970,000
Railway Operating Costs -	50	3	1	\$4,845,664	\$270,000	\$5,240,000
Storm Sewer Maintenance -	50	5		\$128,390	\$50,000	\$160,000
Property Value Increase -		2	\$3,650,000	\$3,188,051		\$3,320,000
Reduced Road Maintenance -	10	5	1	\$307,665	\$50,000	\$330,000

NOTE: Construction costs have been extracted from Appendix II, III and IV and reflect the estimates prepared by the members of the Project Team.

TABLE VII-3

BENEFIT VERSUS COST ANALYSIS - Colborne Street Slope Failure
TANGIBLE DATA INPUT SUMMARY

IMPACT CATEGORY (PV To The Base Year)	DO NOTHING ALTERNATIVE		TOTAL CUT ALTERNATIVE		CUT/FILL ALTERNATIVE			TOTAL FILL ALTERNATIVE		
TANGIBLE BENEFITS AND COSTS	Do Nothing	Relocate Colborne Street	River Reinstat.	Oxbow Cutoff	Widen Channel	Relocate Channel	Oxbow Cutoff	Widen Channel	Relocate Channel	Oxbow Cutoff
COSTS:										
River Training			\$-2,290,000	\$-52,000,000	\$-4,370,000	\$-6,140,000	\$-52,000,000	\$-4,370,000	\$-6,140,000	\$-52,000,000
Bank Stabilization			\$-4,890,000	\$-4,890,000	\$-3,950,000	\$-3,950,000	\$-3,950,000	\$-5,640,000	\$-5,640,000	\$-5,640,000
Road Reinstatement	\$-2,380,000	\$-2,350,000	\$-4,500,000	\$-4,500,000						
Railway Reinstatement		\$-470,000	\$-470,000	\$-470,000	\$-470,000	\$-470,000	\$-470,000	\$-470,000	\$-470,000	\$-470,000
Services Relocation	\$-260,000	\$-260,000	\$-500,000	\$-500,000						
Relocate Storm Sewer	\$-170,000	\$-170,000	\$-170,000	\$-170,000	\$-170,000	\$-170,000	\$-170,000	\$-170,000	\$-170,000	\$-170,000
Environmental Protection			\$-150,000	\$-150,000	\$-150,000	\$-150,000	\$-150,000	\$-150,000	\$-150,000	\$-150,000
Property Acquisition		\$-3,530,000	\$-10,445,000	\$-10,545,000	\$-2,670,000	\$-2,710,000	\$-2,750,000	\$-1,700,000	\$-1,740,000	\$-1,780,000
Legal		\$-60,000	\$-60,000	\$-60,000	\$-60,000	\$-60,000	\$-60,000	\$-60,000	\$-60,000	\$-60,000
Planning and Approvals		\$-30,000	\$-30,000	\$-30,000	\$-30,000	\$-30,000	\$-30,000	\$-30,000	\$-30,000	\$-30,000
Normal & Major Maintenance			\$-60,000	\$-60,000	\$-60,000	\$-60,000	\$-60,000	\$-60,000	\$-60,000	\$-60,000
TOTAL TANGIBLE COSTS	\$-2,810,000	\$-6,900,000	\$-23,565,000	\$-73,375,000	\$-11,930,000	\$-13,740,000	\$-59,640,000	\$-12,650,000	\$-14,460,000	\$-60,360,000
BENEFITS:										
Reduced Flood Hazard			\$1,560,000	\$1,560,000	\$1,560,000	\$1,560,000	\$1,560,000	\$1,560,000	\$1,560,000	\$1,560,000
Reduced Railway Maintenance			\$970,000	\$970,000	\$970,000	\$970,000	\$970,000	\$970,000	\$970,000	\$970,000
Reduced Railway Operating Costs			\$5,240,000	\$5,240,000	\$5,240,000	\$5,240,000	\$5,240,000	\$5,240,000	\$5,240,000	\$5,240,000
Reduced Road Maintenance			\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000	\$330,000
Decreased Storm Sewer Maintenance			\$160,000	\$160,000	\$160,000	\$160,000	\$160,000	\$160,000	\$160,000	\$160,000
Property Values Impact		\$3,530,000	\$3,800,000	\$3,800,000	\$7,330,000	\$7,330,000	\$7,330,000	\$7,330,000	\$7,330,000	\$7,330,000
Road Replacement Cost					\$4,500,000	\$4,500,000	\$4,500,000	\$4,500,000	\$4,500,000	\$4,500,000
TOTAL TANGIBLE BENEFITS		\$3,530,000	\$12,060,000	\$11,900,000	\$20,090,000	\$20,090,000	\$19,930,000	\$20,090,000	\$20,090,000	\$19,930,000
NET TANGIBLE BENEFIT (COST)	\$-2,810,000	\$-3,370,000	\$-11,505,000	\$-61,475,000	\$8,160,000	\$6,350,000	\$-39,710,000	\$7,440,000	\$5,630,000	\$-40,430,000
	-05	-05	-19	-1.00	.13	.10	-.85	.12	.09	-.66
(Note: Rankings for Net Benefits have been Computed Relative to the Maximum Net Benefit Alternative.)										

* - Includes Engineering Costs

TABLE VII-4

BENEFIT VERSUS COST ANALYSIS - Colborne Street Slope Failure
INTANGIBLE DATA INPUT SUMMARY

IMPACT CATEGORY	DO NOTHING ALTERNATIVE		TOTAL CUT ALTERNATIVE		CUT/FILL ALTERNATIVE			TOTAL FILL ALTERNATIVE		
	Do Nothing	Relocate Colborne Street	River Reinstat.	Oxbow Cutoff	Widen Channel	Relocate Channel	Oxbow Cutoff	Widen Channel	Relocate Channel	Oxbow Cutoff
INTANGIBLE BENEFITS AND COSTS										
COSTS:										
Loss of Business Income	-1.00	-1.00	-1.00	-1.00	-.35	-.35	-.40	-.20	-.20	-.25
Personal Disruption	-1.00	-1.00	-1.00	-1.00	-.21	-.21	-.23	-.12	-.12	-.14
Relocation Costs	-1.00	-1.00	-1.00	-1.00	-.21	-.21	-.23	-.12	-.12	-.14
Construction Noise, Dust, Etc.	.00	-.10	-.90	-1.00	-.30	-.40	-.65	-.50	-.60	-.75
Disruption to the Community	-1.00	-.80	-.80	-.85	-.20	-.20	-.20	-.10	-.10	-.10
Disruption of Services	-1.00	-.90	-.50	-.50	-.20	-.25	-.30	-.10	-.15	-.25
Terrestrial Environmental Impact	-.30	-.30	-.50	-.70	-.50	-.50	-.70	-.60	-.60	-.70
Aquatic Environmental Impact	-.30	-.30	-.10	-1.00	-.40	-.40	-1.00	-.40	-.40	-1.00
Traffic Disruption	-1.00	-.90	-.90	-.95	-.10	-.10	-.60	-.30	-.30	-.60
BENEFITS:										
Flow Velocity Maintenance D/S	-1.00	-1.00	.00	1.00	.00	.00	1.00	.00	.00	1.00
Fiscal Planning	.00	.00	1.00	.50	1.00	1.00	.50	1.00	1.00	.50
Reduced Risk to Life and Limb	.00	.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Economic Benefits During Constr.	.00	.40	.70	1.00	.50	.50	.80	.50	.50	.90
SUMMARY - INTANGIBLE IMPACTS	-7.60	-6.90	-4.00	-4.50	.03	-.12	-1.01	.06	-.09	-.53

Note: A Negative Ranking indicates an Adverse impact (Cost).
A Positive Ranking indicated a Beneficial Impact (Benefit).

TABLE VII-5

BENEFIT VERSUS COST ANALYSIS - Colborne Street Slope Failure
STATISTICAL EVALUATIONS

BENEFITS AND COSTS		DO NOTHING ALTERNATIVE			TOTAL CUT ALTERNATIVE			CUT/FILL ALTERNATIVE			TOTAL FILL ALTERNATIVE		
		Relocate											
INTANGIBLE BENEFITS AND COSTS	WEIGHT	Do Nothing	Colborne Street	River Reinstat.	Oxbow Cutoff	Widen Channel	Relocate Channel	Oxbow Cutoff	Widen Channel	Relocate Channel	Oxbow Cutoff	Widen Channel	Relocate Channel
=====													
COSTS:													
Loss of Business Income	.60	-1 -6 -1	-1 -6 -1	-1 -6 -1	-1 -6 -1	-35 -21 -53	-35 -21 -53	-4 -24 -58	-2 -12 -38	-2 -12 -38	-25 -15 -44	-2 -12 -38	-25 -15 -44
Personal Disruption	.60	-1 -6 -1	-1 -6 -1	-1 -6 -1	-1 -6 -1	-21 -13 -39	-21 -13 -39	-23 -14 -41	-12 -07 -28	-12 -07 -28	-14 -08 -31	-12 -07 -28	-14 -08 -31
Relocation Costs	.60	-1 -6 -1	-1 -6 -1	-1 -6 -1	-1 -6 -1	-21 -13 -39	-21 -13 -39	-23 -14 -41	-12 -07 -28	-12 -07 -28	-14 -08 -31	-12 -07 -28	-14 -08 -31
Construction Noise, Dust, Etc.	.60	0 0 0	-1 -06 -25	-9 -54 -94	-1 -6 -1	-3 -18 -49	-4 -24 -58	-65 -39 -77	-5 -3 -66	-6 -36 -74	-75 -45 -84	-5 -3 -66	-6 -36 -74
Disruption to the Community	.60	-1 -6 -1	-8 -48 -87	-8 -48 -87	-85 -51 -91	-2 -12 -38	-2 -12 -38	-2 -12 -38	-1 -06 -25	-1 -06 -25	-1 -06 -25	-1 -06 -25	-1 -06 -25
Disruption of Services	.60	-1 -6 -1	-9 -54 -94	-5 -3 -66	-5 -3 -66	-2 -12 -38	-25 -15 -44	-3 -18 -49	-1 -06 -25	-15 -09 -32	-25 -15 -44	-1 -06 -25	-15 -09 -32
Terrestrial Environmental Impact	.90	-3 -27 -34	-3 -27 -34	-5 -45 -54	-7 -63 -73	-5 -45 -54	-5 -45 -54	-7 -63 -73	-6 -54 -63	-6 -54 -63	-7 -63 -73	-6 -54 -63	-7 -63 -73
Aquatic Environmental Impact	.90	-3 -27 -34	-3 -27 -34	-1 -09 -13	-1 -9 -1	-4 -36 -44	-4 -36 -44	-1 -9 -1	-4 -36 -44	-4 -36 -44	-1 -9 -1	-4 -36 -44	-4 -36 -44
Traffic Disruption	.60	-1 -6 -1	-9 -54 -94	-9 -54 -94	-95 -57 -97	-1 -06 -25	-1 -06 -25	-6 -36 -74	-3 -18 -49	-3 -18 -49	-6 -36 -74	-3 -18 -49	-6 -36 -74
BENEFITS:													
Flow Velocity Maintenance D/S	1.00	0 0 0	0 0 0	0 0 0	1 1 1	0 0 0	0 0 0	1 1 1	0 0 0	0 0 0	1 1 1	0 0 0	0 0 0
Fiscal Planning	.60	0 0 0	0 0 0	1 .6 1	.5 .3 .660	1 .6 1	1 .6 1	.5 .3 .660	1 .6 1	1 .6 1	.5 .3 .660	1 .6 1	1 .6 1
Reduced Risk to Life and Liab	1.00	0 0 0	0 0 0	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1
Economic Benefits During Constr.	.10	0 0 0	.4 .04 .912	.7 .07 .965	1 .1 1	.5 .05 .933	.5 .05 .933	.8 .08 .978	.5 .05 .933	.5 .05 .933	.9 .09 .990	.5 .05 .933	.5 .05 .933
NET BENEFIT (COST)	1.00	-.05 -.05 -.05	-.05 -.05 -.05	-.19 -.19 -.19	-1 -1 -1	.133 .133 .133	.103 .103 .103	-.65 -.65 -.65	.121 .121 .121	.092 .092 .092	-.66 -.66 -.65	.121 .121 .121	.092 .092 .092
=====													
SUMMARY													
(UNWEIGHTED PRODUCT, EXPONENTIAL)		-6.6 -4.2 -6.7	-6.0 -4.0 -5.8	-4.2 -2.7 -4.3	-5.5 -3.9 -5.6	.163 .031 -.72	-.02 -.09 -.90	-1.7 -1.4 -2.5	.181 .007 -.60	.002 -.11 -.78	-1.2 -1.1 -2.0	.181 .007 -.60	.002 -.11 -.78
=====													

Notes: The First Column under each Alternative is its Unweighted Ranking.
The Second Column is the product of the first column and the assigned Weighting.
The Third Column is the first column Raised to the Exponent of the Weighting.

