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GUARDRAIL UTILIZATION: COST-EFFECTIVENESS COMPUTER PROGRAM TO ANALYZE W-BEAM GUARDRAIL ON FILL SLOPES

by

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in cooperation with
NEBRASKA DEPARTMENT OF ROADS

CIVIL ENGINEERING DEPARTMENT
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GUARDRAIL UTILIZATION: A COST-EFFECTIVENESS COMPUTER PROGRAM TO EVALUATE W-BEAM GUARDRAIL ON FILL SLOPES

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ABSTRACT

Key Words: Guardrail, and Roadside Safety

The purpose of this study conducted by the University of Nebraska was to assist the Nebraska Department of Roads in establishing new guardrail design policies and standards in Nebraska which will take into consideration the relative "effectiveness" and "benefit" of guardrail and alternatives to guardrail installations as a function of highway type, traffic volumes, and the annualized costs of construction, maintenance, and repair. Effectiveness is a measure of the annual reduction in the number of injury accidents, whereas, benefit is a measure of the annual reduction in accident costs.

This report describes the computer program developed to expedite the lengthy and tedious cost-effectiveness and benefit-cost calculations for making W-beam guardrail improvements on roadside embankments. Case study problems are worked to illustrate the usage of the hazard inventory and improvement alternative input data coding forms and the interpretation of the output listing. Also, the cost-effectiveness and benefit-cost methodologies, on which the program was developed, are discussed in detail.

The hazard inventory and improvement alternative coding forms developed in this study are general in scope and include most roadside hazards that are likely to be encountered by an errant automobile. Recommendations for future additions to the computer program to include hazards other than W-beam guardrail and embankments are presented.

The work accomplished in this study has demonstrated that the cost-effectiveness and benefit-cost computer program shows great potential in providing highway engineers and administrators in Nebraska with a rapid and efficient managerial tool for evaluating spot safety improvement projects and/or design projects in order to realize the greatest return on the capital investment made to reduce injury accidents.

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Derald S. Kohles, Chairman

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Civil Engineering Department
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INTRODUCTION

During the past year, the Nebraska Department of Roads (NDR) has been engaged in a review of its policy on the use of guardrail. The purpose of the NDR review was to develop a revised policy which more directly considers the relative safety "effectiveness" of guardrail and alternatives to guardrail installation as a function of highway type, traffic volume, and the costs of construction, maintenance, and repair. The research documented in this report was conducted in support of this policy revision effort.

The primary objective of this research study was to provide the Nebraska Department of Roads a computer-aided procedure for comparing the cost-effectiveness of guardrail installations with alternatives to guardrail such as flattening slopes, removing hazards, or doing nothing. Although the application of the program is currently limited to the evaluation of W-beam guardrail installations and fill slopes, the procedure developed in this study has been designed to facilitate expansion of the scope of its application to include other types of guardrails, traffic barriers, and roadside hazards. In addition to serving as a design tool for evaluating the cost-effectiveness of a specific guardrail installation, the computer-aided procedure can also be used to evaluate the cost-effectiveness of alternative guardrail utilization policies and design standards, which is the ultimate use for which the program was intended. However, because of the ease with which the computer-aided procedure can be used, it would be feasible to conduct a detailed analysis of each situation rather than apply a generalized guardrail utilization policy. Thus, it would seem desirable to incorporate this procedure into the Road Design System currently being used by the Nebraska Department of Roads.

This report describes the computer-aided procedure developed for the cost-effectiveness evaluation of guardrail installations. Included are a description of the computer program, instructions for its use, and examples which illustrate the preparation of input data and the interpretation of the output. Also, the cost-effectiveness and benefit-cost methodologies, on which development of the procedure was based, are explained. In addition, recommendations for future additions to the computer program are presented.

COMPUTER PROGRAM

The computer program in this study was developed to expedite the lengthy and tedious cost-effectiveness calculations for making W-beam guardrail improvements on roadside fill slopes. The Logic for the program was developed in earlier studies presented by Post (1, 2). Implementation of the computer program requires that one complete two types of computer coding forms. The first form (see Figure 1) is an inventory form of an existing roadside hazard or base design condition; whereas, the second form (see Figure 2) is an improvement alternative form for reducing the frequency and/or the severity of an existing hazard. Each form represents one computer IBM data card with 80 field specifications. A discussion on the use of each coding form follows.

Roadside Hazard Inventory Form

The inventory form shown in Figure 1 is divided into 6 boxes to facilitate in the presentation of the form to the user. The circle at the left of each box with a pre-marked "x" indicates that the data within that box must always be punched; whereas, the user must put an "x" in an unmarked circle if the data within that box is to be punched. The numbers under each small square within a box represent columns on an IBM data card.

Box 1 - Highway

The data in Box 1 is always punched. This box contains information on the type of highway, highway traffic conditions, and highway geometrics. As an example, Interstate I-80 with an ADT of 20,500 would be coded as shown on the following page. The data on this type highway can be obtained from the NDR Minimum Design Standards (3).

FIGURE 1.

ROADSIDE HAZARD INVENTORY FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Inventory Conducted by _____ Date _____

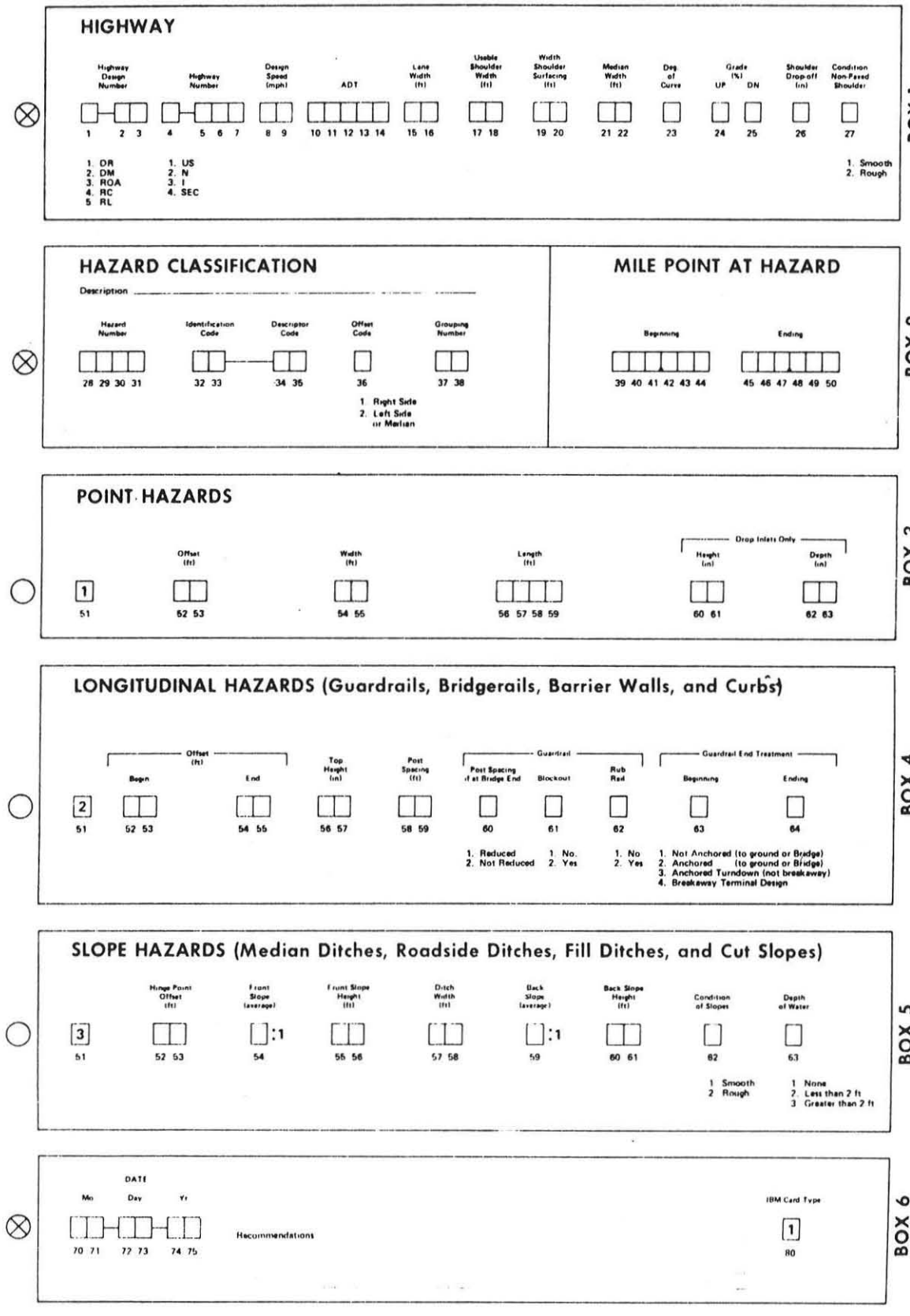
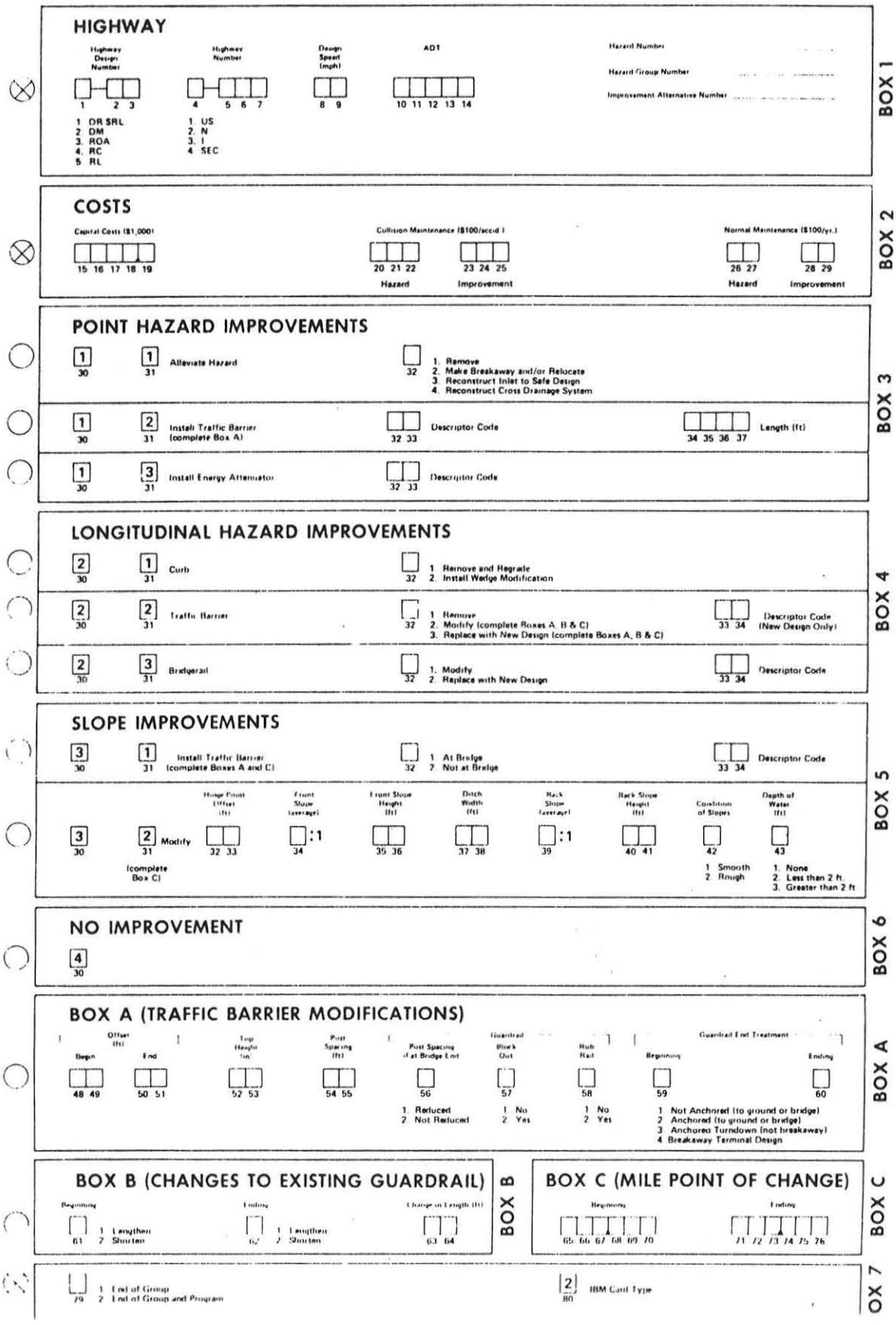


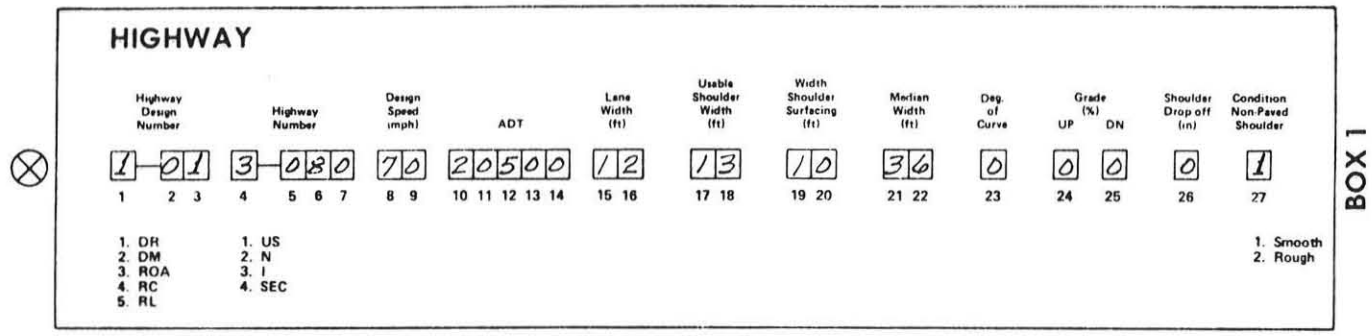
FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by _____ Date _____





Box 2 - Hazard Classification

The data in Box 2 is always punched. A discussion on the hazard number and grouping number will be presented later. A hazard is classified by the Identification and Descriptor Codes listed in Table 1. For example, a 300 ft. (0.057 mi) length of W-beam guardrail with strong wood posts and beginning at mile-post No. 3 would be written as shown below.