TABLE VII-6.2

EVALUATION MATRICES (Page 2 of 4)

MATRIX EVALUATIONS Economic Benefits During Constr.											MATRIX EVALUATIONS Terrestrial Environmental Impact										
1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	*WORSE THAN*	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	*WORSE THAN*
1A	0	1	1	1	1	1	1	1	1	9	1A	0	0	0	0	0	0	0	0	0	0
1B	0	0	1	1	0	0	1	0	0	4	1B	0	0	0	0	0	0	0	0	0	0
2A	0	0	0	0	0	0	0	0	0	0	2A	1	1	0	0	0	0	0	0	0	2
2B	0	0	0	0	0	0	0	0	0	0	2B	1	1	1	0	1	1	0	1	1	7
3A	0	0	0	1	0	0	0	0	0	2	3A	1	1	0	0	0	0	0	0	0	2
3B	0	0	0	1	0	0	0	0	0	2	3B	1	1	0	0	0	0	0	0	0	2
3C	0	0	0	0	0	0	0	0	0	0	3C	1	1	1	0	1	1	0	1	1	7
4A	0	0	0	1	0	0	0	0	0	2	4A	1	1	1	0	1	1	0	0	0	5
4B	0	0	0	1	0	0	0	0	0	2	4B	1	1	1	0	1	1	0	0	0	5
4C	0	0	0	0	0	0	0	0	0	0	4C	1	1	1	0	1	1	0	1	1	7
=====											=====										
BETTER THAN	0	1	2	6	1	1	2	1	1	6	*BETTER THAN*	8	8	5	0	5	5	0	3	3	0

MATRIX EVALUATIONS Reduced Risk to Life and Liab											MATRIX EVALUATIONS Disruption of Services										
1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	*WORSE THAN*	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	*WORSE THAN*
1A	0	0	1	1	1	1	1	1	1	8	1A	0	1	1	1	1	1	1	1	1	9
1B	0	0	1	1	1	1	1	1	1	8	1B	0	0	1	1	1	1	1	1	1	8
2A	0	0	0	0	0	0	0	0	0	0	2A	0	0	0	0	1	1	1	1	1	6
2B	0	0	0	0	0	0	0	0	0	0	2B	0	0	0	0	1	1	1	1	1	6
3A	0	0	0	0	0	0	0	0	0	0	3A	0	0	0	0	0	0	0	1	1	2
3B	0	0	0	0	0	0	0	0	0	0	3B	0	0	0	0	1	0	0	1	1	3
3C	0	0	0	0	0	0	0	0	0	0	3C	0	0	0	0	1	1	0	1	1	5
4A	0	0	0	0	0	0	0	0	0	0	4A	0	0	0	0	0	0	0	0	0	0
4B	0	0	0	0	0	0	0	0	0	0	4B	0	0	0	0	0	0	0	1	0	1
4C	0	0	0	0	0	0	0	0	0	0	4C	0	0	0	0	1	0	0	1	1	3
=====											=====										
BETTER THAN	0	0	2	2	2	2	2	2	2	2	*BETTER THAN*	0	1	2	2	7	5	4	9	8	5

TABLE VII-6.3

EVALUATION MATRICES (Page 3 of 4)

EVALUATION MATRICES (Page 3 of 4)

MATRIX EVALUATIONS										
Fiscal Planning										
1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	"WORSE THAN"
1A	0	0	1	1	1	1	1	1	1	8
1B	0	0	1	1	1	1	1	1	1	8
2A	0	0	0	0	0	0	0	0	0	0
2B	0	0	1	0	1	1	0	1	1	5
3A	0	0	0	0	0	0	0	0	0	0
3B	0	0	0	0	0	0	0	0	0	0
3C	0	0	1	0	1	1	0	1	1	5
4A	0	0	0	0	0	0	0	0	0	0
4B	0	0	0	0	0	0	0	0	0	0
4C	0	0	1	0	1	1	0	1	1	5
=====										
"BETTER THAN"	0	0	2	2	2	2	2	2	2	

MATRIX EVALUATIONS										
Personal Disruption										
1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	"WORSE THAN"
1A	0	0	0	0	1	1	1	1	1	6
1B	0	0	0	0	1	1	1	1	1	6
2A	0	0	0	0	1	1	1	1	1	6
2B	0	0	0	0	1	1	1	1	1	6
3A	0	0	0	0	0	0	0	1	1	3
3B	0	0	0	0	0	0	0	1	1	3
3C	0	0	0	0	0	0	0	1	1	3
4A	0	0	0	0	0	0	0	0	0	0
4B	0	0	0	0	0	0	0	0	0	0
4C	0	0	0	0	0	0	0	0	0	0
=====										
"BETTER THAN"	0	0	0	0	4	4	4	7	7	7

MATRIX EVALUATIONS										
Disruption to the Community										
1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	"WORSE THAN"
1A	0	1	1	1	1	1	1	1	1	9
1B	0	0	0	0	1	1	1	1	1	6
2A	0	0	0	0	1	1	1	1	1	6
2B	0	0	0	0	1	1	1	1	1	6
3A	0	0	0	0	0	0	0	1	1	3
3B	0	0	0	0	0	0	0	1	1	3
3C	0	0	0	0	0	0	0	1	1	3
4A	0	0	0	0	0	0	0	0	0	0
4B	0	0	0	0	0	0	0	0	0	0
4C	0	0	0	0	0	0	0	0	0	0
=====										
"BETTER THAN"	0	1	1	1	4	4	4	7	7	7

MATRIX EVALUATIONS										
Construction Noise, Dust, Etc.										
1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	"WORSE THAN"
1A	0	0	0	0	0	0	0	0	0	0
1B	1	0	0	0	0	0	0	0	0	1
2A	1	1	0	0	1	1	1	1	1	8
2B	1	1	1	0	1	1	1	1	1	9
3A	1	1	0	0	0	0	0	0	0	2
3B	1	1	0	0	1	0	0	0	0	3
3C	1	1	0	0	1	1	0	1	0	5
4A	1	1	0	0	1	1	0	0	0	4
4B	1	1	0	0	1	1	0	1	0	5
4C	1	1	0	0	1	1	1	1	1	7
=====										
"BETTER THAN"	9	8	1	0	7	6	3	5	3	2

TABLE VII-6.4

EVALUATION MATRICES (Page 4 of 4)

MATRIX EVALUATIONS Loss of Business Income												MATRIX EVALUATIONS Relocation Costs											
1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	"WORSE THAN"		1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	"WORSE THAN"	
1A	0	0	0	0	1	1	1	1	1	1	6	1A	0	0	0	0	1	1	1	1	1	1	6
1B	0	0	0	0	1	1	1	1	1	1	6	1B	0	0	0	0	1	1	1	1	1	1	6
2A	0	0	0	0	1	1	1	1	1	1	6	2A	0	0	0	0	1	1	1	1	1	1	6
2B	0	0	0	0	1	1	1	1	1	1	6	2B	0	0	0	0	1	1	1	1	1	1	6
3A	0	0	0	0	0	0	0	1	1	1	3	3A	0	0	0	0	0	0	0	1	1	1	3
3B	0	0	0	0	0	0	0	1	1	1	3	3B	0	0	0	0	0	0	0	1	1	1	3
3C	0	0	0	0	0	0	0	1	1	1	3	3C	0	0	0	0	0	0	0	1	1	1	3
4A	0	0	0	0	0	0	0	0	0	0	0	4A	0	0	0	0	0	0	0	0	0	0	0
4B	0	0	0	0	0	0	0	0	0	0	0	4B	0	0	0	0	0	0	0	0	0	0	0
4C	0	0	0	0	0	0	0	1	1	1	2	4C	0	0	0	0	0	0	0	0	0	0	0
"BETTER THAN"												"BETTER THAN"											
0	0	0	0	4	4	4	8	8	7			0	0	0	0	4	4	4	7	7	7		

MATRIX EVALUATIONS DIRECT (UNWEIGHTED) ANALYSIS												MATRIX EVALUATIONS PRODUCT ANALYSIS											
1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	"WORSE THAN"		1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	"WORSE THAN"	
1A	0	1	1	1	1	1	1	1	1	1	9	1A	0	1	1	1	1	1	1	1	1	1	9
1B	0	0	1	1	1	1	1	1	1	1	8	1B	0	0	1	1	1	1	1	1	1	1	8
2A	0	0	0	0	1	1	1	1	1	1	6	2A	0	0	0	0	1	1	1	1	1	1	6
2B	0	0	1	0	1	1	1	1	1	1	7	2B	0	0	1	0	1	1	1	1	1	1	7
3A	0	0	0	0	0	0	0	0	0	0	0	3A	0	0	0	0	0	0	0	0	0	0	0
3B	0	0	0	0	1	0	0	1	0	0	2	3B	0	0	0	0	1	0	0	1	0	0	2
3C	0	0	0	0	1	1	0	1	1	1	5	3C	0	0	0	0	1	1	0	1	1	1	5
4A	0	0	0	0	0	0	0	0	0	0	0	4A	0	0	0	0	0	0	0	0	0	0	0
4B	0	0	0	0	1	0	0	1	0	0	2	4B	0	0	0	0	1	0	0	1	0	0	2
4C	0	0	0	0	1	1	0	1	1	0	4	4C	0	0	0	0	1	1	0	1	1	0	4
"BETTER THAN"												"BETTER THAN"											
0	1	3	2	8	6	4	8	6	5			0	1	3	2	8	6	4	8	6	5		

TABLE VII-7

BENEFIT VERSUS COST ANALYSIS SUMMARY

Project Life - 50 Years Discount Rate - 7
 Construction Staging - 3 Years Inflation Rate - 4
 Start Date - 1988 Dominance Criterion - .05

	EXPONENTIAL ANALYSIS	PRODUCT ANALYSIS	UNWEIGHTED ANALYSIS
1A Do Nothing	-53	-9	-9
1B Do Nothing - Relocate Colborne St.	-40	-7	-7
2A Cut Only - River Reinstatement	-29	-3	-3
2B Cut Only - Oxbow Cutoff	-52	-5	-5
3A Cut/Fill - Channel Widening	20	8 *	8 *
3B Cut/Fill - Channel Relocation	16	4	4
3C Cut/Fill - Oxbow Cutoff	-15	-1	-1
4A Fill Only - Channel Widening	34 *	8 *	8 *
4B Fill Only - Channel Relocation	29	4	4
4C Fill Only - Oxbow Cutoff	9	1	1

Note: * - Indicates Preferred Alternative

TABLE VII-3

BENEFIT VERSUS COST ANALYSIS - Colborne Street Slope Failure
 SENSITIVITY ANALYSIS SUMMARY - May, 1986 (Post-Slide) Conditions