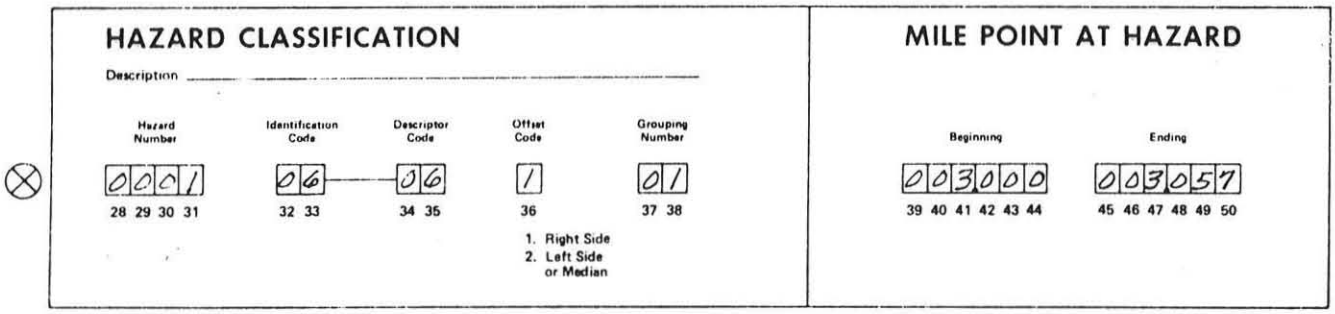


TABLE 1. HAZARD CLASSIFICATION

Identification Code	Descriptor Code
01. Utility Poles (wood)	01. Diameter less than 10 in. 02. Diameter greater than 10 in.
02. Trees	01. Diameter less than 6 in. 02. Diameter between 6 to 12 in. 03. Diameter greater than 12 in.
03. Rigid Sign Supports	01. Single wood post (small size) 02. Single wood post (large size) 03. Single metal post 04. Double wood posts (small size) 05. Double wood post (large size) 06. Double metal posts 07. Triple metal posts 08. Cantilever metal support 09. Overhead sign supports
04. Rigid Base Luminaire Supports	01. Small Size 02. Large size
05. Curbs	01. Mountable design 02. Non-mountable design less than 10 in. high 03. Barrier design greater than 10 in. high

TABLE 1. HAZARD CLASSIFICATION

Identification Code	Descriptor Code
06. Guardrails and Median Barriers	01. Cable (2 strands on one side of post) 02. Cable (3 strands on one side of post) 03. Cable (1 strand on each side of post) 04. Cable (2 strands on each side of post) 05. W-Beam (weak steel posts) 06. W-Beam (strong wood posts) 07. W-Beam (strong steel posts) 08. Thrie-Beam 09. Box Beam (weak posts) 10. Concrete Median Barriers
07. Slopes	01. Ditches 02. Fill Slopes 03. Cut Slopes
08. Culverts	01. Headwall or exposed end of pipe 02. Gap between culverts in medians 03. Sloped culvert with grate 04. Sloped culvert without grate
09. Inlets	01. Raised drop inlet (tabletop) 02. Depressed drop inlet 03. Sloped inlet

TABLE 1. HAZARD CLASSIFICATION

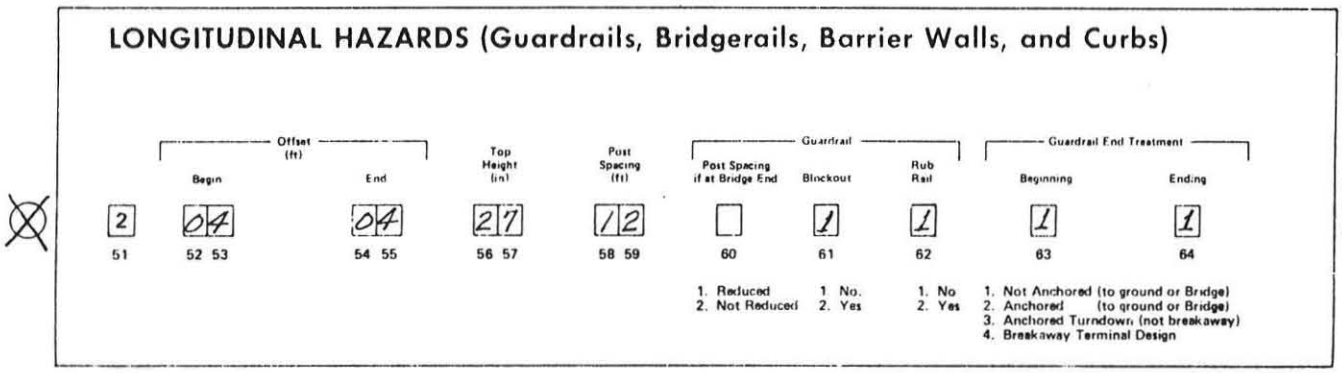
Identification Code	Descriptor Code
10. Roadway under bridge	01. Bridge piers 02. Bridge abutment
11. Roadway over Bridge	01. Open gap between parallel bridges 02. Closed gap between parallel bridges 03. Elevated gore abutment 04. Sidewalk or safety walks in front of bridgerail
12. Bridgerails	01. Rigid bridgerail ... smooth and continuous construction 02. Semi-Rigid bridgerail ... smooth and continuous construction 03. other bridgerail ... probable penetration, severe snagging and/or pocketing or vaulting
13. Retaining Wall	01. End exposed 02. End shielded
14. Energy Attenuator	01. Rich Hydro Cells 02. Fitch Barrier ... 8 Modules (11,900 lbs) 03. " " ... 9 " (12,300 lbs) 04. " " ...10 " (12,700 lbs) 05. " " ...12 " (13,100 lbs) 06. " " ...15 " (17,700 lbs)

Box 3 - Point Hazard

A point hazard is a hazard of small dimensional measurements. Typical examples of point hazards are trees, utility poles, sign supports, and drainage inlet structures. Point hazards were not considered in this study. Additional subroutines would need to be developed in order to include point hazards.

Box 4 - Longitudinal Hazards

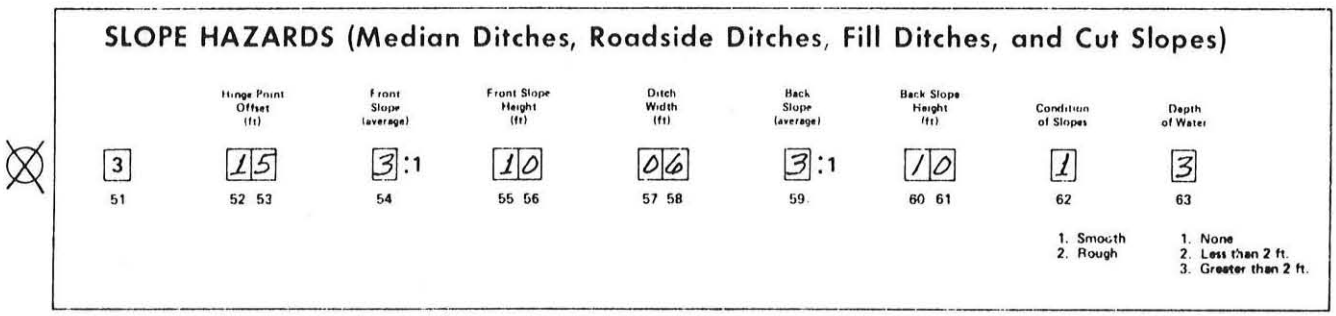
As indicated in Box 4, longitudinal hazards are hazards that have long dimensional measurements such as guardrails, bridgerails, barrier walls, and curbs. An "x" must be placed in the unmarked circle to the left of Box 4 to signal the key punch operator to punch the data in Box 4. Of the four hazards identified, this study included only roadside W-beam guardrail. The offset distance in Box 4 is the lateral distance from the edge of the traveled lane to the face of the W-beam guardrail. A typical W-beam guardrail located very close to the roadway with a standard height of 27 in., a non-standard post spacing of 12 ft-6 in., and unanchored ends would be coded as shown below. The length of guardrail would be coded in Box 2.



The guardrail height effect on vehicle vaulting in depressed medians and the guardrail end treatment were not considered in this study. Guardrail end treatments would be most critical on the approach to a bridge structure. Additional subroutines would need to be developed to handle the cases not considered in this study.

Box 5 - Slope Hazards

The only slope hazard identified in Box 5 that was not covered in this study is Cut Slopes. An "x" must be placed in the unmarked circle to the left of Box 5 to signal the key punch operator to punch the data in Box 5. The hinge point offset is defined as that point between the shoulder and front fill slope, or that point between slopes flatter than or equal to 6:1 and the front fill slope. A typical roadside ditch 10 ft. deep, with smooth side slopes of 3:1 and a 6 ft. bottom width carrying 4 ft. of water would be coded as shown below.



Box 6

The data in Box 6 must always be punched. This box includes the date, recommendations (provides additional clarification of hazard) and type of IBM card. The number 1 in column box 80 signals the computer program that it is reading data on the hazard inventory form.

Summary of Inventory Form

On the hazard inventory form, three basic types of hazards are identified--point hazards, longitudinal hazards, and slope hazards. These hazards are each identified in the same pre-marked column box, No. 51, as numbers 1, 2, and 3, respectively. This scheme is used in order that all the data for a hazard can be placed on one IBM card. Therefore, it is to be emphasized that the user can mark only one of the three type hazards on any one inventory coding form. The coding of multiple hazards of the same and/or different types all within a single group will be discussed later.

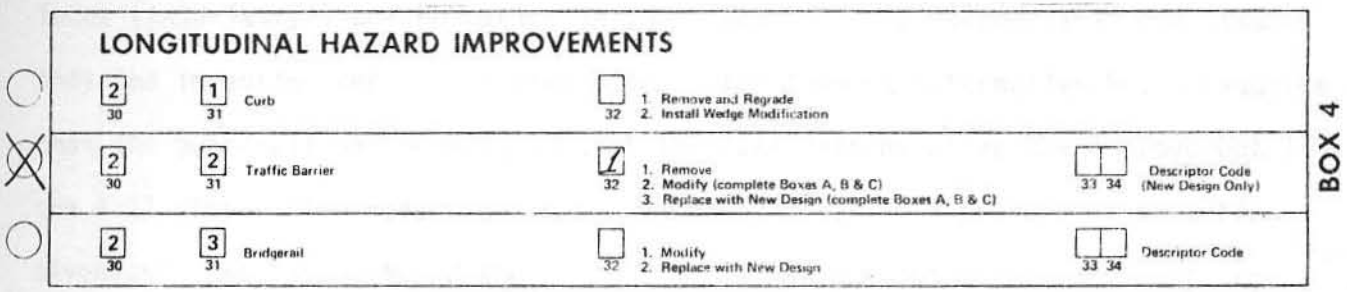
Roadside Hazard Improvement Form

The hazard improvement form shown in Figure 2 follows the same basic format as the hazard inventory form in Figure 1. The improvement form identifies three types of hazard improvements--point hazard improvements (Box 3); longitudinal hazard improvements (Box 4); and, slope improvements (Box 5). This format requires that the inventory form and improvement form be compatible; in other words, a hazard identified as a longitudinal hazard on the inventory form must have an improvement that corresponds to (1) a longitudinal hazard improvement (Box 4), or a no-improvement (Box 6). A no-improvement recommendation helps to minimize the working load of the user in that redundant data is not recorded again.

As before, the circles to the left of each box with a pre-marked "x" signal the key punch operator that the data in these boxes must always be typed, whereas, the user must place an "x" in one or more of the unmarked circles to signal the key punch operator to type the data in those boxes.

The types of improvements being made are identified on the computer output listing as an improvement code consisting of three single numbers contained in

column boxes 30, 31, and 32. For example, an improvement code of 2-2-1 in Box 4 shown below would identify a longitudinal traffic barrier in which the improvement would consist of removing the traffic barrier.



Point hazard improvements were not considered in this study. Also, there were two other improvements listed under the longitudinal improvement category (Box 4 above) that were not considered. Those improvements not included were curbs (code 2-1-x) and bridgerail (code 2-3-x). Additional subroutines would need to be developed to include these improvements.

A pre-marked number 2 in column 80 of Box 7 signals the computer program that it is reading data on the hazard improvement form. The meaning of the numbers 1 or 2 in column 79 will be discussed later.

Input Data Format

Referring back to Box 2 of the Hazard Inventory Form (Figure 1), it is necessary to define hazard number and grouping number. A group may consist of one single hazard or a multiple number of hazards. A group of hazards is defined as a condition in which all the hazards are located close together so that an

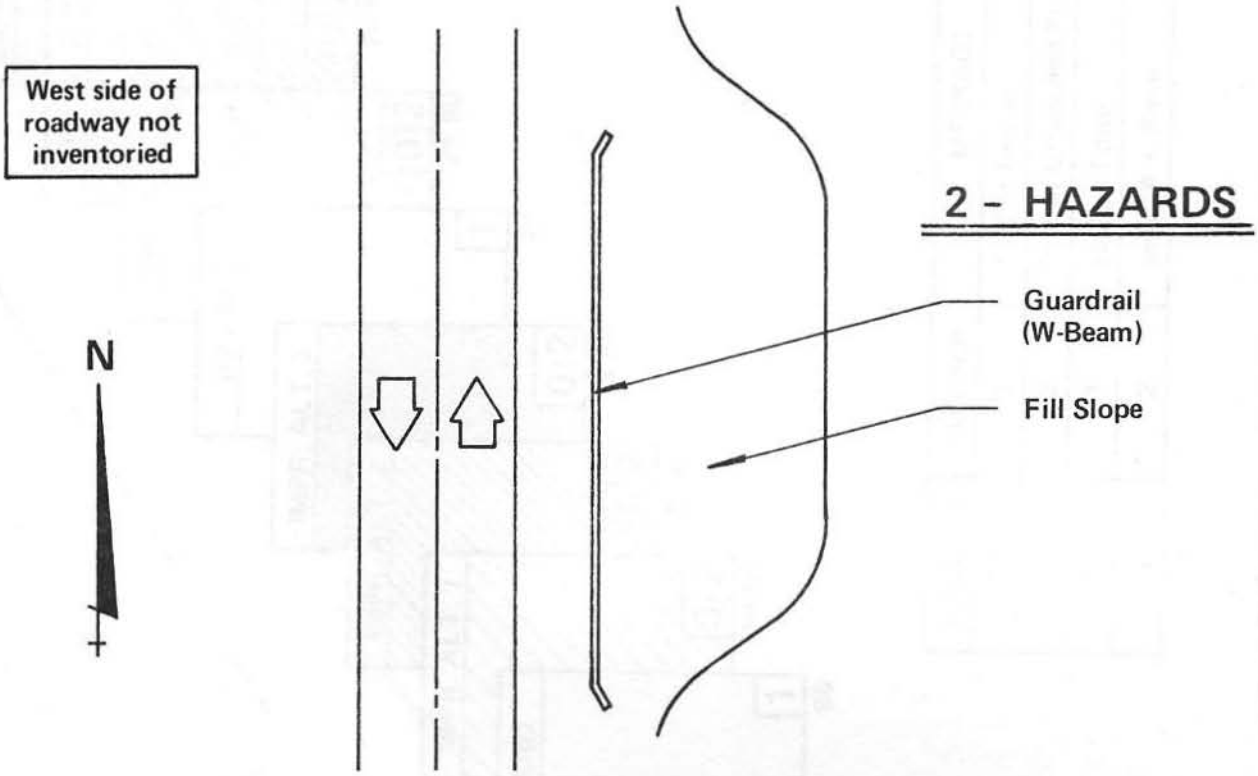
improvement of one hazard will effect the degree of hazardousness of the other hazards.

An example of two hazards in a group is shown in Figure 3. In this case, a guardrail (Hazard No. 1) is protecting a fill slope (Hazard No. 2). The hazard-index (injuries/yr) before making an improvement is the guardrail if one assumes that the impacting vehicle is redirected. Improvement Alternative No. 1 requires that the guardrail be removed, so that the hazard-index after the improvement is the fill slope. The reduction in the hazard-indices is a measure of the effectiveness. Case Study No. 2 shown in Figure 3 was a hypothetical case used for debugging the computer program. The input data and results of Case Study No. 2 are presented in Appendix J.