WEIGHTING SCENARIO	DO NOTHING ALTERNATIVE		TOTAL CUT ALTERNATIVE		CUT/FILL ALTERNATIVE			TOTAL FILL ALTERNATIVE		
	Do Nothing	Relocate Colborne Street	River Reinstat.	Oxbow Cutoff	Widen Channel	Relocate Channel	Oxbow Cutoff	Widen Channel	Relocate Channel	Oxbow Cutoff
1. - COST Weighted HIGH - ENVIRONMENT Weighted LOW - SOCIAL Weighted MODERATE	POOR	POOR	POOR	POOR	GOOD	GOOD	FAIR	BEST	VERY GOOD	GOOD
2. - COST Weighted HIGH - ENVIRONMENT Weighted MODERATE - SOCIAL Weighted LOW	POOR	POOR	GOOD	POOR	BEST	BEST	GOOD	BEST	BEST	GOOD
3. - COST Weighted MODERATE - ENVIRONMENT Weighted LOW - SOCIAL Weighted HIGH	POOR	POOR	POOR	POOR	VERY GOOD	VERY GOOD	GOOD	BEST	VERY GOOD	VERY GOOD
4. - COST Weighted MODERATE - ENVIRONMENT Weighted HIGH - SOCIAL Weighted LOW	POOR	POOR	GOOD	POOR	BEST	BEST	GOOD	BEST	BEST	GOOD
5. - COST Weighted LOW - ENVIRONMENT Weighted MODERATE - SOCIAL Weighted HIGH	POOR	POOR	POOR	POOR	VERY GOOD	VERY GOOD	FAIR	BEST	VERY GOOD	GOOD
6. - COST Weighted LOW - ENVIRONMENT Weighted HIGH - SOCIAL Weighted MODERATE	POOR	POOR	POOR	POOR	GOOD	GOOD	FAIR	BEST	VERY GOOD	GOOD
7. ALL COSTS INCREASED BY 20% (Preliminary Estimates)	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR
8. ALL COSTS DECREASED BY 20% (Preliminary Estimates)	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR
9. ALL BENEFITS INCREASED BY 20% (Due to Uncertainty)	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR
9. ALL BENEFITS DECREASED BY 20% (Due to Uncertainty)	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR
10. DELETE RAILWAY CONSIDERATIONS	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR
11. ZERO SALVAGE VALUE FOR FILL	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR
12. PROJECT LIFE = 25 YEARS	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR
13. DISCOUNT RATE = 10 PERCENT	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR
14. DISCOUNT RATE = 5 PERCENT	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR
15. PROJECT START DATE = 1990	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR
16. STAGED IMPLEMENTATION - 5 YRS	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR
17. ZERO PROPERTY VALUE BENEFIT	POOR	POOR	POOR	POOR	GOOD	GOOD	POOR	BEST	VERY GOOD	FAIR

DEFAULT VALUES - BASE YEAR = 1988 50 YEAR PROJECT LIFE 3 YEAR IMPLEMENTATION PERIOD DISCOUNT RATE = 7 % INFLATION RATE = 4 % DOMINANCE CRITERION = 0.05

July, 1987

VII-35

86105.004

TABLE VII-9

BENEFIT VERSUS COST ANALYSIS - Colborne Street Slope Failure
SENSITIVITY ANALYSIS SUMMARY - March, 1987 Conditions

WEIGHTING SCENARIO	DO NOTHING ALTERNATIVE Relocate		TOTAL CUT ALTERNATIVE		CUT/FILL ALTERNATIVE			TOTAL FILL ALTERNATIVE		
	Do Nothing	Colborne Street	River Reinstat.	Oxbow Cutoff	Hidden Channel	Relocate Channel	Oxbow Cutoff	Hidden Channel	Relocate Channel	Oxbow Cutoff
1. - COST Weighted HIGH - ENVIRONMENT Weighted LOW - SOCIAL Weighted MODERATE	POOR	POOR	POOR	POOR	BEST	VERY GOOD	GOOD	GOOD	GOOD	FAIR
2. - COST Weighted HIGH - ENVIRONMENT Weighted MODERATE - SOCIAL Weighted LOW	POOR	POOR	GOOD	POOR	BEST	BEST	GOOD	BEST	BEST	GOOD
3. - COST Weighted MODERATE - ENVIRONMENT Weighted LOW - SOCIAL Weighted HIGH	POOR	POOR	POOR	POOR	BEST	VERY GOOD	VERY GOOD	VERY GOOD	VERY GOOD	GOOD
4. - COST Weighted MODERATE - ENVIRONMENT Weighted HIGH - SOCIAL Weighted LOW	POOR	POOR	GOOD	POOR	BEST	BEST	GOOD	BEST	BEST	GOOD
5. - COST Weighted LOW - ENVIRONMENT Weighted MODERATE - SOCIAL Weighted HIGH	POOR	POOR	POOR	POOR	BEST	VERY GOOD	GOOD	VERY GOOD	VERY GOOD	FAIR
6. - COST Weighted LOW - ENVIRONMENT Weighted HIGH - SOCIAL Weighted MODERATE	POOR	POOR	POOR	POOR	BEST	VERY GOOD	GOOD	GOOD	GOOD	FAIR
7. ALL COSTS INCREASED BY 20% (Preliminary Estimates)	POOR	POOR	POOR	POOR	BEST	VERY GOOD	FAIR	GOOD	GOOD	POOR
8. ALL COSTS DECREASED BY 20% (Preliminary Estimates)	POOR	POOR	POOR	POOR	BEST	VERY GOOD	FAIR	GOOD	GOOD	POOR
9. ALL BENEFITS INCREASED BY 20% (Due to Uncertainty)	POOR	POOR	POOR	POOR	BEST	VERY GOOD	FAIR	GOOD	GOOD	POOR
9. ALL BENEFITS DECREASED BY 20% (Due to Uncertainty)	POOR	POOR	POOR	POOR	BEST	VERY GOOD	FAIR	GOOD	GOOD	POOR
10. DELETE RAILWAY CONSIDERATIONS	POOR	POOR	POOR	POOR	BEST	VERY GOOD	FAIR	GOOD	GOOD	POOR
11. ZERO SALVAGE VALUE FOR FILL	POOR	POOR	POOR	POOR	BEST	VERY GOOD	FAIR	GOOD	GOOD	POOR
12. PROJECT LIFE = 25 YEARS	POOR	POOR	POOR	POOR	BEST	VERY GOOD	FAIR	GOOD	GOOD	POOR
13. DISCOUNT RATE = 10 PERCENT	POOR	POOR	POOR	POOR	BEST	VERY GOOD	FAIR	GOOD	GOOD	POOR
14. DISCOUNT RATE = 5 PERCENT	POOR	POOR	POOR	POOR	BEST	VERY GOOD	FAIR	GOOD	GOOD	POOR
15. PROJECT START DATE = 1990	POOR	POOR	POOR	POOR	BEST	VERY GOOD	FAIR	GOOD	GOOD	POOR
16. STAGED IMPLEMENTATION - 5 YRS	POOR	POOR	POOR	POOR	VERY GOOD	BEST	FAIR	GOOD	GOOD	POOR
17. ZERO PROPERTY VALUE BENEFIT	POOR	POOR	POOR	POOR	BEST	VERY GOOD	FAIR	GOOD	GOOD	POOR

DEFAULT VALUES -

BASE YEAR = 1988

50 YEAR PROJECT LIFE

3 YEAR IMPLEMENTATION PERIOD

DISCOUNT RATE = 7 %

INFLATION RATE = 4 %

DOMINANCE CRITERION = 0.05

July, 1987

VII-36

86105.004

6.0 SUMMARY

The benefit versus cost analysis clearly defines two alternatives as being preferred. The TOTAL FILL-RIVER WIDENING alternative is preferred primarily due to benefits accrued as a result of table land maintenance with minimal social impacts related to property acquisition. If the project is phased over a number of years and the benefits and costs of property acquisition between a CUT/FILL and a TOTAL FILL alternative are considered similar, the CUT/FILL-CHANNEL RELOCATION scheme is preferred primarily due to a lower construction cost for slope stabilization and a lower risk in terms of toe erosion mitigation. From a more practical point of view, a CUT/FILL-CHANNEL RELOCATION alternative also facilitates a phased approach in a more orderly and feasible manner in that a channel relocation avoids the possibility of channel constriction during the phasing period due to the on-going potential for continued slope instability and failure. This conclusion is confirmed by a sensitivity analyses of the phasing period (Table VII-9).

The benefit versus cost analysis has yielded the following conclusions:

- 1) The evaluation of alternatives has been undertaken using the technological criteria of a class environmental assessment to ensure that all reasonable alternatives which fulfill the project requirements are objectively evaluated.
- 2) Specific, obvious costs are incurred if nothing is done. In addition, the perceived social impacts of unpredictable slope failures on the services and properties are considered unacceptable.
- 3) There is an economic benefit to the public of carrying out the suggested alternative works. This benefit is reflected as a positive net benefit, can be measured in real dollars and is based upon estimates of cost savings to be accrued through implementation of the recommended scheme.

- 4) The selection of the preferred alternative can be accomplished without the need to refine the parameters and numbers related to the benefits and costs beyond the preliminary stage, as the ranking of the alternatives is relatively insensitive to changes in these variables.
- 5) The benefit versus cost analysis has been made independent of cost distribution among benefiting parties and the impact on the budgets of potential funding agency(s).
- 6) An unphased implementation approach should consider the CUT/FILL - CHANNEL WIDENING alternative as preferred, primarily due to lower initial construction cost and maximized net benefit. This conclusion is economically justified on the basis of the recent property acquisition proposal adopted by the Grand River Conservation Authority.
- 7) If a phased implementation approach is preferred, the CUT/FILL-CHANNEL RELOCATION alternative provides additional safe guards against the upstream impacts of possible channel constrictions resulting from slope failures which might occur during the phasing period.
- 8) A phased implementation, although roughly equivalent to an unphased approach in terms of net present worth, has a higher total capital requirement over the project period. Therefore, an unphased approach to the project would require reduced overall capital expenditures.

7.0 LIST OF REFERENCES

1. Grand River Conservation Authority, Terms of Reference for carrying out a Preliminary Engineering Study of the Colborne Street Failure, Brantford, Ontario, August 11, 1986 (Appendix I).
2. Benefit-Cost Guidelines for Conservation Authority Flood and Erosion Control Projects, Conservation Authorities and Water Management Branch, Ontario Ministry of Natural Resources, May, 1983.
3. Grand River Conservation Authority Resolution No. 145-87, dated March 27, 1987.



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**APPENDIX VIII
LAND USE PLANNING**

**PRELIMINARY ENGINEERING STUDY
GRAND RIVER VALLEY WALL SLOPE FAILURE
COLBORNE STREET EAST
BRANTFORD, ONTARIO**

July 1987

Project: 86105

Burlington — Cambridge — St Catharines — London — Regina

TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1
2.0 EXISTING LAND USE OF THE AREA	2
3.0 METHODS OF CONTROLLING LAND USE	6
3.1 Official Plan	6
3.2 Zoning By-law	8
3.3 Interim Control By-law	8
3.4 Fill Line Designation	10
4.0 IMPACTS OF SLOPE STABILIZATION	11
5.0 LAND USE CONTROLS	12
5.1 Pre-Construction Stage	12
5.2 Construction Stage	12
5.3 Post Construction Stage	12
5.4 Implementation	15
5.4.1 Official Plan Proposed Modification	18
5.4.2 Proposed Amendments to the Zoning By-law	20
6.0 SUMMARY	22

LIST OF FIGURES

Figure No.	Description	Page
VIII-1	Key Plan	4
VIII-2	Commercial Land Uses	5
VIII-3	Official Plan	7
VIII-4	Zoning By-law	9

1.0 INTRODUCTION

Philips Planning + Engineering Limited has been engaged in this study to provide the land use planning aspects as set out in the Terms of Reference and as detailed in the proposal (6.2 Land Use and Property).

Due to the preliminary nature of the information and the potential for phasing of the stabilization works available for the selected alternative. For this reason, the land use planning component of the study is also preliminary. The precise boundaries and lots involved in the remedial works cannot be determined at this stage of the engineering analysis.