The input data arrangement of the hazard inventory and improvement coding forms for three different size groups is illustrated in Figure 4. Group No. 1 consists of one hazard and one improvement alternative; Group No. 2 consists of one hazard and two improvement alternatives; and, Group No. 3 consists of two hazards and three improvement alternatives. It is to be noted that for multiple hazard groups that each hazard must be followed by the same number of improvement alternative forms as shown in Group 3. The computer program as it now stands is capable of evaluating four improvement alternatives for a single hazard or a group containing two hazards with four improvement alternatives per hazard. Multiple hazard groups with more than two hazards would require expansion of the program. An upper limit on the number of hazards per group would be fifteen.

Program Strategy

The computer program reads, operates, and prints the results for one group of data at a time. Referring to Group 3 in Figure 4, the computer reads the first



EXISTING ROADWAY

(2 Roadside Hazards)

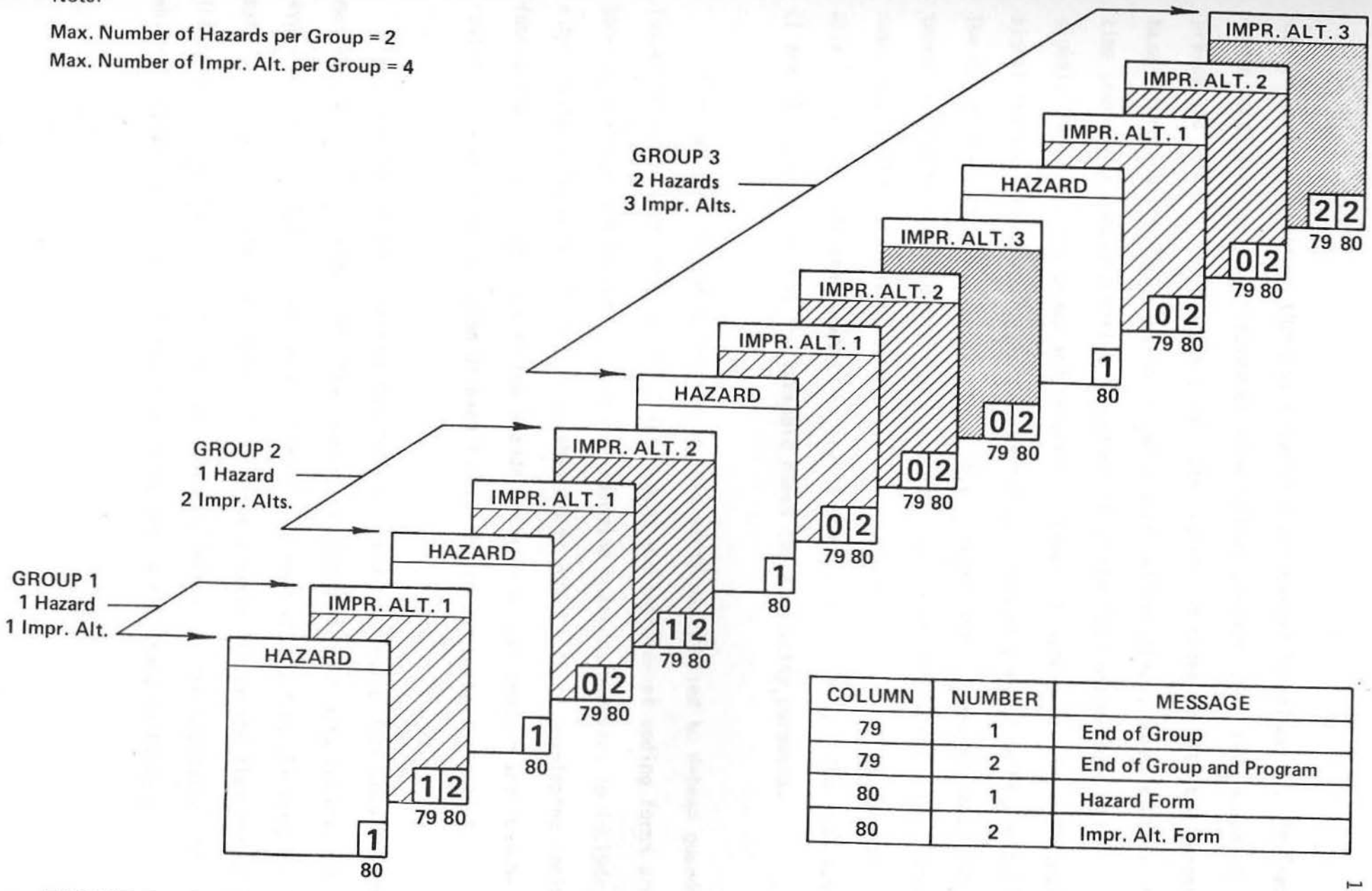
ALTERNATIVE IMPROVEMENT	IMPROVEMENT
No. 1	Remove guardrail, and make no fill slope improvements.
No. 2	Shorten guardrail length, and modify fill slope.
No. 3	Shorten length and move guardrail laterally, and modify fill slope.
No. 4	Decrease guardrail post spacing, and make no fill slope improvements.

FIGURE 3. CASE STUDY NO. 2

Note:

Max. Number of Hazards per Group = 2

Max. Number of Impr. Alt. per Group = 4



COLUMN	NUMBER	MESSAGE
79	1	End of Group
79	2	End of Group and Program
80	1	Hazard Form
80	2	Impr. Alt. Form

FIGURE 4. ARRANGEMENT OF HAZARD INVENTORY AND IMPROVEMENT ALTERNATIVE CODING FORMS FOR DIFFERENT SIZE GROUPS.

card as a hazard because there is a number 1 pre-marked in column 80. The next three cards are read as improvement alternatives because there is a number 2 pre-marked in column 80 of each card. The process is repeated with the second hazard card and the following three improvement alternatives, however, this time there is a number 2 marked in column 79 of the last improvement which signals the end of the group and program. A number 1 marked in column 79 would signal the end of a group only as illustrated by Groups 1 and 2 in Figure 4. The hazard inventory data is processed in a 1-dimensional array, whereas, the improvement alternative data is processed in a 2-dimensional array. The variable names assigned to the hazard inventory data (i.e., H2(I) and the improvement data (i.e., C12(I,J) are shown in Figures 5 and 6, respectively. The indicies (I and J) are omitted from the variable names for simplicity purposes.

The computer program developed in this study was limited to W-beam guardrail installed on roadside fill slopes. The hazard and improvement coding forms are general in scope and include all type of roadside hazards, however, to include other roadside hazards not covered in this study would require developing additional subroutines. The program as it now stands contains a main program and 16 subroutines. A brief description of each subroutine is contained in Table 2.

Because operation of a computer program requires precise data input, error messages were incorporated into the program to identify input data errors. To avoid program termination, which would occur for each data error, the program bypasses erroneous data and prints out an error message number and then continues. The error message number describes the source of error and the subroutine in which it occurred. A list of the error messages is contained in Table 3.

FIGURE 5. HAZARD INVENTORY VARIABLE NAMES, Hxx(I)

ROADSIDE HAZARD INVENTORY FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Inventory Conducted by _____ Date _____

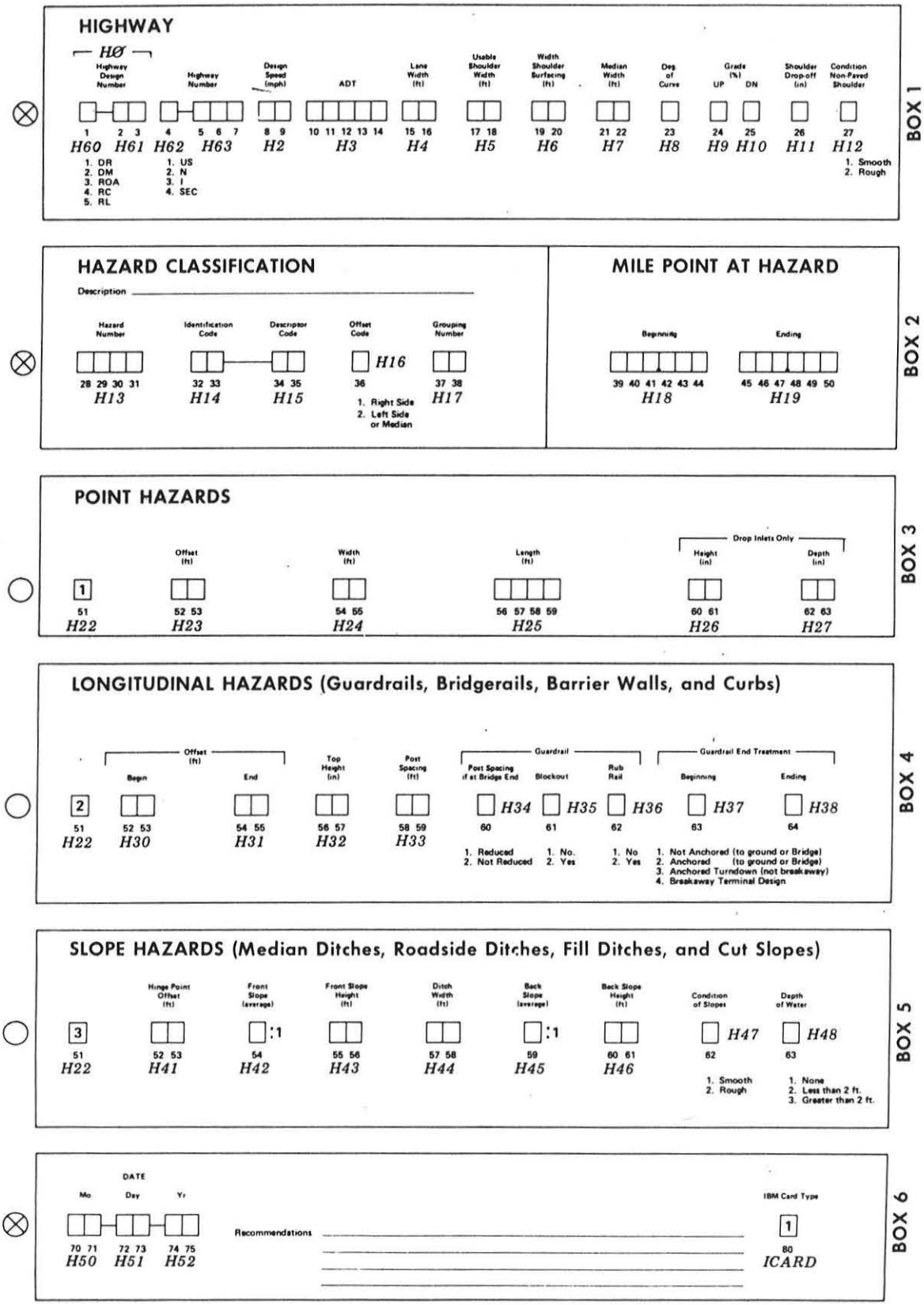


FIGURE 6. HAZARD IMPROVEMENT VARIABLE NAMES, Cxx (I, J)

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by _____ Date _____

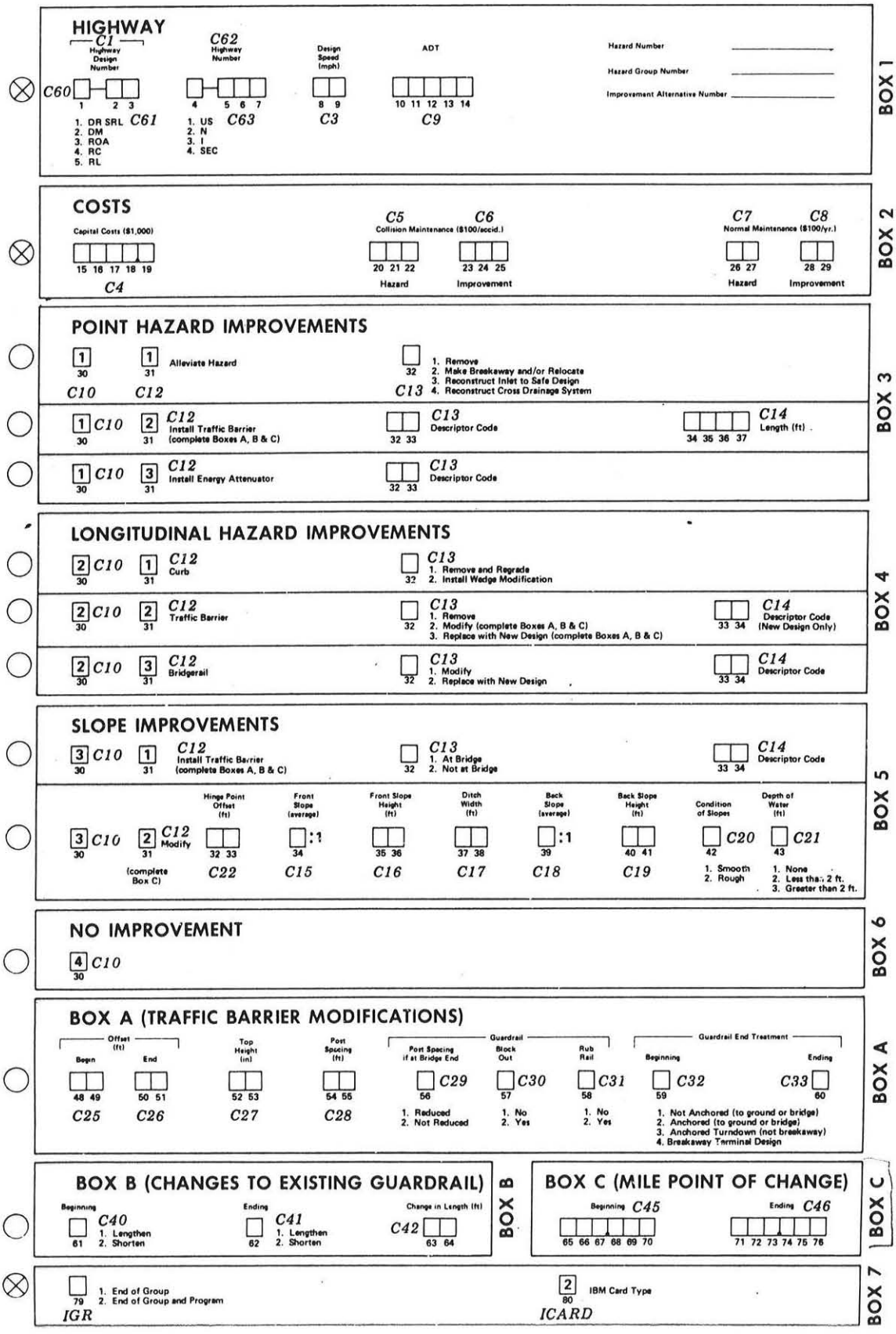


TABLE 2. DESCRIPTION OF SUBROUTINES

Subroutine Name	Subroutine Description
MAIN 1	Main subroutine that links nearly all subroutines
RESULT	Subroutine calculates cost-effectiveness, zero accident reduction, and benefit-cost
IMPCST	Subroutine calculates capital recovery factor and annualized first costs
OUTPUT	Subroutine prints listing of computer output
FREQ	Subroutine calculates the encroachment frequency of a specified roadway design
PROB 1	Subroutine calculates lateral offset probabilities for 5 different encroachment angles. If the front slope is steep (2:1 or 3:1) it is a certainty a vehicle will impact ditch bottom, therefore, the probability of reaching the hinge point is assigned. For 4:1 and flatter front slopes the probability of reaching the ditch bottom is assigned.
HINDEX	Subroutine calculates "average" hazard-index taking into consideration all possible combinations of encroachment speed and angle.
PROB 2	Subroutine assigns impact condition probabilities for a specified roadway design taking into consideration all possible combinations of encroachment speed and angle.
WBEAM	Subroutine calculates severity-indicies of standard size automobile impacting a standard W-beam guardrail under all possible combinations of encroachment speed and angle. (BARRIER VII computer model used to generate severity-index equations). Adjustment factors used for guardrail with 12 ft-6 in. post spacings.
PROB 3	Subroutine calculates the probability of an injury for a specified severity-index
DATA	Subroutine reads and stores hazard inventory data and hazard improvement data in groups
SLOPE	Subroutine calculates severity-indicies of standard size automobile traversing various embankment configurations (combinations of front slope angle, front slope height, ditch width, and back slope angle) under all possible combinations of encroachment speed and angle. (HVOSM computer model used to generate severity-index equations).
COST 3	Subroutine calculates injury accident cost for a specified severity-index

TABLE 2. DESCRIPTION OF SUBROUTINES

Subroutine Name	Subroutine Description
REPAIR	Subroutine calculates "average" collision maintenance cost for W-beam guardrail taking into consideration all possible combinations of encroachment speed and angle. (Length of guardrail damage expressed as function of severity-index).
ACCID	Subroutine calculates "average" injury accident cost taking into consideration all possible combinations of encroachment speed and angle.
NOIMPR	No improvement subroutine. Subroutine sets improvement data equal to hazard inventory data.