The following sections include a review of the existing planning policies contained in the proposed Official Plan and the present Zoning By-law No. 3649 which have been carried out in relation to the requirements of this study. The impacts of the recommended slope stabilization scheme, and the land use controls before, during and after construction are discussed in this report. Implementation measures are finally set forth. The recommendations for the implementation of the land use planning recommendations are also provided.

2.0 EXISTING LAND USE OF THE AREA

As shown on Figure VIII-1, the study area extends along Colborne Street (Highway No. 2) for a distance of 970 metres (3182 ft.) between Clara Crescent on the west and the City Limits on the east, corresponding to the location of the T. H. & B. Railway underpass. To the south of Clara Crescent and Colborne Street, the study area extends southerly to the Grand River.

The land use of the south side of Colborne Street area is a mixture of residential and commercial. West of Garden Avenue there are twelve residences and residential use predominates east of Garden Avenue. There are five residences located east of Garden Avenue. To the east of No. 1025 Colborne Street a dwelling and garage have been removed, and this easterly section is vacant land.

The commercial uses on the south side of Colborne Street include the following (from west to east - refer to Figure VIII-2):

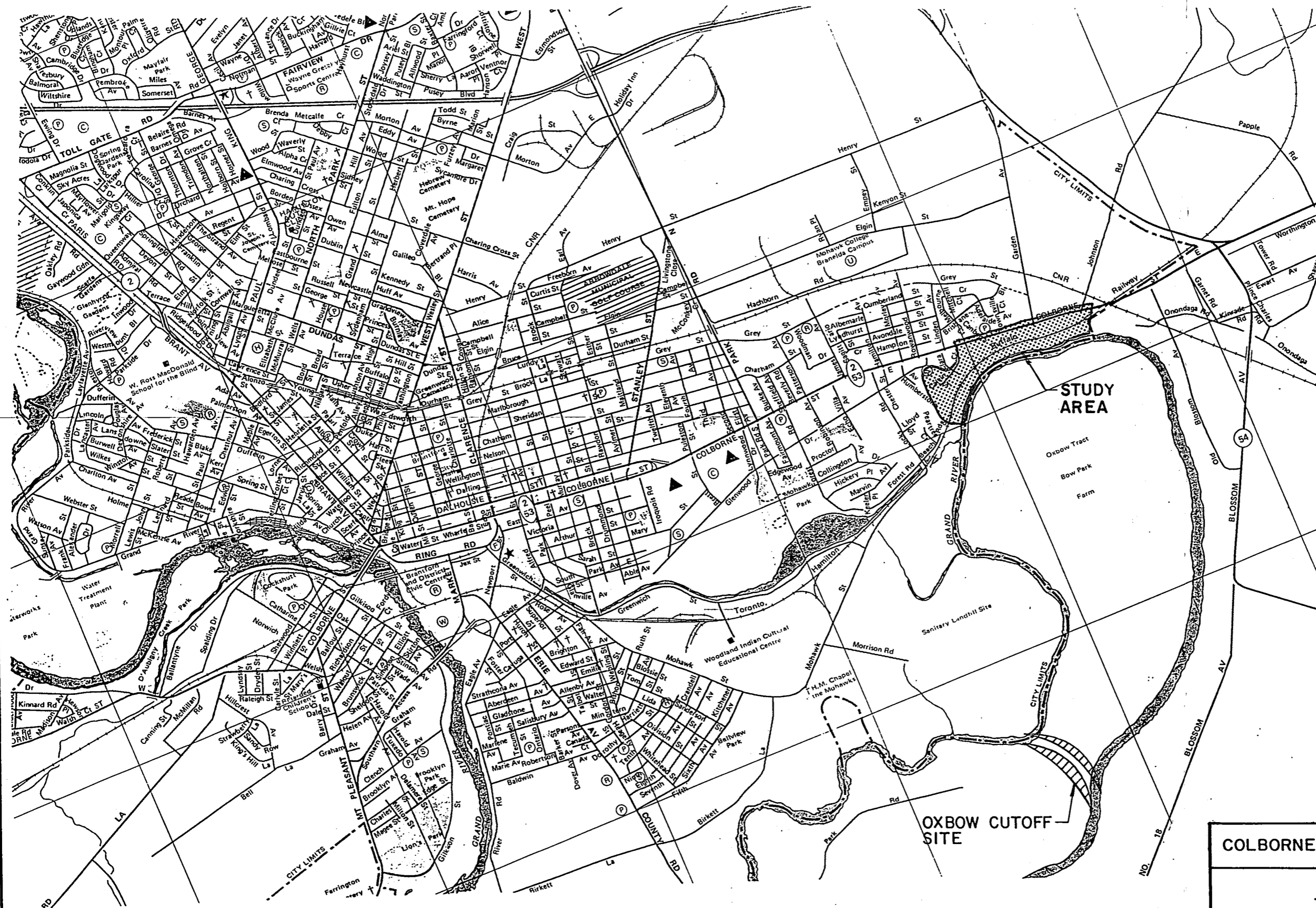
- Area # 1 - Clubine's Lumber
- Area # 2 - Gas Bar
- Area # 3 - Travel Agency
- Area # 4 - Wicker Shop
- Area # 5 - Dan's Wet Pets (fish)
- Area # 6 - Heat Pump sales
- Area # 7 - Music Studio
- Area # 8 - 2 Billboards
- Area # 9 - T.V. Repair
- Area #10 - Antique Sales

All of the preceding commercial uses except the gas bar and billboards also include an accessory residential use in conjunction with the commercial use.

Some of the commercial uses are situated in renovated residences, while others are in buildings designed for commercial purposes. The quality of the commercial buildings is generally good, but the quality of the dwellings ranges from poor to good. Clubine's lumber operation is comprised of five large buildings, one of which suffered damages due to the May, 1986 slope failure and the south part of the building has been demolished. The car wash was rendered unsafe by the failure and it has been demolished, so that only the gas bar remains on this property at present.

The westerly section of the study area contains residential uses on Clara Crescent and the Brantford Christian School to the west overlooking the valley. A dwelling, which was constructed in 1984 on this lower slope, is situated to the south of the railway.

The majority of the land between the top of slope and the river is wooded as is the southerly bank of the River. The land south of the river and to the south of the wooded area is in agricultural use.



COLBORNE STREET SLOPE FAILURE

KEY MAP OF AREA

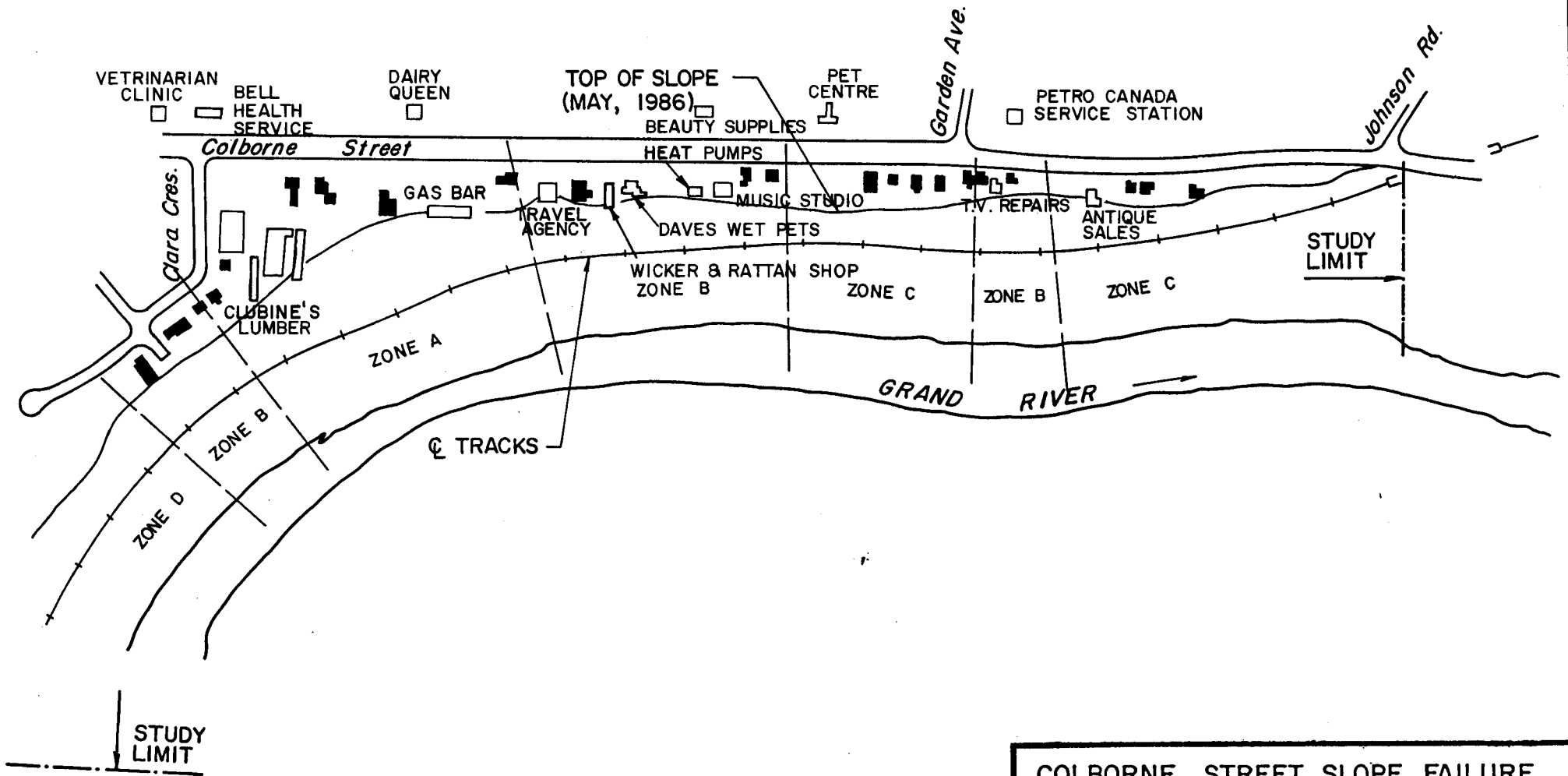


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PROJECT NO. FIGURE NO.

86105

VIII - I



COLBORNE STREET SLOPE FAILURE

COMMERCIAL LAND USES



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FIGURE Nº

VIII-2

3.0 METHODS OF CONTROLLING LAND USE

3.1 Official Plan

The Official Plan covering the City of Brantford has been revised and replaced by a new Official Plan adopted by Council on November 3, 1986 and now awaiting the Minister's approval. This Plan sets out the long range land use planning policies for the City.

Three land use designations affect the Study Area, as shown on Schedule 1 of the Official Plan, and also on Figure VIII-3 attached.