TABLE 3. ERROR MESSAGES

No.	Message	Subroutine
1		
2		
3		
4		
5	Lateral Offset Limits Violated	PROB 1
6		
7		
8		
9		
10	Program Valid only for Slope and W-Beam Type Hazard	MAIN 1
11		
12		
13		
14		
15	Undefined Highway Design Number	PROB 2
16		
17		
18		
19		
20	Undefined Front Slope	SLOPE
21	Undefined Back Slope	SLOPE
22	Undefined Front Slope Height	SLOPE
23	Undefined Back Slope Height	SLOPE
24		
25		
26		
27		
28		
29		
30		

Output Data Format

The output format of the computer program is illustrated in Figure 7 for Case Study No. 2. The plan view of the case study site was shown in Figure 3. The site has two hazards in which a guardrail (hazard 1) is protecting a fill slope (hazard 2). The four improvement alternatives being considered for this case study were outlined in Figure 3.

Page 1 of the output in Figure 7 contains general information on the highway design number (see NDR Minimum Design Standards, ref 3), type highway, design speed, ADT, project life, compound interest rate, and the date. If any one of these first four items changes, then this block of information is reprinted starting on a new page.

Page 2 of the output in Figure 7 contains information on both the hazard and improvement. The Identification and Descriptor Codes (see Table 1) define the type hazard, whereas, the Improvement Code defines the type improvement. An indepth discussion on the definitions of hazard-index, cost-effectiveness, zero accident reduction, and benefit-cost ratio are presented later in the report.

Improvement Alternatives 1, 2, and 4 were not cost-effective because in each case there was no net reduction in the number of injuries per year (summation of the hazard-indicies of improvements were greater than the summation of hazard-indicies of the hazards).

Improvement Alternative 3 resulted in an error message because of an invalid type hazard (see Table 3 for a list of the error messages).

C O S T E F F E C T I V E N E S S P R O G R A M

UNIVERSITY OF NEBRASKA
AND
NEBRASKA DEPARTMENT OF ROADS

HIGHWAY DESIGN NUMBER = DR- 7
TYPE HIGHWAY = US-123
DESIGN SPEED = 60 MPH
ADT = 1234
PROJECT LIFE = 20.0 YRS
INTEREST RATE = 9.000 %
DATE = 9- 6-79

H A Z A R D								I M P R O V E M E N T							
HAZARD NO	GROUP NO	IDENT CODE	DESC CODE	HAZARD INDEX (INJ/YR)	SIDE OF ROAD	MILE-POST BEG	MILE-POST END	IMPR ALT	IMPR CODE	HAZARD INDEX (INJ/YR)	CLEAR RECOVERY ZONE (FT)	FIRST COST ($1000)	TOTAL ANNUAL COST ($/YR)	COST EFFECTIVE VALUE	ZERO ACCIDENT REDUCTION (%)	BENEFIT COST RATIO
2	2	6	6	0.01494	1	50.100	50.250	1	2-2-1	0.00000	6	2.4	**********	GROUP	**********	
3	2	7	2	0.00000	1	50.100	50.250	1	4-0-0	0.01784	6	0.0	---------	NOT COST-EFFECTIVE	--------	
2	2	6	6	0.01494	1	50.100	50.250	2	2-2-2	0.01355	7	0.5	**********	GROUP	**********	
3	2	7	2	0.00000	1	50.100	50.250	2	3-2-0	0.01610	8	2.5	---------	NOT COST-EFFECTIVE	----------	
2	2	6	6	0.01494	1	50.100	50.250	3	2-2-2	0.01243	10	1.9	**********	GROUP	**********	
3	2	7	2	0.00000	1	50.100	50.250	3	2-2-0	0.00000	0	3.0	*********	ERROR MESSAGE = 10	********	
2	2	6	6	0.01494	1	50.100	50.250	4	2-2-3	0.00000	10	13.5	**********	GROUP	**********	
3	2	7	2	0.00000	1	50.100	50.250	4	3-2-0	0.01517	10	1.5	---------	NOT COST-EFFECTIVE	--------	

FIGURE 7: COMPUTER OUTPUT LISTING OF CASE STUDY NO. 2

COMPUTER MODELS OF AUTOMOBILE

During the past three decades, many highway organizations have relied heavily upon experience and judgment in the design of roadside appurtenances; and, trial and error full scale tests were often conducted to determine the feasibility of these appurtenances. Significant advancements in technology and an increase in safety have evolved from these efforts. However, this type of design approach appears to be insufficient by itself because one or more full scale tests were required to effectively evaluate the influence of any one variable. Conducting many full scale tests can be both time consuming and costly.

Mathematical model simulation provides a rapid and economical method to investigate the many variables involved in a run-off-the-road automobile collision or maneuver. A limited number of full scale tests can then be conducted to confirm the simulation results. When supplemented by experience, judgment and tests, model simulation can be a very helpful tool in achieving efficient and safe designs.

HVOSM

The Highway-Object-Simulation-Model, designated as HVOSM, was used in the subsequent work to study the dynamic motion of a standard size automobile traversing different embankment configurations. HVOSM was developed by McHenry (4,5) of the Cornell Aeronautical Laboratories and modified for specific field applications by the Texas Transportation Institute (6).

The idealized-free-body-diagram of HVOSM is shown in Figure 8. The model has 11 degrees of freedom and consists of four isolated masses. The masses of

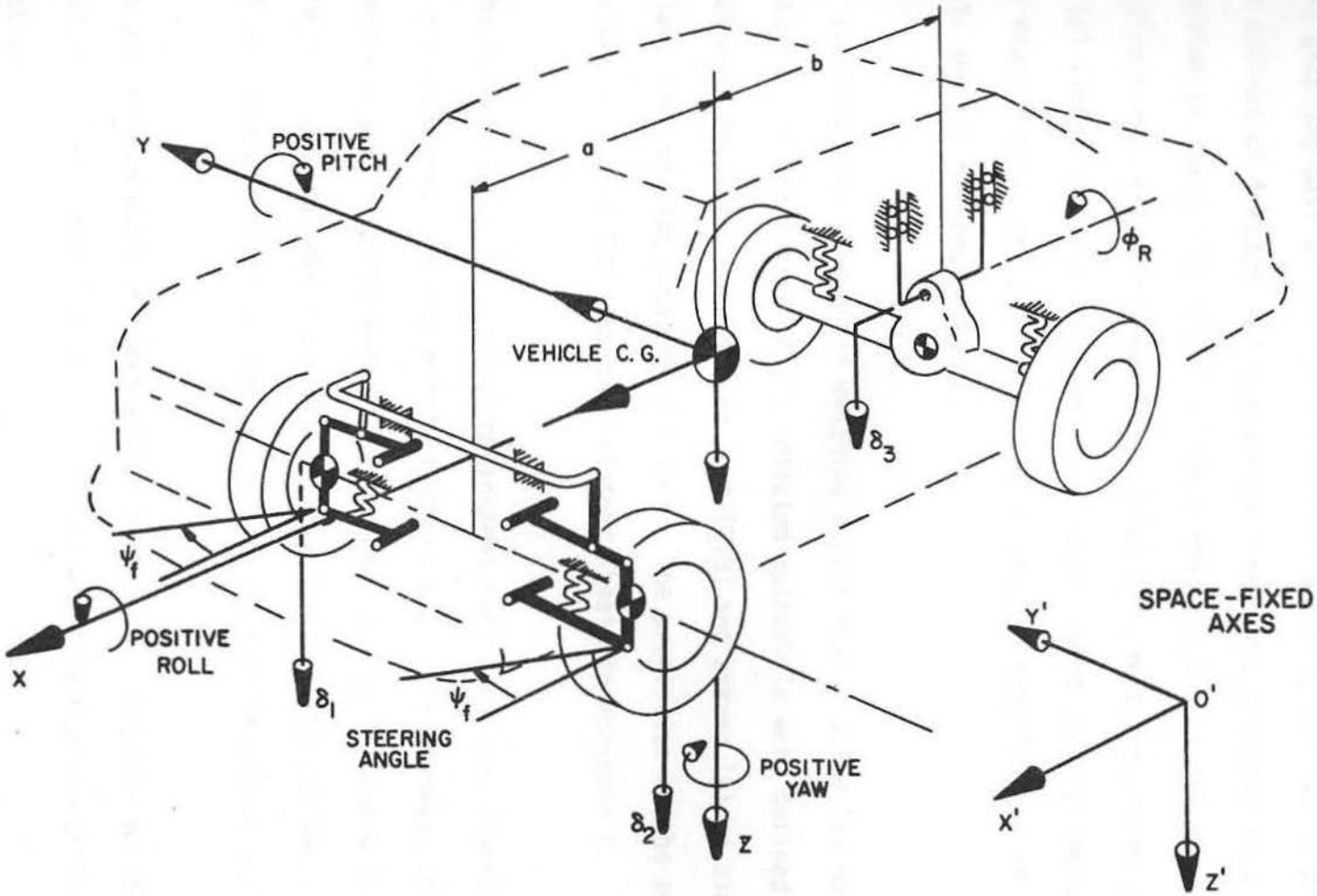


FIGURE 8 : IDEALIZATION OF HVOSM

the automobile include: (a) the sprung mass of the body, engine and transmission supported by the front and rear suspension system, (b) the unsprung masses of the left and right independent suspensions systems of the front wheels, and (c) the unsprung mass of the solid rear axle assembly and its suspension system. The 11 degrees of freedom of the automobile measured relative to a fixed coordinate system in space include: (a) linear translations of the sprung mass in three directions, (b) rotational roll, pitch and yaw translations of the sprung mass, (c) linear translation of the front wheel suspension systems, (d) steering of the front wheels, and (e) linear and rotational translations of the rear axle assembly and its suspension system.

A standard size automobile weighing approximately 3,800 lbs was used in this study. The properties of the selected automobile were defined in previous research work conducted by Ross and Post (7,8) and Weaver (9) on sloping grates in medians and roadside embankment slopes. The properties of the selected vehicle are listed on the computer printout sheets in Appendix C.

The terrain data of a typical embankment configuration, expressed in terms of x-y-z coordinates, are presented in Appendix D. The roadway, shoulder, and soil were assigned friction coefficient values of 0.8, 0.6 and 0.2, respectively; and, the soil was assigned a stiffness value of 4,000 lbs per inch. Terrain contact was only monitored at the two corners of both the front and rear bumpers.

No attempt was made to steer and/or brake the automobile during any of the simulations. This "free-wheeling" condition would be representative of an inattentive driver.

The Texas Transportation Institute's (6) modified version of the HVOSM program was used in this study. On the average, 1 sec of event time required

approximately 1 min of time on the University of Nebraska IBM 370 computer system. Computer costs per simulation ranged from 10 to 20 dollars. In comparison, full scale tests range from 5,000 to 15,000 dollars depending on the repetitiveness of the tests, vehicle control apparatus, type and amount of electronic instrumentation, and data reduction analysis techniques including high speed photography.

HVOSM has undergone many rigorous comparisions to full-scale testing with excellent correlation. An example of such a comparison is shown in Figure 9 in which Ross and Post (7) compared the decelerations computed by HVOSM with the decelerations measured by accelerometers during a full scale test on an embankment simulation runs in this study.

BARRIER VII

The BARRIER VII program was utilized subsequently in this study to determine the dynamic effect of an automobile interacting with a traffic barrier system. BARRIER VII was developed by Powell (10, 11).

The traffic barrier is idealized as a plane framework composed of elastic-inelastic one-dimensional elements of a variety of types. The automobile is idealized as a plane rigid body surrounded by a cushion of springs. A large displacement dynamic structural analysis problem is solved by numerical methods.

The analysis is two-dimensional in the horizontal plane. Out-of-plane effects, which include vertical displacements of both the automobile and the barrier, are not considered. The automobile slides along the barrier, and the effects of normal, force, friction forces, and wheel drag forces are considered

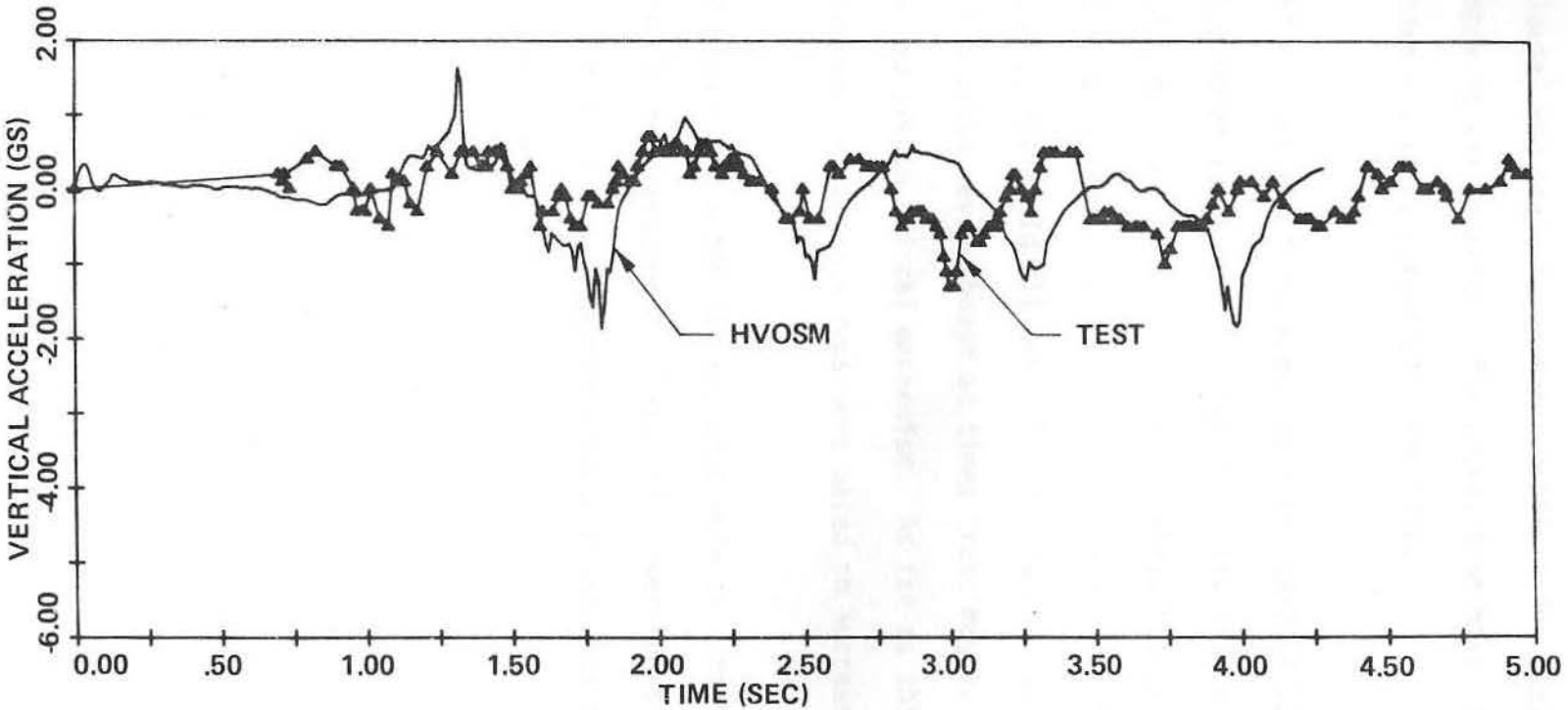


FIGURE 9. COMPARISON OF HVOSM AND FULL SCALE TEST ON EMBANKMENT WITH 3:1 FRONT SLOPE

in determining its motion. Data necessary for input to the program consists of the barrier configuration, the properties of the barrier members and automobile and the velocity and trajectory of automobile before impact. Output consists of barrier member forces, barrier deflections, time histories of automobile positions, and velocities and acceleration of automobile.

A final comment should be made about the BARRIER VII program. It is a two dimensional program and therefore placed limitations on this study. BARRIER VII cannot predict roll motion of the vehicle, wheel snagging or vehicle vaulting. BARRIER VII also will not predict situations where the vehicle could break through the guardrail. In all BARRIER VII simulations, the railing will return to the elastic state, even though at times these may be sufficient plastic hinges formed so as to create a local mechanism. As far as this study was concerned, all the guardrail performance runs were based on successful guardrail tests.

Output results from BARRIER VII that were of direct interest in this study were the vehicle accelerations. These values were used to determine the severity-index (SI) of the different guardrail vehicle interactions. Explanation of SI follows in the report.

SEVERITY OF AUTOMOBILE ENCROACHMENTS

The severity of an automobile impacting a guardrail or traversing an embankment ditch configuration was expressed in terms of a Severity-Index. The severity-index is computed as the ratio of the measured or computed resultant automobile acceleration to the resultant "tolerable" automobile acceleration that defines an ellipsoidal surface. This ratio can be expressed mathematically by Eq. 1. An in-depth discussion on the development of Eq. 1 was presented by Ross and Post (12) and Weaver (9).

$$SI = \frac{G_{\text{total Auto}}}{G_{\text{total Occupant}}} = \sqrt{\left[\frac{G_{\text{long}}}{G_{XL}}\right]^2 + \left[\frac{G_{\text{lat}}}{G_{YL}}\right]^2 + \left[\frac{G_{\text{vert}}}{G_{ZL}}\right]^2} \qquad \text{---Eq. 1}$$

where:

SI = Severity-Index

$G_{\text{total Auto}}$ = Resultant Auto Acceleration

$G_{\text{total Occupant}}$ = Resultant Tolerable Acceleration

G_{long} = Auto Acceleration along longitudinal x-axis (see Figure 3)

G_{lat} = Auto Acceleration along lateral y-axis

G_{vert} = Auto Acceleration along vertical z-axis

G_{XL} = Tolerable Acceleration along x-axis

G_{YL} = Tolerable Acceleration along y-axis

G_{ZL} = Tolerable Acceleration along z-axis

The severity-index computations in the subsequent work will be based on accelerations tolerable to an unrestrained occupant, and the automobile accelerations will be averaged over a time duration of 50 msec. The relationship between severity-index and injury levels will be discussed in a later section. Tolerable accelerations suggested by Weaver (9) for use in the severity-index equation are shown in Table 4.

TABLE 4

TOLERABLE AUTOMOBILE ACCELERATIONS

Degree of Occupant Restraint	Accelerations		
	G_{YL}	G_{XL}	G_{ZL}
Unrestrained	5	7	6
Lap Belt Only	9	12	10
Lap Belt and Shoulder Harness	15	20	17

Severity-Index Equations for Embankments

A typical graph of a plot of the computed severity-indicies versus encroachment speed and angle is shown in Figure 10 for a front fill slope of 2:1, a fill height of 20 ft., a ditch width of 4 ft, and a back slope of 2:1. Linear regression lines were fitted to the data point using the method of least squares.

Because no HVOSM simulations were made for 10 and 20 deg encroachment traversals, the lines shown in Figure 10 for these two conditions were fitted by visual means. Likewise, all of the linear lines were simply extended to cover the lower and upper speed ranges of 40 and 80 mph which were not simulated in this study.

A total of 180 linear equations were derived in this study to cover all possible embankment configurations and vehicle speed and angle combinations.

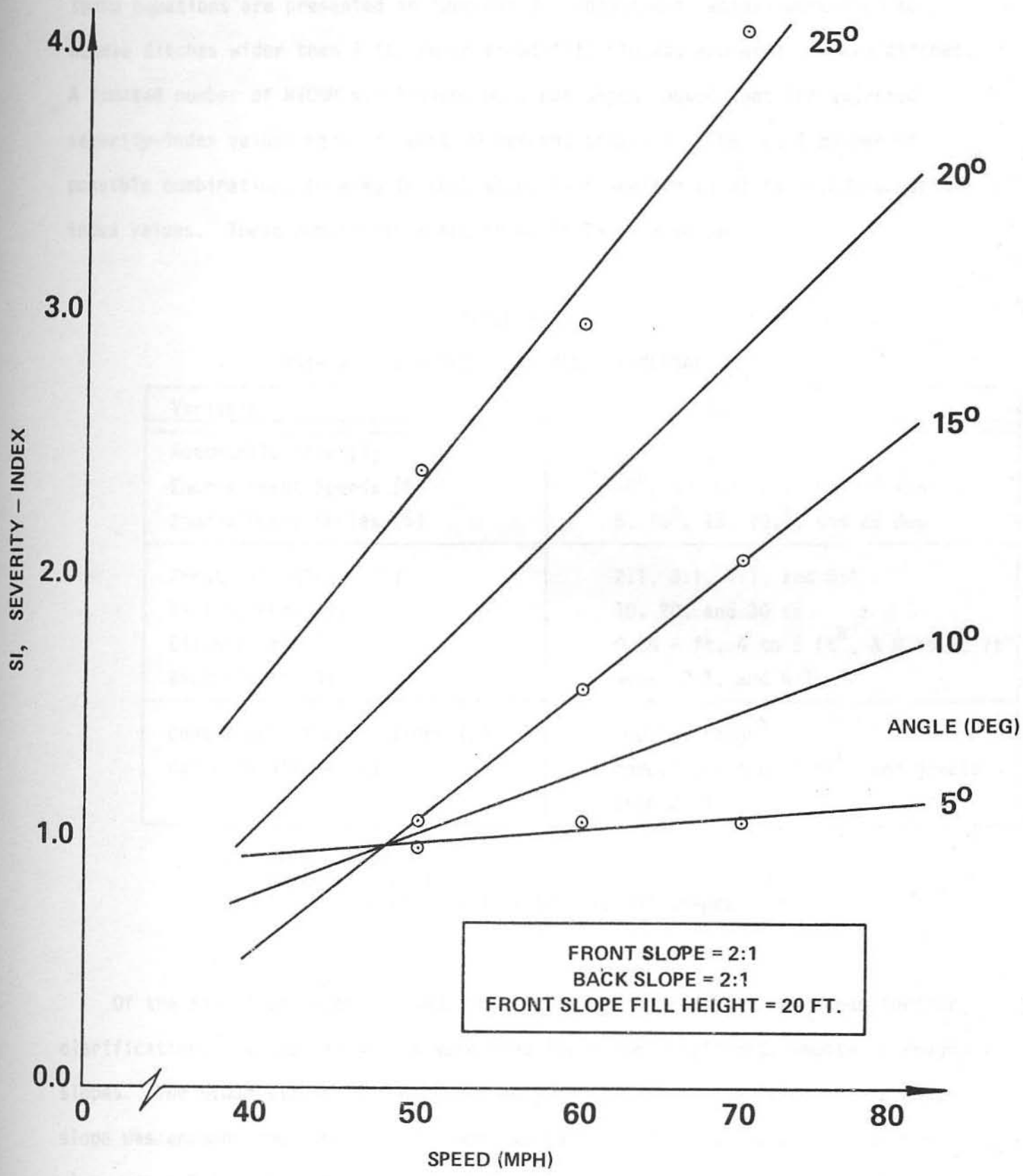


FIGURE 10. RELATIONSHIP BETWEEN SEVERITY – INDEX AND VEHICLE ENCROACHMENT CONDITIONS AND FILL SLOPE CONFIGURATION.

These equations are presented in Appendix F. Adjustment factors were used to handle ditches wider than 4 ft, rough front fill slopes, and water in the ditches. A limited number of HVOSM simulations were run which showed that the adjusted severity-index values were at least 90 percent accurate. The total number of possible combinations covered in this study is therefore equal to 16,200 severity-index values. These combinations are shown in Table 5 below.

TABLE 5

MATRIX OF VEHICLE EMBANKMENT TRAVERSALS

Variable	Combinations
Automobile Size (1)	3,800 lbs
Encroachment Speeds (5)	40[a], 50, 60, 70, and 80[a] mph
Encroachment Angles (5)	5, 10[a], 15, 20,[a], and 25 deg
Front Fill Slopes (4)	2:1, 3:1, 4:1, and 6:1
Fill Heights (3)	10, 20, and 30 ft
Ditch Widths (3)[c]	0 to 4 ft, 4 to 8 ft[b], & 8 to 12 ft[b]
Back Slopes (3)	None, 2:1, and 4:1
Conditions of Front Slope (2)	smooth, rough[b]
Water in ditches (3)	none, less than 2 ft[b], and greater than 2 ft[b]

a. Interpolated
b. Adjustment Factor
c. Flat (no back slope) or trapezoidal shaped

Of the adjustment factors used, the situation for rough slopes needs further clarification. Two possibilities were used for slope conditions, smooth or rough slopes. The HVOSM simulations were run only on the smooth condition. If a rough slope was encountered, the program then examined the front slope angle. If the slope was a 2:1 or 3:1, then the rough slopes were not adjusted for severity-indices. If, however, the front slopes were flatter, then an adjustment factor

was added to the SI to increase the value. The reasoning behind this is that when a vehicle encroaches a steep front slope, there is a high probability that it will reach the ditch bottom and undergo high decelerations. However, if the front slope is 4:1 or 6:1, it is likely that a vehicle could be steered back toward the road and avoid the ditch bottom. In this case, the vehicle will undergo higher decelerations on a rough slope than on a smooth slope.

The data reduction and results of the HVOSM simulations of a vehicle traversing different embankment configurations are presented in Appendix E.

Severity-Index Equations for Guardrail

The BARRIER VII (10, 11) computer program was used to obtain the severity index equations for an automobile impacting a guardrail. It was necessary to specify input values for the wooden post, W-Beam rail, and vehicle inertial properties. The values for those parameters were obtained primarily from the work of Southwest Research Institute (20) in which BARRIER VII results were correlated with similar full-scale tests.

A severity index adjustment factor was built into the program to adjust the severity of a vehicle impact on a 12'-6" post spacing in addition to the 6'-3" post spacing design. These severity index equations and the SI adjustment factors are presented in Appendix H.

COST-EFFECTIVENESS METHODOLOGY

The cost-effectiveness of an improvement alternative is its annualized cost per unit of improvement (effectiveness) it provides. In general, the lower this cost, the more cost-effective the alternative.

The method used by the computer program to calculate the cost-effectiveness of improvement alternatives was derived from the cost-effectiveness priority approach formulated by Glennon (13) and implemented in Texas in the management of roadside safety improvement programs on both freeways and non-controlled access roadways (1). With this approach, the effectiveness of an improvement alternative is measured in terms of the number of injury (fatal and non-fatal) accidents that it can be expected to eliminate each year. The expected annual reduction in injury accidents attributed to a particular improvement is the difference between the expected number of injury accidents per year under the existing condition and the number of injury accidents expected per year after the improvement has been made. In each case, before and after improvement, the expected number of injury accidents per year is referred to as the hazard index. Therefore, the measure of effectiveness of given improvement alternative is the difference between the hazard index before and after the improvement.

Thus, the computer program calculates the cost-effectiveness of an improvement alternative as follows:

$$CE = \frac{C_I - C_E}{H_E - H_I} \qquad \text{---Eq. 2}$$

where:

CE = cost-effectiveness of improvement, cost to reduce one injury accident (dollars/injury accident reduced);

C_I = annualized cost of improvement (dollars/year);

C_E = annualized cost of existing condition (dollars/year);

H_E = hazard index of existing condition (expected number of injury accidents/year);

H_I = hazard index of improvement (expected number of injury accidents/year).

The annualized cost of the improvement alternative includes normal and collision maintenance costs as well as the first cost of the improvement. The annualized cost of the existing condition is cost of maintaining it, which includes both normal and collision maintenance costs.

In evaluating the cost-effectiveness of improvement alternatives, the computer program considers any alternative which does not have a hazard index lower than that of the existing condition (i.e., $H_I \geq H_E$) to be "not cost-effective". Therefore, in such cases, the program merely prints out the message "NOT COST-EFFECTIVE", instead of the cost-effectiveness value. However, in the case of an improvement alternative which does have a hazard index lower than that of the existing condition (i.e., $H_I < H_E$), and which is therefore considered to be cost-effective, the program prints out the cost-effectiveness value computed for the alternative. For a cost-effective improvement alternative (i.e., $H_I < H_E$), the lower its cost-effectiveness value, the more cost-effective it is. This interpretation also applies to negative cost-effectiveness values, because in the case of a cost-effective improvement alternative a negative value indicates that its annualized cost is less than that of the existing condition (i.e., $C_I < C_E$). Thus, an alternative which has a negative cost-effectiveness value is more cost-effective than one with a positive value, given that both are cost-effective.

A description of the procedures used by the computer program to calculate hazard indices and annualized cost follows.