(a) "Special Park and Open Space - Major Open Space"

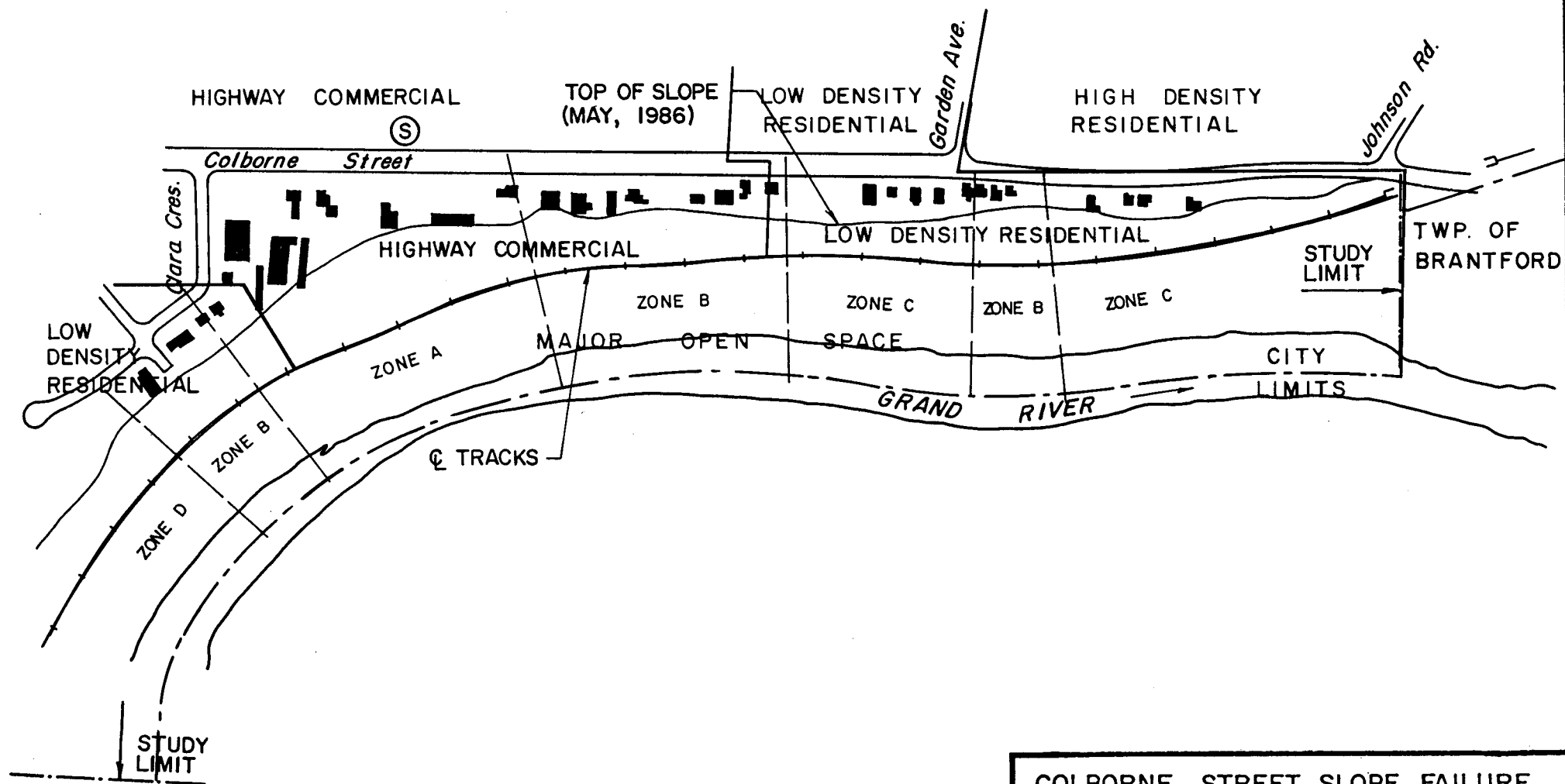
This includes the area from the railway property to the Grand River.

(b) "Highway Commercial Area"

This includes the properties on both sides of Colborne Street west of a point about 190 metres west of Garden Avenue, and extending south to the railway.

(c) "Low Density Residential Area"

This includes the area to the south and west of Clara Crescent south to the railway, and the properties fronting on the south side of Colborne Street east of the Highway Commercial Area to the east limit of the Study Area near the railway underpass, south to the railway property.



COLBORNE STREET SLOPE FAILURE

OFFICIAL PLAN



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FIGURE N^o
VIII - 3

3.2 Zoning By-law

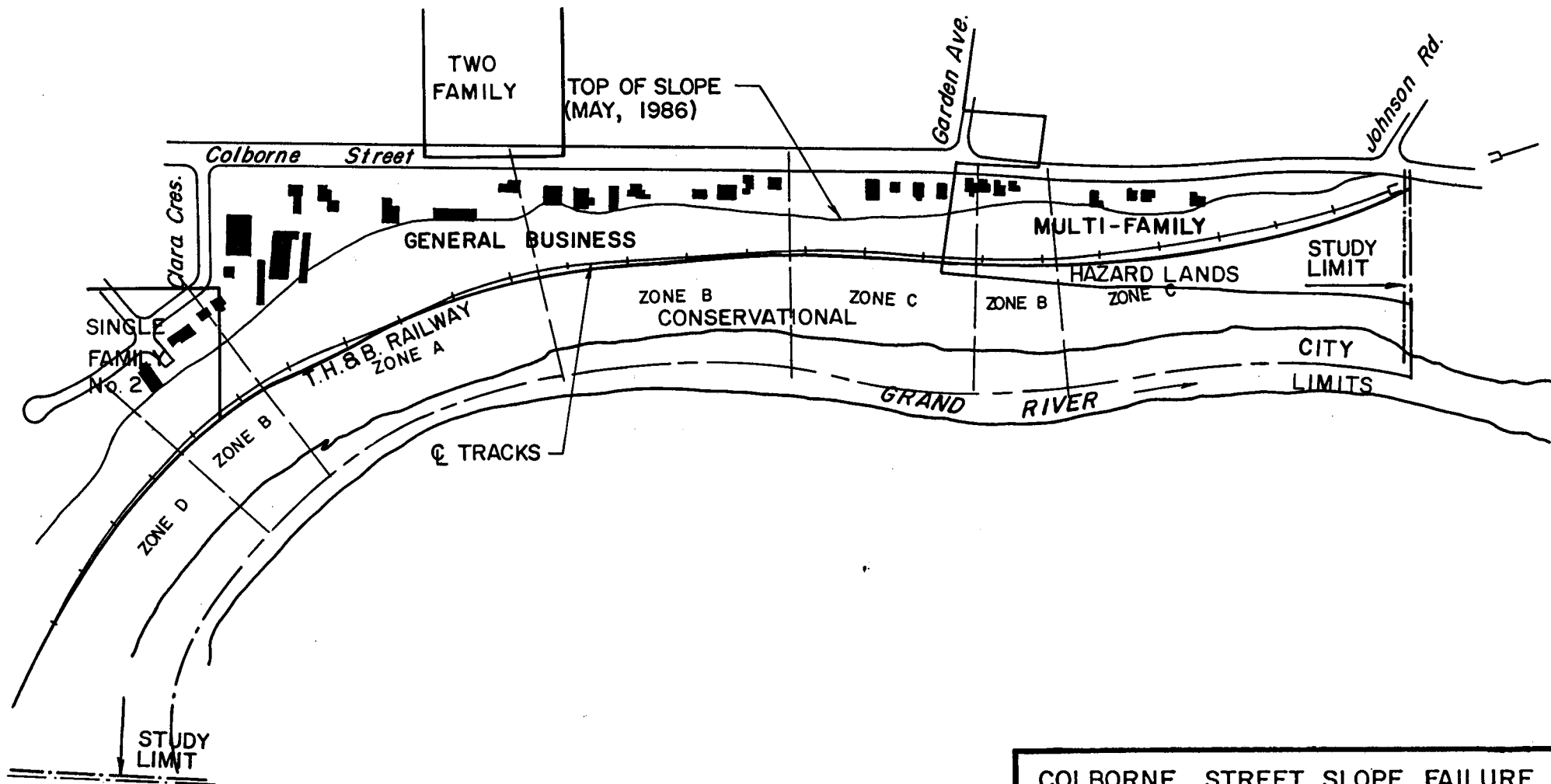
The legal control over the use of land is found in the Zoning By-law. The City of Brantford Zoning By-law No. 3649 zones the area as shown on Figure VIII-4 attached. This By-law was passed on September 12, 1955.

- (a) The lands between the railway and the River are zoned Conservational, with the exception of a small triangular-shaped area lying south of the railway adjacent to the easterly City Limits which is Hazard Lands (H.L.).
- (b) General Business zoning applies to the south side of Colborne Street from west of Clara Crescent to Garden Avenue, and to the north side of Colborne Street to a point 46 metres east of Garden Avenue, with the exception of a Two Family Zone (Residential) on the site of the Cainsville Public School.
- (c) Single Family No. 2 Zone applies to the area south and west of Clara Crescent south to the railway.
- (d) Multi-Family Zone applies to the easterly part of Colborne Street east of Garden Avenue.

It is noted that the sloping area is affected by zoning that permits development ranging from residential to commercial, although accessibility and the slope characteristics make such development impractical and unwise.

3.3 Interim Control By-law

Section 37 of The Planning Act, 1983 permits Council to pass an Interim Control By-law which has the effect of freezing land uses and prohibiting building in a defined area pending completion of a study of the area affecting land use planning policies. An Interim Control By-law can be in effect for a period of up to one year, but can be extended for a total period of two years from the original date of passing.



COLBORNE STREET SLOPE FAILURE

EXISTING ZONING



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FIGURE Nº
VIII - 4

SOURCE : ZONING BY-LAW No.3649

3.4 Fill Line Designation

The Conservation Authority's power to control filling in defined areas below a designated "fill line" may be utilized within the Study Area in order to control filling on privately-owned lands. It is noted that the powers of the Conservation Authority are derived from permissive legislation under the Ontario Statutes and the actions of the Authority should therefore remain consistent with normal policy. It is therefore suggested that the policy for designating fill lines should not be changed arbitrarily, but should be subject to the request of the municipality coordinating land use and Zoning By-laws.

4.0 IMPACTS OF SLOPE STABILIZATION

The initial impact of the slope stabilization project is the change in ownership of the lands from private to public. Because of the hazardous nature of the slope and the upper area along Colborne Street, the buildings used for residential purposes will be vacated. It is anticipated that the other non-residential buildings will also be vacated.

As part of the detailed engineering for the project a new top of slope and an engineered line will be determined. This will enable a decision to be made regarding the future of the buildings in the area affected. It is impossible at this stage to predict which buildings can be retained and which will have to be demolished. The impacts of the slope stabilization project, therefore, are difficult to predict, and they could vary widely from a re-use of many buildings as they were used prior to the study, to a clearance of many buildings and the creation of an open space strip south of Colborne Street.

When the slope is stabilized and the river relocated to the south there will be immediate loss of the existing wooded areas. With a proper replanting program, the natural beauty of the area can be retained so that it will remain a significant scenic vista in this area.

5.0 LAND USE CONTROLS

5.1 Pre-Construction Stage

During the pre-construction stage the most important control is the Interim Control By-law which was passed in July, 1986, and which places a freeze on building. It is permitted to be in effect for one year, but with an optional additional year through another by-law of Council. Section 37 of the **Planning Act** does not permit such a control to be in effect for more than two years as it is considered that two years is ample for the necessary study of the area and for reaching an agreement concerning the planning and zoning of the area affected.

It is assumed that the two-year period, which will end in July, 1988, will provide ample time for the affected properties to be acquired.

Because the exact location of the engineered line north of the present top of slope cannot be determined at this point in the engineering and decision making processes, the impact on the existing buildings also cannot be determined. As an interim measure it is therefore recommended that the Official Plan policies and implementing zoning by-law be changed to establish a special hazard area for the area now controlled by the interim control by-law.

The Ministry of Municipal Affairs has indicated that the designations in the Official Plan be reviewed in light of this Study, including the sloping lands to the west of the Study Area. We are of the opinion that the HC & R designations are inappropriate at this time and should therefore be changed immediately to reflect the serious risk that exists and which the geotechnical evidence concludes will continue until the remedial measures are completed. It appears likely that such measures will be carried out over a period of time extending past the termination of the interim control by-law, therefore it will be essential to have the changes made in both the Official Plan and Zoning By-law prior to the expiry date.

Whether the lands fronting on Colborne Street remain in public ownership or are returned to private ownership cannot be determined until after the remedial works are carried out, however, the planning controls should be placed on the entire properties south of Colborne Street in order to prevent possible development or building additions while the lands are at risk.

5.2 Construction Stage

Since the lands will be in public ownership during the construction of the project, there will be no adverse effect created by the reinstatement of the existing zoning following the expiry of Interim Control in July, 1988.