Hazard Index

The generalized equation used to compute the hazard index of an improvement alternative, or existing condition, is:

$$H = E \sum_{\Theta} P_{\Theta}(C/E) \sum_{v} P_{\Theta,v} \, P_{\Theta,v}(I/C) \qquad \text{---Eq. 3}$$

where:

H = hazard index (expected number of injury accidents/year);

E = encroachment rate (number of roadside encroachments/mile/year);

$P_{\Theta}(C/E)$ = probability that the improvement, or existing condition, will be encountered given that an encroachment at angle Θ has occurred;

$P_{\Theta,v}$ = probability of an encroachment at angle Θ and speed v given that an encroachment has occurred;

$P_{\Theta,v}(I/C)$ = probability of an injury accident given that the improvement, or existing condition, has been encountered by a vehicle encroachment at angle Θ and speed v;

Θ = angle of encroachment (degrees);

v = speed of encroachment (miles/hour).

The method by which each of the independent variables in this equation is computed is described below.

Encroachment Rate

Knowledge of the rate at which vehicles encroach on the roadside of various types of highways is very limited. In fact the only pure encroachment data available are that of Hutchinson and Kennedy (14), which were collected on freeway medians. More recently Glennon (15) has estimated

encroachment rates for different types of highways as linear functions of average daily traffic (ADT). These relationships were derived from an analysis of roadside accident rates for different types of highways and a comparison of the freeway encroachment rate determined by Hutchinson and Kennedy and the freeway roadside accident rate in Missouri.

Therefore, because they are the only ones available for different highway types, the encroachment-rate-versus-ADT relationships determined by Glennon are used by the computer program to compute the encroachment rate to be used in Equation 3 to calculate the hazard index of an improvement alternative, or existing condition. The appropriate relationship is first selected based on the highway type which corresponds to the highway design number input on the Roadway Hazard Inventory Form (Figure 1) in the case of an existing condition or on the Roadway Hazard Improvement Form (Figure 2) in the case of an improvement alternative. The encroachment rate is then computed using the selected encroachment rate function and the ADT input on the same form as the highway design number. The encroachment rate function for each highway type and design number is shown in Table 6. It should be noted that the number of encroachments is the total for both directions of traffic. Therefore, if only one side of a highway is being considered, this number is divided by two.

Probability of Encounter

The probability that a vehicle which encroaches on the roadside will encounter (i.e., collide with or traverse) the improvement alternative, or existing condition, is dependent on the angle of encroachment. This probability is the product of two other conditional probabilities expressed as follows:

TABLE 6. ENCROACHMENT RATE VS ADT RELATIONSHIPS

Highway Design Number	Highway Type	Encroachment Rate (encroachments/mile/year)
DR 1	Rural Interstate	0.0009 ADT
DR 2	Rural Multilane	0.00059 ADT
DR 3	Divided Highway	0.00059 ADT
DR 4	Wide Rural	0.000742 ADT
DR 5	Two-Lane Highway	0.000742 ADT
DR 6	(Roadbed $\geq$ 36 ft.)	0.000742 ADT
DR 7	Narrow Rural Two-Lane Highway (Roadbed < 36 ft.)	0.00121 ADT
DM 10	Urban Interstate	0.0009 ADT
DM 20		0.0009 ADT
DM 30	Urban Multilane	0.0009 ADT
DM 40	Divided Highway	0.0009 ADT
DM 50	Urban Major Arterial	0.00133 ADT
DM 60	Street	0.00133 ADT

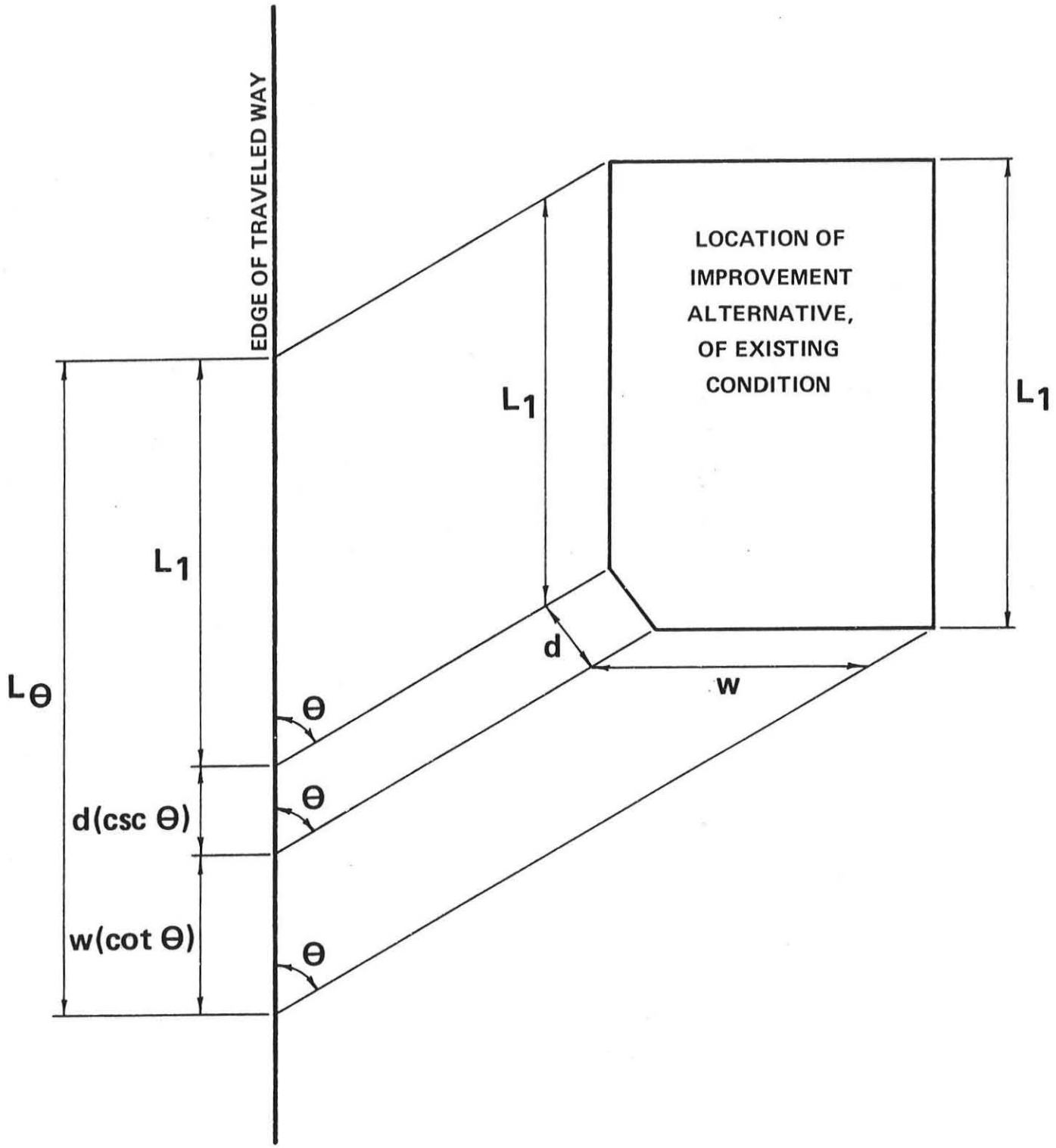


FIGURE 11. LOCATION OF IMPROVEMENT ALTERNATIVE AND ITS RELATIONSHIP TO PATH OF ENCROACHING VEHICLE

$$P_{\Theta}(C/E) = P_{\Theta}(X/E)\ P_{\Theta}(C/X) \qquad \text{---Eq. 4}$$

where:

$P_{\Theta}(C/E)$ = probability of encounter given an encroachment at angle Θ;

$P_{\Theta}(X/E)$ = probability that path of vehicle will intersect location of improvement alternative, or existing condition, given an encroachment at angle Θ;

$P_{\Theta}(C/X)$ = probability of vehicle impacting, or traversing, improvement alternative, or existing condition, given that vehicle is on an intersecting path for an encroachment of angle Θ.

The probability that an encroaching vehicle will be on a path that intersects the location of the improvement alternative, or existing condition, is proportional to the longitudinal length of roadway within which this can occur. As illustrated in Figure 11, this longitudinal length is a function of the angle of encroachment, the width of the vehicle, and the longitudinal length and lateral width of the location of the improvement alternative, or existing condition. This relationship is defined by the following equation:

$$L_{\Theta} = L_1 + d\ (\csc\ \Theta) + w\ (\cot\ \Theta) \qquad \text{---Eq. 5}$$

where:

L_{Θ} = longitudinal length of roadway within which the path of a vehicle encroachment at angle Θ will intersect the location of the improvement alternative, or existing condition (feet);

L_1 = longitudinal length of location of improvement alternative, or existing condition (feet);

w = lateral width of location of improvement alternative, or existing condition (feet);

d = width of encroaching vehicle (feet);

Θ = encroachment angle (degrees).

Due to a lack of data on the effects of roadway geometrics on the frequency and nature of encroachments, it is assumed that the longitudinal distribution of encroachments along a roadway is uniform. Therefore, the probability that a vehicle encroachment at angle Θ will be on a path that intersects the location of the improvement alternative, or existing condition is:

$$P_{\Theta}(X/E) = L_{\Theta}/5,280 \qquad \text{---Eq. 6}$$

The constant term in this equation is the number of feet in a mile.

The probability that an encroaching vehicle on an intersecting path will impact, or traverse, the improvement alternative, or existing condition, is a function of the lateral distance between the outside edge of the travelled way and the location of the improvement alternative, or existing condition. The greater this distance, the further the vehicle must travel along the path to reach the location and the less likely it is that it will impact, or traverse, the improvement alternative, or existing condition. Therefore, the encroachment data of Hutchinson and Kennedy (14) were analyzed to determine the relationship between encroachment angle and the probability distribution of the lateral extent of encroachment. The four distributions shown in Figure 12 were found to be significantly different. These distributions are used by the computer program to determine the probability of impacting, or traversing, the improvement alternative, or existing condition, given that the encroaching vehicle is on an intersecting path for a given angle of encroachment; because this probability is equal to the probability that the lateral extent of the encroachment is greater than the lateral distance between the outside edge of the travelled way and the location of the improvement alternative, or existing condition.

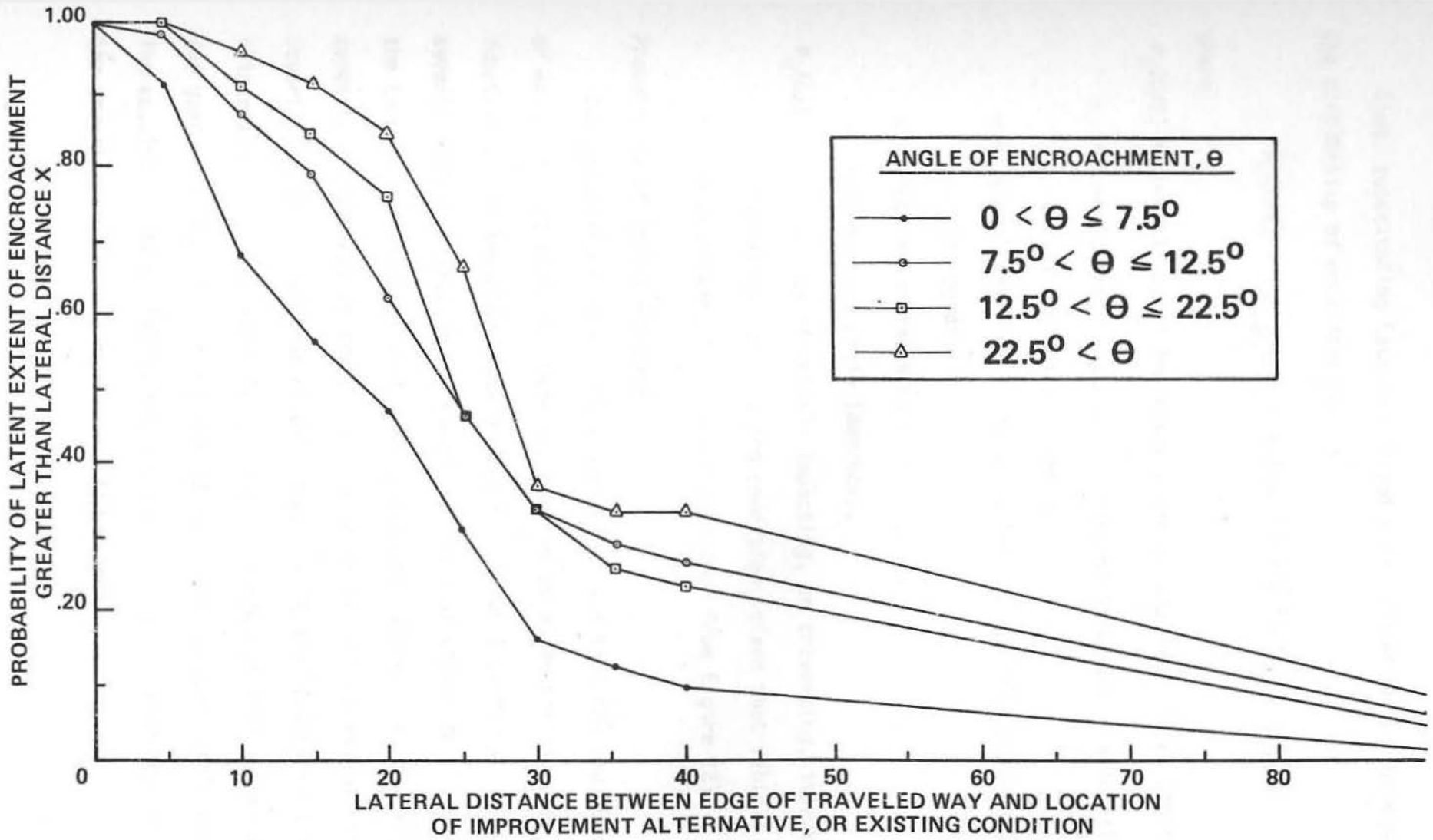


FIGURE 12. DISTRIBUTIONS OF LATERAL EXTENT OF ENCROACHMENTS

Thus, substituting Equations 5 and 6 into Equation 4, the equation for the probability of encounter becomes:

$$P_{\Theta}(C/E) = (\frac{1}{5,280})[L_1 + d\ (\csc\ \Theta) + w\ (\cot\ \Theta)]\ P_{\Theta}(C/X) \qquad \text{---Eq. 7}$$

where:

$P_{\Theta}(C/E)$ = probability of encounter given an encroachment at angle Θ;

L_1 = longitudinal length of location of improvement alternative, or existing condition (feet);

w = lateral width of location of improvement alternative, or existing condition (feet);

d = width of encroaching vehicle (feet);

Θ = encroachment angle (degrees);

$P_{\Theta}(C/X)$ = probability of vehicle impacting, or traversing, improvement alternative, or existing condition, given that vehicle is on an encroachment at angle Θ (obtained from Figure 12).

Probability of Injury Accident

The probability of an injury accident given that the improvement alternative, or existing condition, has been encountered by an encroaching vehicle is a function of the severity index of the impact, or traversal. In turn, the severity index depends on the speed and angle of encroachment as well as the type and configuration of the improvement alternative, or existing condition, impacted, or traversed. As described in a previous section of this report, computer simulation models (i.e., HVOSM and BARRIER VII) were used in this research to determine the severities indices of side-slope-ditch traversals and guardrail impacts over a range of encroachment speed-angle combinations. The results of these simulations are used by the computer program to determine the severity indices of impacts and traversals.

In earlier research conducted at the University of Nebraska-Lincoln (16), a relationship between severity index and probability of an injury accident was developed. This relationship is presented in Table 7. To facilitate its use in the computer program, the histogram relationship is approximated by the two linear functions shown in Figure 13.

TABLE 7. RELATIONSHIP BETWEEN SEVERITY-INDEX AND PROBABILITY OF INJURY ACCIDENTS

Severity-Index (SI)	Probability of Injury Accident
$SI \leq 0.5$	0.1
$0.5 < SI \leq 1.0$	0.3
$1.0 < SI \leq 1.5$	0.5
$1.5 < SI \leq 2.0$	0.7
$2.0 < SI \leq 2.5$	0.8
$2.5 < SI$	1.0

Encroachment Speed-Angle Probabilities

The probabilities of encroachment speed-angle combinations were computed by combining the distributions of vehicle speeds and encroachment angles. The vehicle speed distributions were determined from an analysis of spot speed data contained in the 1978 annual speed monitoring certification report prepared by the Nebraska Department of Roads. It was assumed that vehicle speeds are normally distributed with the mean and standard deviation values computed from the spot speed data. These values are shown in Table 8. The

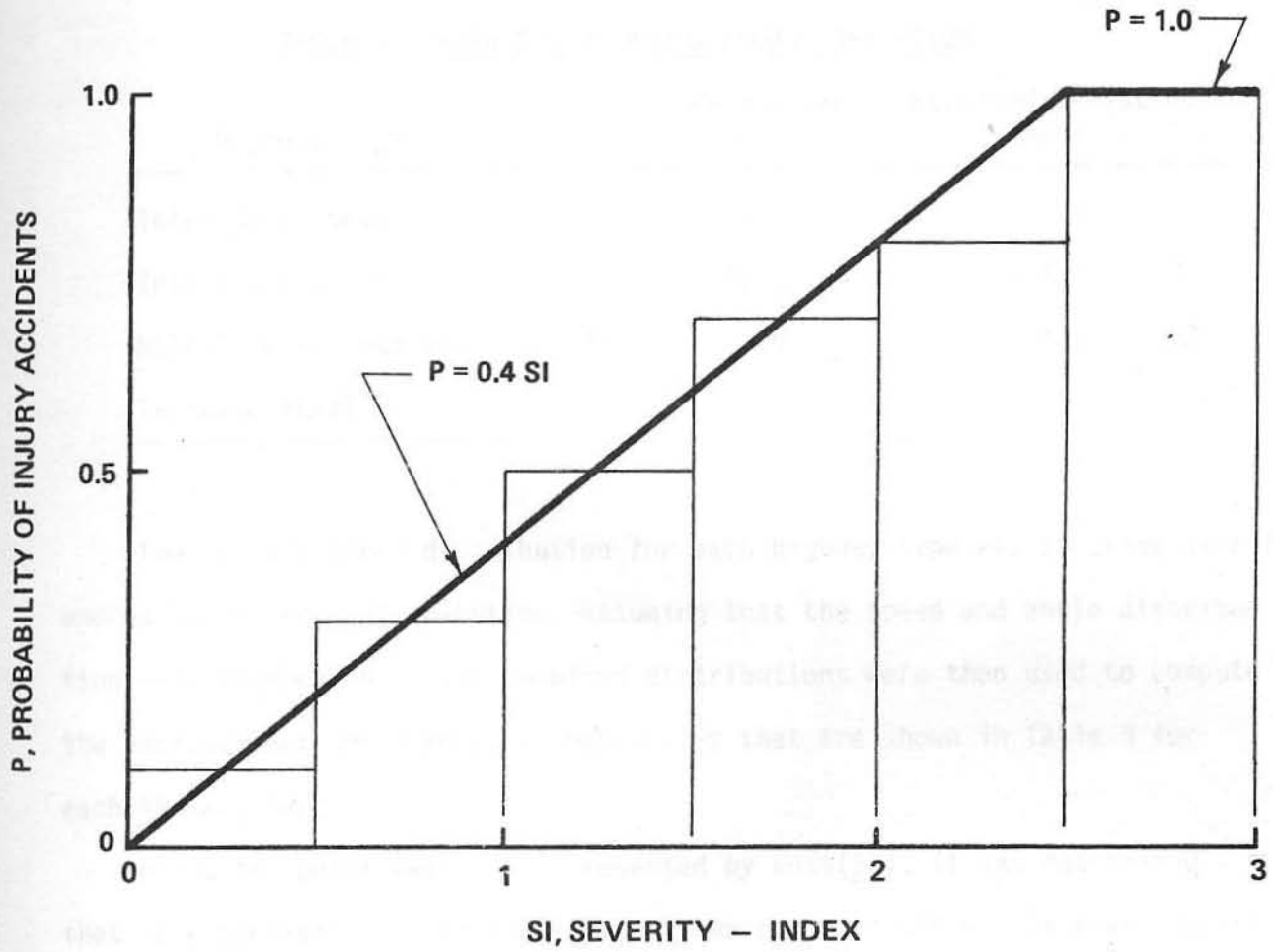


FIGURE 13. RELATIONSHIP BETWEEN SEVERITY – INDEX AND PROBABILITY OF INJURY ACCIDENTS

encroachment angle distribution used was that reported by Hutchinson and Kennedy (14).

TABLE 8. MEAN SPEEDS AND STANDARD DEVIATIONS

Highway Type	Mean Speed (mph)	Standard Deviation (mph)
Interstate-Rural	59.2	± 4.8
Interstate-Urban	55.5	± 5.2
Multilane-Divided and Undivided	53.8	± 4.8
Two-Lane-Rural	55.4	± 4.6

The vehicle speed distribution for each highway type was combined with the encroachment angle distribution, assuming that the speed and angle distribution were independent. The combined distributions were then used to compute the encroachment speed-angle probabilities that are shown in Table 9 for each highway type.

Using the point mass model presented by Ross(17), it was determined that some high-speed, high-angle impacts were not possible. However, because of the lack of encroachment data on speed-angle combinations to support this conclusion, it was decided that adjustment of the impact condition probabilities to account for the apparent impossibility of high-speed, high-angle impacts was not warranted.

Annualized Cost

The annualized cost of an improvement alternative, or existing condition, is computed as follows:

TABLE 9. ENCROACHMENT SPEED-ANGLE PROBABILITIES

Vehicle Speed (MPH)	IMPACT ANGLE (Degrees)					
	<7.5	7.5-12.5	12.5-17.5	17.5-22.5	22.5-27.5	>27.5
INTERSTATE-URBAN						
<45	.010	.004	.003	.002	.001	.002
45-55	.210	.088	.053	.035	.022	.031
55-65	.243	.101	.061	.040	.025	.035
65-75	.016	.007	.004	.003	.002	.002
>75	.000	.000	.000	.000	.000	.000
INTERSTATE-RURAL						
<45	.001	.000	.000	.000	.000	.000
45-55	.090	.038	.022	.015	.009	.013
55-65	.335	.139	.084	.056	.035	.049
65-75	.054	.023	.014	.009	.006	.008
>75	.000	.000	.000	.000	.000	.000
MULTILANE-DIVIDED AND UNDIVIDED						
<45	.016	.007	.004	.003	.002	.002
45-55	.271	.113	.068	.045	.028	.040
55-65	.188	.078	.047	.031	.020	.027
65-75	.005	.002	.001	.001	.000	.001
>75	.000	.000	.000	.000	.000	.000
2-LANE RURAL						
<45	.006	.002	.001	.001	.001	.001
45-55	.217	.090	.054	.036	.023	.032
55-65	.249	.104	.062	.041	.026	.036
65-75	.009	.004	.002	.001	.001	.001
>75	.000	.000	.000	.000	.000	.000

$$C = CI + CCM + CNM \qquad \text{---Eq. 8}$$

where:

C = annualized cost (dollars/year);

CI = annualized first cost of improvement alternative and zero in the case of existing condition (dollars/year);

CCM = annual collision maintenance cost (dollars/year);

CNM = annual normal maintenance cost (dollars/year).

The first cost of an improvement alternative is input on the Roadside Hazard Improvement Form (Figure 2), and it is annualized by the computer program using a 20-year life, 9% interest rate, and zero salvage value. The annual normal maintenance in the above equation is input directly on this form.

The annual collision maintenance cost is computed as follows:

$$CCM = E \sum_{\Theta} P_{\Theta}(C/E) \sum_{v} P_{\Theta,v} \cdot CM_{\Theta,v} \qquad \text{---Eq. 9}$$

where:

CCM = annual collision maintenance cost (dollars/year);

E = encroachment rate (number of roadside encroachments/mile/year);

$P_{\Theta}(C/E)$ = probability that the improvement alternative, or existing condition, will be encountered given an encroachment at angle Θ;

$P_{\Theta,v}$ = probability of an encroachment at angle Θ and speed v given that an encroachment has occurred;

$CM_{\Theta,v}$ = collision maintenance cost per encounter at angle Θ and speed v (dollars/encounter);

Θ = encroachment angle (degrees);

v = encroachment speed (miles/hour).

In the case of slope improvements, or existing slope conditions, the collision maintenance cost per encounter is the same regardless of the angle and speed of encroachment. Therefore, the value input on the Roadside Hazard Improvement Form is used in the above equation for all encroachment speed-angle combinations.

However, in the case of guardrail, the relationship between guardrail collision maintenance cost and severity index, which was established in previous research conducted at the University of Nebraska-Lincoln (2) is used. In that study, the length of guardrail damaged and the number of posts that failed during an automobile collision were estimated from BARRIER VII computer simulations. The relationships between severity index and guardrail damage are shown in Figure 14 for installation lengths of 95 ft and 200 ft. Based on the cost values in AASHTO (18), the collision repair costs for the standard W-Beam guardrail was estimated as 9/10 of the current installation costs. Therefore, to calculate the collision maintenance cost per guardrail impact for a particular encroachment speed-angle combination, the computer program determines the length of damage from the relationship shown in Figure 14 using the severity index for the given speed-angle combination and multiples of the length of damage by $7.60.

Probability of Zero Accident Reduction

At a given location, traffic accidents are random events, the occurrence of which can be described by a Poisson probability distribution. Therefore, even though an improvement alternative is expected to provide a reduction in injury accidents there is a certain probability that no reduction will result during the life of the improvement. The probability of zero injury accident reduction is:

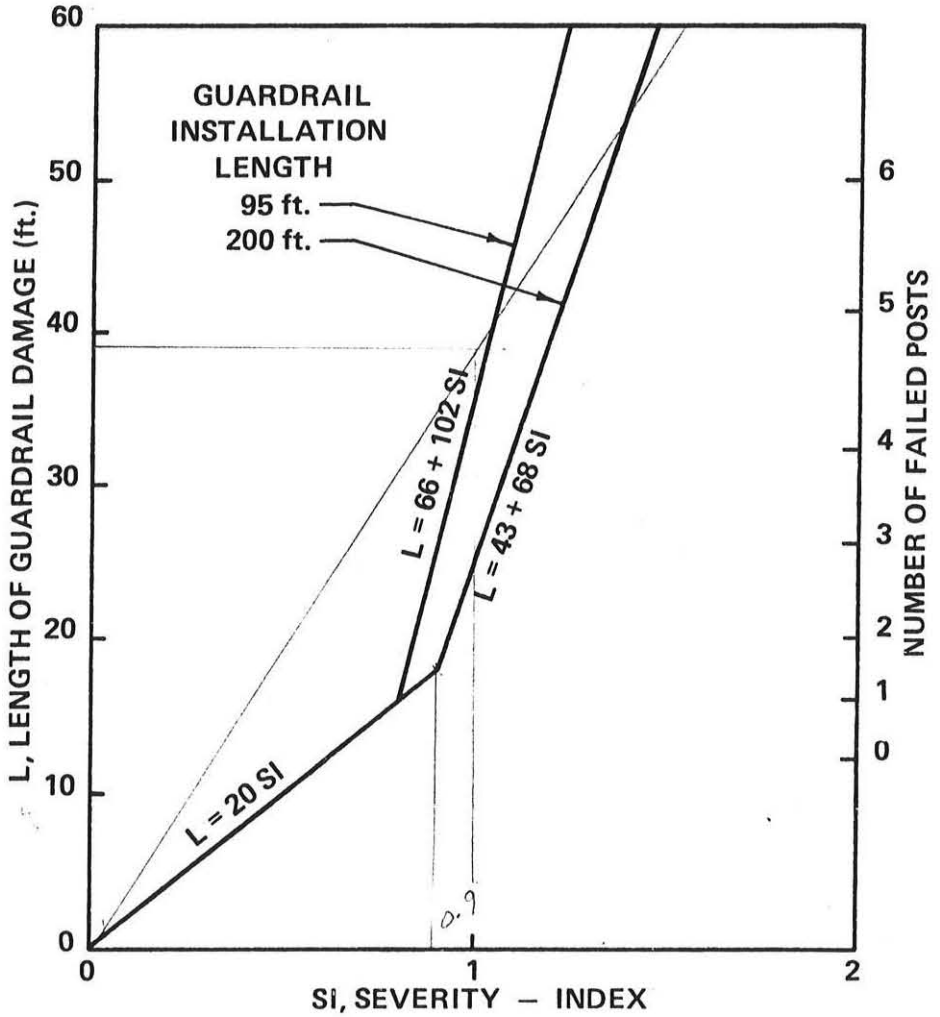


FIGURE 14. RELATIONSHIP BETWEEN SEVERITY – INDEX AND LENGTH OF GUARDRAIL DAMAGE

$$P(0) = e^{-m} \qquad \text{---Eq. 10}$$

where:

P(0) = probability of zero injury accident reduction;

m = expected number of injury accidents reduced over the life of the improvement alternative (reduction in hazard index provided by alternative times its life in years).

The computer program calculates and outputs this probability for each cost-effective improvement alternative. Values for various expected injury accident reductions are shown in Table 10.

The probability of zero injury accident reduction provides a basis for eliminating those improvement alternatives with relatively high cost-effectiveness values but with little chance of providing any reduction in injury accidents during their life times. For example, an improvement with a 20-year life and a 0.020 expected injury accident reduction per year would have a 0.67 probability of zero injury accident reduction, whereas a 40-year life improvement with the same expected reduction would have only a 0.45 probability. If both of these alternatives had the same annualized cost, they would then have the same cost-effectiveness value, but the 40-year life alternative would have a higher probability of actually providing a reduction.

TABLE 10. PROBABILITY OF ZERO INJURY ACCIDENT REDUCTION

Improvement Life (years)	Expected Reduction In Number Of Injury Accidents Per Year	Probability of Zero Injury Accident Reduction
20	0.050	0.37
	0.040	0.45
	0.030	0.55
	0.020	0.67
	0.010	0.82
40	0.050	0.14
	0.040	0.20
	0.030	0.30
	0.020	0.45
	0.010	0.67

BENEFIT-COST METHODOLOGY

The primary difference between the benefit-cost method of improvement evaluation and the cost-effectiveness approach is that the measure of performance is accident cost savings instead of reduction in injury accidents. The benefit-cost ratio of an improvement alternative is computed as follows:

$$B/C = \frac{A_E - A_I}{C_I - C_E} \qquad \text{---Eq. 11}$$

where:

B/C = benefit-cost ratio;

A_E = expected annual accident cost of existing condition (dollars/year);

A_I = expected annual accident cost of improvement alternative (dollars/year);

C_I = annualized cost of improvement alternative (dollars/year);

C_E = annualized cost of existing condition (dollars/year).