Although it would be possible to effect the zoning changes as each construction year completes a separate "strip" of the slope, this phasing in of new zoning controls would be unnecessarily protracted, and would not have the same psychological and community impact that a single zoning by-law amendment would have

5.3 Post-Construction Stage

The changes recommended in the Official Plan and Zoning By-law should be in place at the completion of the project construction. The implementation of any land use recommendations for the post-construction period, are contingent upon whether the project is completed as a singular undertaking, or whether the project is phased over a period of years, since the construction period affects the viability of the properties for certain land uses. On the assumption that lands which can feasibly be used for permitted land uses will be offered for sale either to the original owner or to the public, it is important that the final planning and zoning controls are in effect when the property reverts to public ownership. The proposed fill line of the Conservation Authority should also be in effect by this stage.

We believe that it is important for the City Council to demonstrate its leadership in the matter of stabilization as well as the re-planning of the entire area that is affected. The planning controls, therefore, should be resolved and in effect completed, on the assumption that certain lands will then be sold to private owners so that their use can be reinstated. The impact on the residents of the City and tourists who might view vacant buildings along this arterial route is a negative one. This negative aspect, therefore, should be removed by reinstating the appropriate use of the property under private ownership, or if the building has been removed by ensuring that the vacant land is in a "parkland" condition.

On properties where the engineered line and boundary of the General Business or Residential Zone are located too close to Colborne Street to provide a final viable lot for development, such properties should be cleared and retained in public ownership. Such lands should be integrated if feasible into a parkland or parkette area, which would enhance the appearance of the area and provide an excellent vista of the Grand River valley from Colborne Street.

It should be noted that from the top of slope down to the railway property, the land is designated either as Low Density Residential or Highway Commercial. It is recommended that the Official Plan be altered so that the lands south of an engineered line (to be determined) to the River (including the railway) be designated Major Open Space.

It would therefore be appropriate for the City to carry out certain amendments to the Zoning By-law in this area, as follows:

- (a) Limit the depth of the General Business Zone and the Multiple Family Zone south of Colborne Street to an engineered line 6 metres north of the new top of slope, and similarly south of the Clara Crescent Single Family area.
- (b) All lands south of the revised zone boundary in (a) above within the Study Area should be rezoned to the Conservational Zone in order to prevent development. The Hazard Lands Zone adjacent to the easterly City Limits could remain.

As recommended, under Section 3.2, the engineered line would become a zoning boundary for development on the south side of Colborne Street and Clara Crescent. There will probably be some properties where this line cuts through an existing building. In such cases a decision would be required on the future of the building and it should be based on an engineering and geotechnical evaluation. It is possible that very minor intrusions south of the engineered line could be permitted provided that the foundation and site evaluation are investigated and are not found to be at risk. This should not be interpreted however as permitting new extensions to existing buildings.

In the event that a significant number of buildings must be removed from the area as a result of the location of the new top of slope and the engineered line, we recommend that an overall parks and landscaping plan be prepared by the City of Brantford for the affected lands. Such a plan should be integrated with the remaining developed lands in the study area. As set out in the Official Plan (Section 7.3.7.5), the Highway Commercial area should be improved through co-ordination of access points, integrated parking areas, consistent streetscape and other design features.

The land assembly of all the properties in the affected area, therefore, provides the City with an opportunity to integrate the parkland and Highway Commercial development that will remain so that an improved streetscape and more advantageous arrangement of accesses and parking areas can be achieved.

5.4 Implementation

The following are the major activities to be carried out in order to implement our recommendations:

- (a) Prior to July, 1987, the City Council should pass a by-law pursuant to Section 37 of the Planning Act to extend the Interim Control for an additional year to July, 1988.
- (b) A Minister's modification of the Official Plan should be requested by the City Council that will place the Study Area (and similar hazardous adjacent areas) in a special hazard designation until the slope rehabilitation has been completed.
- (c) Upon approval by the Minister of the Official Plan change in (b) above, the City Council should initiate an amendment to the Zoning By-law to prevent development in the Study Area until the slope rehabilitation has been completed. This amendment should be effective prior to July, 1988 at a date when the Interim Control By-law can be repealed concurrently.
- (d) When the final top of bank is determined through detailed engineering,

- (i) The Grand River Conservation Authority should initiate the process of designating the engineered line (6 metres north of the top of bank) as a fill line for planning purposes not necessarily in accordance with the Conservation Authorities Act, insofar that surface drainage across the line should be prevented to avoid gullies developing , but to promote regrading of lots to slope from the fill line down to the street,
- (ii) The City of Brantford should amend the Official Plan to change the land use designations south of the engineered line in the study area, to the Major Open Space Designation,
- (iii) The City Planning Department should carry out a study of the lands between Colborne Street and the engineered line 6 m north of the new top of bank, and determine the long range Official Plan designation of these lands which could range from Major Open Space to Highway Commercial and Low Density Residential, or a combination thereof. An Official Plan amendment should be prepared to make these changes in the designation but it should not be adopted by Council until the slope rehabilitation has been completed and it is feasible to eliminate the special hazard designation referred to in (b) above, and
- (iv) The City of Brantford should initiate an amendment to the City's Zoning By-law No. 3649 to implement the Official Plan (as amended by the preceding action) and to provide appropriate zoning controls within the study area that will affect all remaining buildings and structures and establish standards for any new construction.

- (e) When it is ascertained which buildings are to remain and which are to be removed, the City of Brantford should initiate a parks and landscaping plan for the affected lands if a significant number of buildings must be removed, and such plan should be integrated if feasible with a streetscape and development plan as set out in Section 7.3.7.5 of the proposed Official Plan for the designated Highway Commercial area, in order to provide a consistent streetscape, co-ordinated access points, integrated parking areas and other design improvements for this area, which is a major entrance to the City.

5.4.1 Official Plan Proposed Modification

- (a) Section 7 is amended by adding a new subsection 7.2.5.11, as follows:

"Area 24 - Colborne Street Slope Failure Area

The major slope failure that occurred in this area in May, 1986 and other minor failures are the result of the Grand River eroding its channel into the toe of the original slope combined with the characteristics of the slope and its constituent materials, as reported in two independent studies carried out in 1968 for the Canadian Pacific Railway and in 1986 for the Grand River Conservation Authority. Unless remedial measures are carried out, there will be ongoing slope failures which pose a serious risk to life and property above the top of the existing slope. Golder Associates have been retained by the Grand River Conservation Authority to prepare recommendations for the resolution of this problem. After a decision is made concerning this Study's recommendation, a further detailed engineering study will be required to prepare the necessary plans for the remedial works, and the required funding will have to be resolved. Following this the necessary construction work will be required to be carried out so that the risk can be removed.

Due to the uncertainty regarding the results of the engineering studies and work, and the period of time that will elapse until the area above the slope is rendered safe for human habitation and occupation, the lands in Area 24 cannot be designated in a final land use category. Within this area, therefore, only existing land uses are permitted until such time as the lands above the slope are deemed safe by a competent qualified professional engineer, and an appropriate amendment has been made to this Plan to designate these lands in a final category or categories. Council's policy for this interim period is to implement this policy by an amendment to the City's Zoning By-law which will permit only the existing uses, buildings and structures, and will not permit any extensions."

- (b) Section 7 is further amended by adding a new subsection 7.3.7.9, as follows:

"Special Policy Area

Area 24 - Colborne Street Slope Failure Area

The policy for this area is set out in subsection 7.2.5.11 of this Plan."

5.4.2 Proposed Amendments to the Zoning By-law

The following amendments to the Zoning By-law should be enacted to ensure proper interim control of land uses in the study area:

**PROPOSED AMENDMENT TO THE BRANTFORD
ZONING BY-LAW NO. 3649**

WHEREAS certain lands south of Colborne Street East sloping to the Grand River are at risk of slope failure which can result in loss of life, personal injury and loss of real property, and such lands can only be protected by slope rehabilitation and related engineering work;

AND WHEREAS the City of Brantford's By-law No. 3649 imposed an interim control on such lands pursuant to Section 37 of the Planning Act and such By-law will cease to have effect as of August 5, 1988;

AND WHEREAS remedial work to stabilize the slope will require more time to carry out;

AND WHEREAS it is deemed expedient to impose strict land use controls on the area;

NOW THEREFORE the Council of the Corporation of the City of Brantford enacts as follows:

1. The zoning on Sheet 9 of By-law No. 3649 of the lands within the defined area shown on attached Schedule "A", which is hereby declared to form part of this By-law, is changed from:

- (a) Single Family No. 2 Zone (SF-2),
- (b) Multi-Family Zone (MF),
- (c) General Business Zone (GB), and
- (d) Conservational Zone (CONS)

to Development Constraint Zone (DC).

2. By-law No. 3649 is amended by adding a new subsection 13.B. as follows:

"SECTION 13.B: DEVELOPMENT CONSTRAINT ZONE (DC)

In a Development Constraint Zone, no building or structure shall be used and no land shall be used except for such purposes and in accordance with such standards as were existing on the date of passing hereof, provided however that the foregoing shall not apply to prevent the carrying out of:

- (a) municipal or public works by the City or the Grand River Conservation Authority, or
 - (b) construction or repair of the Canadian Pacific Railway (T.H.& B. Railway) in order to restore or impose rail service through the Zone."
3. This By-law shall take effect on the day of passing, subject to the approval of the Ontario Municipal Board if required.

ENACTED this ____ day of _____, 198__.

Mayor

Clerk

NOTE: The existing Hazard Lands (HL) Zone is excluded from this amending by-law as it is adequate for land use control in the southeasterly section of the Study Area. Although it would be possible to utilize the Hazard Lands Zone for the entire Study Area, it was considered that a distinctive zone would be preferable since it is intended to apply only until the engineering work is completed and will be repealed and replaced with final zoning controls.

6.0 SUMMARY

In addition to the implementation of the engineered works required to stabilize the slope, it is also necessary to provide the regulatory agencies with the "tools" required to ensure that land uses at the top of the slope can be restricted to those which are considered compatible and safe. To do so, a review of existing land use policies and controls was carried out and general recommendations made with regard to the formation and provision of such controls.

In order to prevent any undesirable building above the top of the bank, it is suggested that a Zoning Bylaw amendment be passed that will prohibit building within an engineered distance from the finished top of slope (6 metres as suggested in Appendix II). Such zoning should also restrict land use below the top of bank in accordance with the recommendations for changes in the proposed Official Plan. In addition to zoning controls, a Fill line if recommended by the municipality, should be established by the Conservation Authority under their regulations (R.S.O. 1981 as amended) to restrict the placement of fill beyond the engineered setback from the top of the slope.

The suggested controls will take time to implement and by necessity, require detailed information as to the final top of the slope in order to define the line for control. The proposed maximum permitted extension of the existing interim control bylaw restricting development to July, 1988 is therefore recommended. Also, a special hazard designation should be incorporated in the Official Plan for the Study Area and be implemented in the Zoning By-law before the interim control expires. Such controls would be replaced upon completion of the slope stabilization works.

The acquisition of all land south of Colborne Street will eliminate the need to have the ultimate land use policies and controls in place prior to the end of the construction period. Furthermore, if the acquired lands remain in public ownership following construction, it may be desirable to zone the lands as conservation/open space.

Nevertheless, it is recommended that the re-zoning of the lands and any fill line designation proceed immediately following the identification of the final top of the slope to ensure that the necessary controls are in place, should the lands be returned to private ownership after the construction period.

**APPENDIX IX
PRELIMINARY DESIGN DRAWINGS**

**PRELIMINARY ENGINEERING STUDY
GRAND RIVER VALLEY SLOPE FAILURE
COLBORNE STREET EAST
BRANTFORD, ONTARIO**

Golder Associates
Philips Planning + Engineering Limited
McCormick, Rankin & Associates Limited
Ecologistics Limited

July 1987

861-3257

TABLE OF CONTENTS

	<u>Page</u>
1. INTRODUCTION	IX-1
2. SLOPE WORKS	IX-2
3. RIVER WORKS	IX-4
4. COSTS	IX-7

1. INTRODUCTION

This Appendix contains the preliminary design drawings for the selected alternative which is the cut and fill scheme. For details of the various aspects of the work, reference should be made to the pertinent Appendices in Volume II of this report.

The results of the revised benefit cost analysis, based upon the factors noted in Appendix VII, indicate that scheme (4), the Cut and Fill alternative with river channel widening, evolves as the most appropriate and beneficial scheme.

However, potential fiscal constraints may necessitate phased implementation of stabilization measures over a number of years. Staging, in practical terms, means that the actual top of bank would be still further back than it is at present.

Therefore, in addition to carrying out the complete stabilization measures immediately, an examination was also made of phasing/staging the remedial measures over a period of time. It was concluded that, in order to minimize risk to life due to continued instability, it would be necessary to prioritize the work with the phased approach as follows:

- initially acquire the property on top of the bank in the study area

- widen or construct a new river channel to the south of the existing river (rather than river widening)
- stabilize, over a period of time, the slope (top to bottom) in selected sections

Benefit versus cost analyses indicate that the longer the phasing period, the more beneficial a complete channel relocation becomes.

The Plan, Figure IX-1, outlines the extent of the slope regrading works, the river channel widening and related works, as well as the proposed centreline for the railway reinstallation. Figures IX-2, IX-3 and IX-4 present typical sections through zones A, B and C, respectively, which indicate the finished geometry of the slope and river works for the widening scheme.

Similarly, the Plan, Figure IX-5 outlines the extent of the works for the cut and fill scheme with the river realignment and Figures IX-6, IX-7 and IX-8, respectively, indicate the required slope geometry for this scheme.

2. SLOPE WORKS

Conceptually, the cut and fill scheme consists of stabilizing and protecting the lower slope by filling and regrading the slope to a broken back geometry with a series of benches and stabilizing the upper slope by cutting. The reinstatement and preservation of the toe of the slope constitutes a key element in the design of

the remedial works. To this end, river works have been included to relocate the main channel and to provide erosion protection. With this scheme, the railway embankments would be restored on the benches to much the same grades and alignments existing prior to the 1986 failure.

As shown on the Plans, Figures IX-1 and IX-5, the recommended limits of the work include all of zones A, B and C. In addition, the limits of the work have been extended upstream some 100 metres into zone D and downstream to provide effective transitions to the portion of the study area in which no remedial works are proposed and to enhance the stability of the portion of the valley wall slope in the transition areas.

The preliminary design of the cut and fill scheme is based on the premise that a 6 metre wide setback from the regraded top of slope would establish a restrictive hazard zone in anticipation of post-construction deformations.

Based on the results of the stability analyses, it is considered that the regrading scheme must be sufficient to achieve an overall slope inclination of 4 horizontal to 1 vertical or flatter. With the use of horizontal benches, maximum allowable side slopes of 3.0 horizontal to 1 vertical and 2.5 horizontal to 1 vertical have been set for the lower and upper slopes, respectively.

Typically, construction would entail placement of a berm of compacted granular material at the toe of the slope, having a finished grade at about elevation 197.5 metres. This berm should be designed with side slopes inclined

at 3 horizontal to 1 vertical or flatter and provided with erosion protection. Use of a flexible but durable type of erosion protection with a suitable separation medium would be required.

It is considered essential that an adequate drainage system be incorporated into the design of the work to facilitate construction and to provide long term groundwater control. To this end, the full face of all areas of the slope to be cut or filled should be blanketed with a drainage medium consisting of select granular material meeting the pertinent filter criteria.

In addition, a subsurface drainage system, utilizing perforated collector drains within the granular blanket, adequately filtered lateral drains to intercept localized seepage zones and horizontal bench subdrains, should be included. Surface runoff could be controlled by effective back grading along benches and providing catch basins as required. The underdrain system should discharge into free flowing outlets located within the revetment.

Under this scheme, the railway embankment would be restored to the approximate pre-slide alignment and grade. This embankment would be reconstructed consistent with the criteria outlined for the benches.

3. RIVER WORKS

The channel widening option consists of extending the existing channel to the south to provide sufficient capacity to convey all of the river flow after the fill required

for slope stabilization has been placed on the north side of the existing channel. Gabion erosion protection is provided along the entire length of the widened channel. The preliminary channel alignment is shown on Figure IX-1. Since the channel curvature is increased at the inlet and outlet, more substantial grouted gabion erosion protection measures are required at these points.

The channel relocation option involves the creation of a second river channel, approximately parallel to the existing channel, which would be capable of passing all of the river flow through the area. The existing channel, which would be reduced in its cross-sectional flow area, would be maintained for local drainage and overflow purposes while the new channel would be designed to accommodate design flood flows. A groin and submerged sill system would be incorporated to act as a deflector to maintain higher flows within the new channel, permitting only lower flows to pass into the restricted channel.

The preliminary channel relocation alignments shown on Figure IX-5 have been established based on an interactive assessment of hydraulic conditions to minimize impact at the upstream and downstream extents of the project. The preferred channel cross section incorporates a gabion anti-erosion revetment along the north bank of the new channel alignments. Gabions have been selected primarily due to their proven effectiveness against erosion, resistance to ice damage, hydraulic efficiency and cost-effectiveness. Rip rap erosion protection is provided at other locations identified as erosion prone. Hard point deflectors have been incorporated along the north

channel bank at the upstream and downstream ends of the alignments to provide an additional safeguard against erosion at points of greatest alignment curvature where flow velocities are a maximum.

Figures IX-6, IX-7 and IX-8 show typical cross sections through the channel relocation alignment, indicating the erosion protection on both the new channel and the old channel. In the case of the new channel, into which the majority of the flows are to be diverted, a gabion mat slope protection extending approximately 10 metres beyond the river toe on the north bank is proposed. The existing river channel incorporates a rip rap form of revetment protection to the 197.0 metre elevation as an erosion resistant blanket. A levee constructed of excavated material is located between the channels to increase the flow capacity of the new channel.

Enhanced erosion pockets would be required at the upstream and downstream sections of the work. The use of a gabion revetment form of protection with additional free board to account for velocity run-up at the outside of the curvature would be used to provide additional factors of safety against stream bank erosion. The use of a grouted gabion will be necessary on the north river bank at the inlet to protect the bank from scour.

A gabion submerged groin is proposed as a flow deflector which would be placed on the bank at the regional flood level to ensure that flows in excess of channel capacity are deflected away from the marginally stable slope. This will minimize erosion of the bank during infrequent flood events and help to ensure the long term integrity of slope stabilization measures.

4. COSTS

A summary of the estimated costs associated with the various components of the cut and fill scheme and river works option is outlined below:

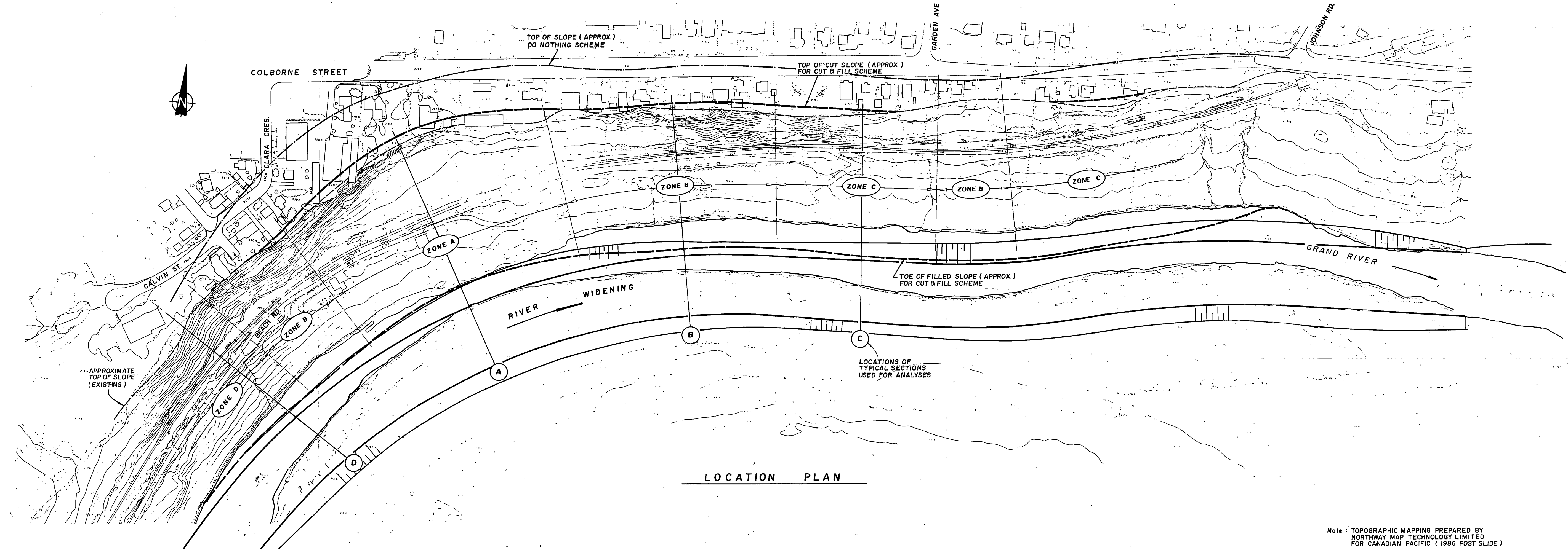
	<u>OPTION 1</u>	<u>OPTION 2</u>
	Constructed Immediately (River Widened)	Phased Construction (Channel Relocated)
1) Property Acquisition	2.7	2.7
2) River Channelization	4.2	5.9
3) Storm Sewer Repairs	0.2	0.2
4) Slope Stabilization	4.7	5.5*
5) Railway Line Reinstatement	0.6	0.6
Total Cost	\$12.4 Million	\$14.9 Million

*includes increased mobilization and temporary erosion protection costs

The costs include an engineering design and supervision allowance.

River relocation would cost approximately \$1.7 million more to construct than a channel widening. However, the river widening design, as proposed, cannot be implemented if the slope is stabilized in a series of vertical strips. For a phased approach, river widening would require interim erosion protection which would significantly increase the costs. In addition, with a channel widening scheme, there remains a risk of further channel constriction as a result of additional/continual slope failures during the phased construction period.


The river relocation scheme has been configured to utilize a portion of the existing river channel as a secondary flow channel, thereby reducing the size of the new channel as detailed in Appendix III of this report. Alternatively, the existing river channel can be filled in completely and the size of the new relocated channel increased to accommodate all flows. The total cost of either configuration is virtually the same.



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LOCATION PLAN

(CUT & FILL SCHEME WITH RIVER WIDENING)

PROJECT No. 861-3257

DATE JULY, 1987

SCALE 1:2000

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
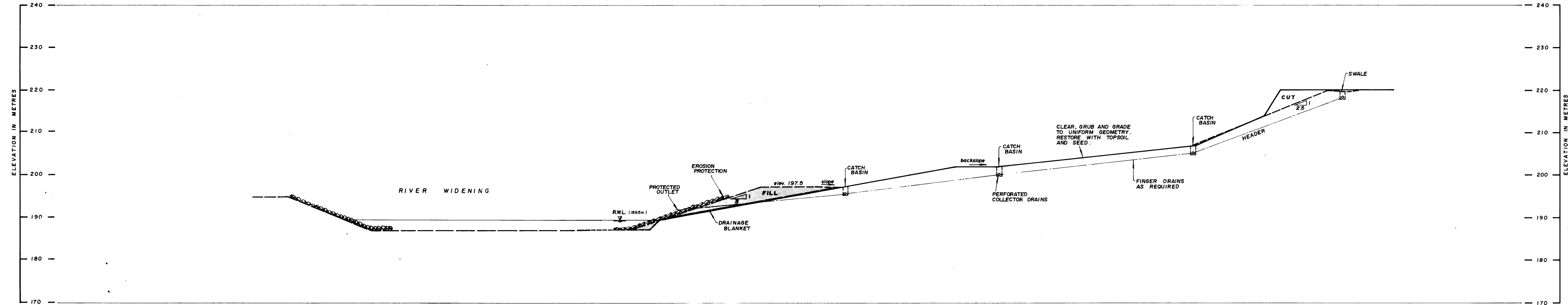
CHKD. 

FIGURE IX-1,


Note: TOPOGRAPHIC MAPPING PREPARED BY
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SCHEMATIC SECTION - ZONE A
(CUT & FILL SCHEME WITH RIVER WIDENING)

PROJECT No. 861-3257

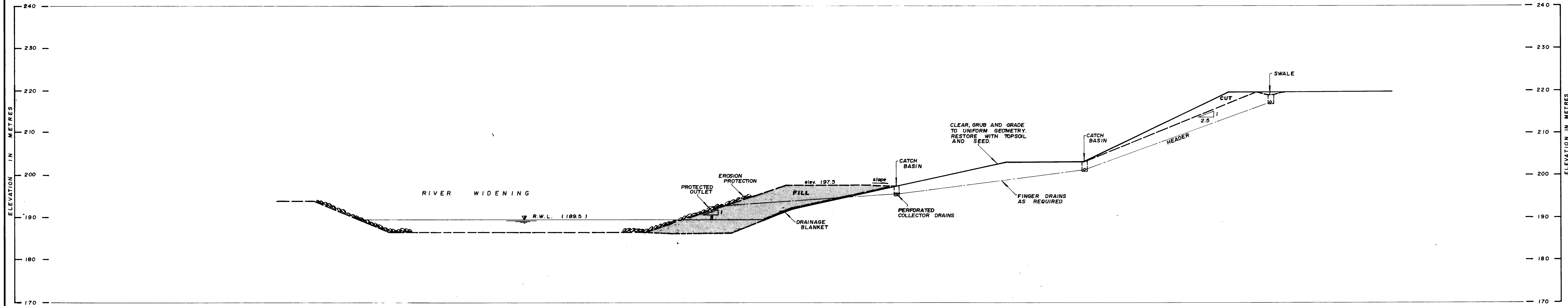
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FIGURE IX-2



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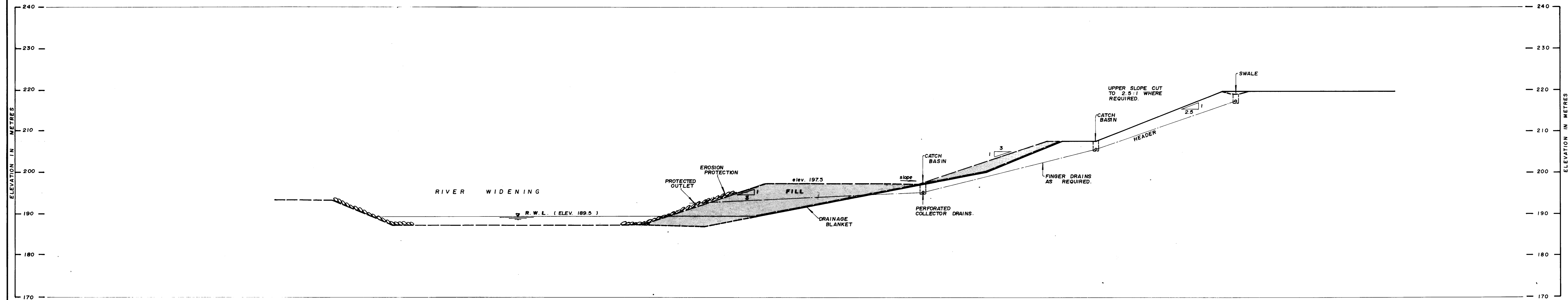
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FIGURE IX-3



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SCHEMATIC SECTION - ZONE C
(CUT & FILL SCHEME WITH RIVER WIDENING)

PROJECT No. 861-3257

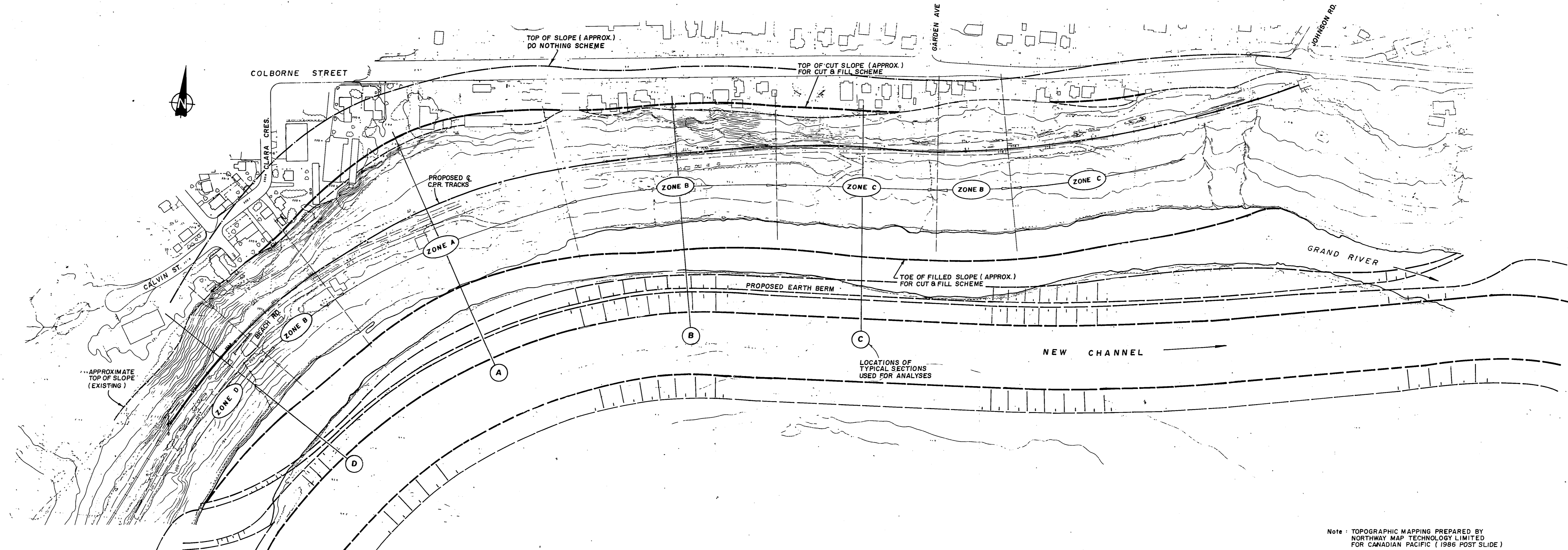
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FIGURE IX-4



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LOCATION PLAN (CUT & FILL SCHEME WITH RIVER RELOCATION)

PROJECT No 861-3257

DATE JULY, 1987

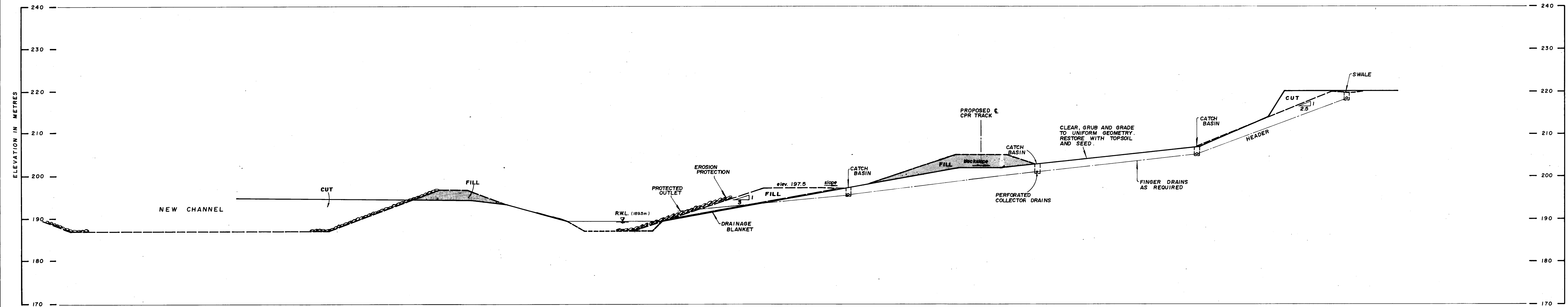
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FIGURE IX-5

Note: TOPOGRAPHIC MAPPING PREPARED BY
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SCHEMATIC SECTION - ZONE A
(CUT & FILL SCHEME WITH RIVER RELOCATION)

PROJECT No. 861-3257

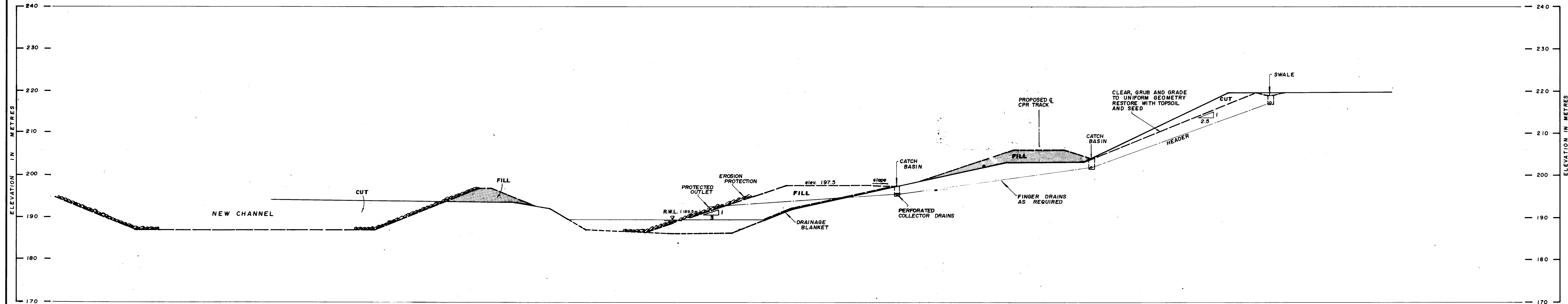
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FIGURE IX-6



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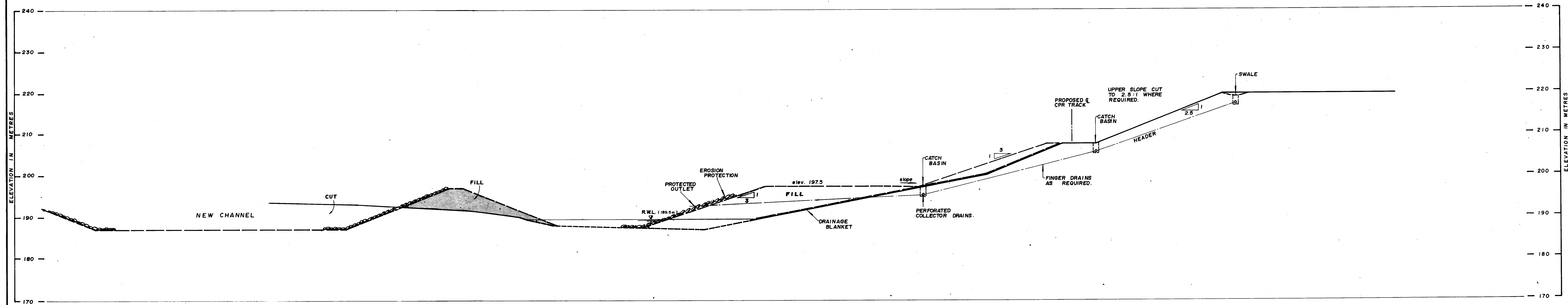
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CHKD. *[Signature]*

FIGURE IX-7



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SCHEMATIC SECTION - ZONE C
(CUT & FILL SCHEME WITH RIVER RELOCATION)

PROJECT No. 8613257

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FIGURE IX-8