The annualized costs of the improvement alternative and the existing condition in the above equation are the same as those used in the cost-effectiveness value equation (Equation 2).

The computer program does not calculate benefit-cost ratios for those improvement alternatives that are determined to be "not cost-effective." Thus, benefit-cost ratios are not computed for improvement alternatives that do not provide an accident cost savings (i.e., $A_I \geq A_E$). Therefore, a benefit-cost ratio less than one indicates that the alternative is not economically worthwhile. Whereas, a benefit-cost ratio greater than one or less than zero would indicate that the alternative is economical justifiable.

The expected annual accident cost of an improvement alternative, or existing condition, is computed as follows:

$$A = E \sum_{\Theta} P_{\Theta}(C/E) \sum_{v} P_{\Theta,v} AC_{\Theta,v} \qquad \text{---Eq. 12}$$

where:

A = expected annual accident cost of improvement alternative, or existing condition (dollars/year);

E = encroachment rate (number of roadside encroachments/mile/year);

$P_{\Theta}(C/E)$ = probability that the improvement alternative, or existing condition, will be encountered given that an encroachment at angle Θ has occurred;

$P_{\Theta,v}$ = probability of an encroachment at angle Θ and speed v given that an encroachment has occurred;

Θ = encroachment angles (degrees);

v = encroachment speed (miles/hour).

The only difference between this equation and the hazard index equation (Equation 3) is that the average accident cost per encounter replaces the probability of an injury accident term.

As are the probability of injury and the guardrail collision maintenance cost variables, the average accident cost per encounter is computed as a function of severity index. An approach similar to that used by Weaver (18) was used to establish a relationship between severity index and accident costs. As shown in Table 10, the severity index and probability of injury accident were equated to a percentage distribution in terms of three accident severity classes: fatal, injury, and property damage only. The total accident costs shown in this table were determined by using the following accident cost

figure provided by the Nebraska Department of Roads:

Property Damage Only Accidents ---	$ 900
Injury Accident ---	$ 4,900
Fatal Accident ---	$336,000

A third-degree curve drawn to the histogram relationship in Table 11 is used by the computer program to determine the average accident cost per encounter used in Equation 12.

TABLE 11

RELATIONSHIP BETWEEN SEVERITY-INDEX AND INJURY ACCIDENT PROBABILITIES, ACCIDENT CLASSIFICATIONS, AND TOTAL ACCIDENT COSTS

Severity-Index[a]	Probability of Injury Accident[b]	Accident Classification[c]			Accident Cost[d] ($)
		PDO Accidents (%)	Injury Accidents (%)	Fatal Accidents (%)	
SI $\leq$ 0.5	0.1	90	10	0	1,300
0.5 < SI $\leq$ 1.0	0.3	60	40	0	2,500
1.0 < SI $\leq$ 1.5	0.5	40	50	10	36,410
1.5 < SI $\leq$ 2.0	0.7	10	60	30	103,830
2.0 < SI $\leq$ 2.5	0.8	0	50	50	170,450
2.5 < SI	1.0	0	10	90	302,890

a. Computed by HVOSM and BARRIER VII Simulations

b. Refer to Table 7

c. Assumed in similar manner as done in TTI Report (18)

d. Accident Costs: $336,000 per fatal accident

$4,900 per injury accident

$ 900 per property-damage-only accident

CASE STUDY NO. 3

This case study consisted of an actual field problem being considered by the Nebraska Department of Roads for a spot type improvement. A cross section of the 2-lane highway is shown in Figure 15. The roadway is classified as a DR-3 Major Arterial (3) with a design speed of 65 mph and an ADT of 3,650 vpd. The site is located on a tangent level section of US 15 between mile-posts 3.678 and 3.788. The shoulders are paved out 8 ft.

Existing Roadway

The existing roadway had a non-standard guardrail protecting the embankment, however, this guardrail will be completely removed and scrapped. The hinge point of the existing embankment is located 18 ft from the edge of the traveled lane. The embankment has a front slope of 2:1, a fill height of 20 ft., a ditch width of 10 ft., a back slope of 2:1, and a back slope height of 5 ft. The condition of the front slope is smooth and the ditch carries no water. Coding of the existing roadway is shown on the "Roadside Hazard Inventory Form" in Figure 16.

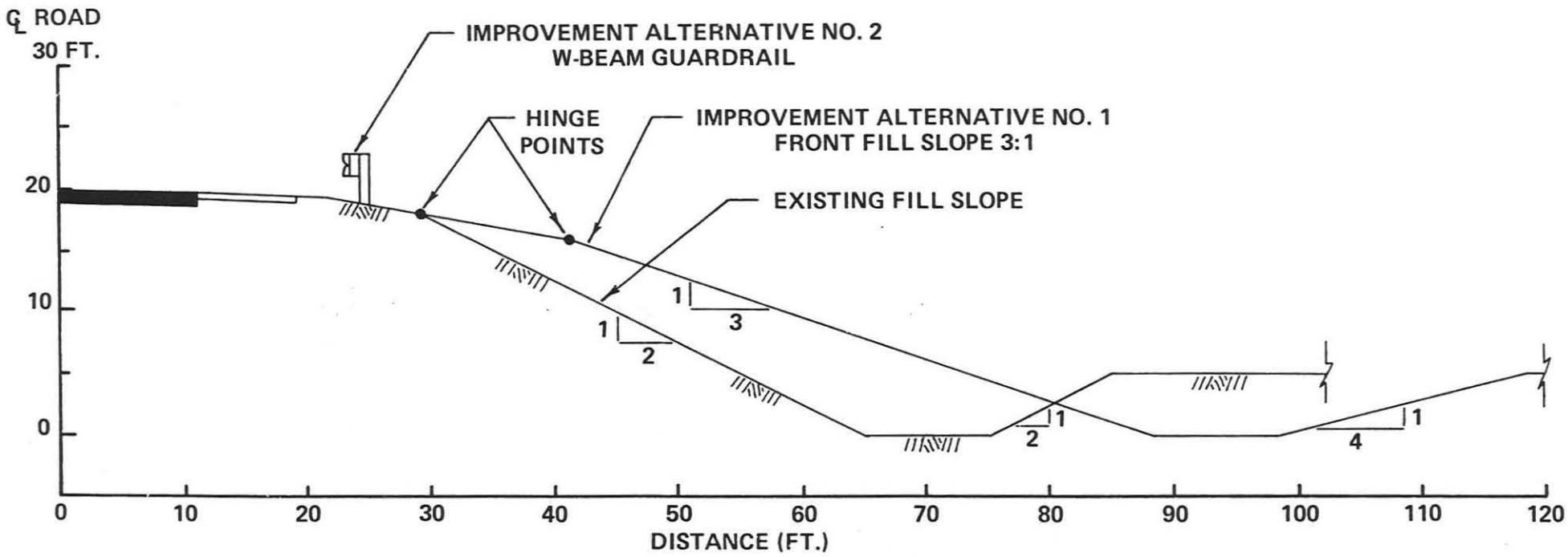
Improvement Alternative No.1

Improvement Alternative No. 1 consisted of modifying the existing roadside embankment. The roadside will be extended to provide a clear-recovery-area of 30 ft on a flat slope of 6:1. The embankment will have a front slope of 3:1, a fill height of 20 ft., a ditch width of 10 ft., a back slope of 4:1, and a back slope height of 5 ft.

Using the NDR earthwork program (RDS system), the following cost estimates in Table 12 were obtained:

STATE OF NEBRASKA
BOARD OF PUBLIC ROADS CLASSIFICATIONS AND STANDARDS
TYPICAL CROSS SECTIONS OF IMPROVEMENT FOR
RURAL STATE HIGHWAYS

DR-3
MAJOR ARTERIAL
750 - 400 D.H.V.



60

FIGURE 15. HIGHWAY CROSS SECTION FOR CASE STUDY NO. 3

CASE STUDY NO. 3

FIGURE 16

ROADSIDE HAZARD INVENTORY FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Inventory Conducted by Richard Ruby Date 10 Sept 1979

HIGHWAY

Highway Design Number	Highway Number	Design Speed (mph)	ADT	Lane Width (ft)	Usable Shoulder Width (ft)	Width Shoulder Surfacing (ft)	Median Width (ft)	Deg of Curve	Grade (%) UP	Grade (%) DN	Shoulder Drop-off (in)	Condition Non-Paved Shoulder
1-03	1-015	65	03650	12	10	08	00	0	0	0	0	1
1 2 3	4 5 6 7	8 9	10 11 12 13 14	15 16	17 18	19 20	21 22	23	24	25	26	27

1. DR
2. DM
3. ROA
4. RC
5. RL

1. US
2. N
3. I
4. SEC

1. Smooth
2. Rough

BOX 1

HAZARD CLASSIFICATION

Description Slope

Hazard Number	Identification Code	Descriptor Code	Offset Code	Grouping Number
0001	07-02	1	03	
28 29 30 31	32 33	34 35	36	37 38

1. Right Side
2. Left Side or Median

MILE POINT AT HAZARD

Beginning	Ending
00367 8	00378 8
39 40 41 42 43 44	45 46 47 48 49 50

BOX 2

POINT HAZARDS

	Offset (ft)	Width (ft)	Length (ft)	Drop Inlets Only: Height (in)	Drop Inlets Only: Depth (in)
1					
51	52 53	54 55	56 57 58 59	60 61	62 63

BOX 3

LONGITUDINAL HAZARDS (Guardrails, Bridgerails, Barrier Walls, and Curbs)

	Offset (ft) Begin	Offset (ft) End	Top Height (in)	Post Spacing (ft)	Guardrail: Post Spacing at Bridge End	Guardrail: Blockout	Guardrail: Rub Rail	Guardrail End Treatment: Beginning	Guardrail End Treatment: Ending
2									
51	52 53	54 55	56 57	58 59	60	61	62	63	64

1. Reduced
2. Not Reduced

1. No
2. Yes

1. No
2 Yes

1. Not Anchored (to ground or Bridge)
2. Anchored (to ground or Bridge)
3. Anchored Turndown (not breakaway)
4. Breakaway Terminal Design

BOX 4

SLOPE HAZARDS (Median Ditches, Roadside Ditches, Fill Ditches, and Cut Slopes)

	Hinge Point Offset (ft)	Front Slope (average)	Front Slope Height (ft)	Ditch Width (ft)	Back Slope (average)	Back Slope Height (ft)	Condition of Slopes	Depth of Water
3	18	2:1	20	10	2:1	05	1	1
51	52 53	54	55 56	57 58	59	60 61	62	63

1. Smooth
2. Rough

1. None
2. Less than 2 ft.
3 Greater than 2 ft.

BOX 5

DATE

Mo	Day	Yr
09	10	79
70 71	72 73	74 75

Recommendations

IBM Card Type: 1 (80)

BOX 6

TABLE 12. IMPROVEMENT ALTERNATIVE NO. 1 COST ESTIMATES

Item	Quantity	Unit Costs	Cost ($)
1. ROW	1.269 ac.	$1500/ac.	1,904
2. Culvert Excavation	96 cyd	$6/cyd	576
3. Roadway Excavation	1504 cyd	$0.66/cyd	993
4. 30 in. Culvert Pipe	40 lf	$17.96/lf	718
		Total	= $4,191

Coding of Improvement Alternative No. 1 is shown on the "Roadside Hazard Improvement Form" in Figure 17.

Improvement Alternative No. 2

Improvement Alternative No. 2 will consist of installing a standard W-beam guardrail at a lateral offset distance of 10 ft. from edge of traveled lane. No changes will be made to the existing embankment. The guardrail will be 300 ft. long and both ends will have breakaway terminal designs. A rub rail will be used to prevent vehicle snagging because the height of guardrail is 1-in. higher than a standard design of 27 in. Cost estimates for the guardrail are shown in Table 13.

TABLE 13. IMPROVEMENT ALTERNATIVE NO. 2 COST ESTIMATES

Item	Quantity	Unit Costs	Cost ($)
1. W-Beam Guardrail	300 lf	$8.0914/lf	2,427
2. Breakaway Terminals	2	$464.1778 ea.	928
		Total	= $ 3,355

CASE STUDY NO. 3

FIGURE 17

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by *Richard Ruby* Date *10 Sept 1979*

HIGHWAY

Highway Design Number	Highway Number	Design Speed (mph)	ADT
1-03	1-015	65	03650
1 2 3	4 5 6 7	8 9	10 11 12 13 14
1. DR SRL 2. DM 3. ROA 4. RC 5. HL	1. US 2. N 3. I 4. SEC		

Hazard Number: 1
Hazard Group Number: 3
Improvement Alternative Number: 1

BOX 1

COSTS

Capital Costs ($1,000)	Collision Maintenance ($100/accid.)		Normal Maintenance ($100/yr.)	
	Hazard	Improvement	Hazard	Improvement
00042	001	001	01	01
15 16 17 18 19	20 21 22	23 24 25	26 27	28 29

BOX 2

POINT HAZARD IMPROVEMENTS

BOX 3

- ○ 1 (30) 1 (31) Alleviate Hazard — (32) 1. Remove 2. Make Breakaway and/or Relocate 3. Reconstruct Inlet to Safe Design 4. Reconstruct Cross Drainage System
- ○ 1 (30) 2 (31) Install Traffic Barrier (complete Box A) — (32 33) Descriptor Code — (34 35 36 37) Length (ft)
- ○ 1 (30) 3 (31) Install Energy Attenuator — (32 33) Descriptor Code

LONGITUDINAL HAZARD IMPROVEMENTS

BOX 4

- ○ 2 (30) 1 (31) Curb — (32) 1. Remove and Regrade 2. Install Warige Modification
- ○ 2 (30) 2 (31) Traffic Barrier — (32) 1. Remove 2. Modify (complete Boxes A, B & C) 3. Replace with New Design (complete Boxes A, B & C) — (33 34) Descriptor Code (New Design Only)
- ○ 2 (30) 3 (31) Bridgerail — (32) 1. Modify 2. Replace with New Design — (33 34) Descriptor Code

SLOPE IMPROVEMENTS

BOX 5

- ○ 3 (30) 1 (31) Install Traffic Barrier (complete Boxes A and C) — (32) 1. At Bridge 2. Not at Bridge — (33 34) Descriptor Code
- ⊗ 3 (30) 2 (31) Modify (complete Box C)

Hinge Point Offset (ft)	Front Slope (average)	Front Slope Height (ft)	Ditch Width (ft)	Back Slope (average)	Back Slope Height (ft)	Condition of Slopes	Depth of Water (ft)
30	3:1	20	10	4:1	05	1	1
32 33	34	35 36	37 38	39	40 41	42	43
						1. Smooth 2. Rough	1. None 2. Less than 2 ft. 3. Greater than 2 ft.

NO IMPROVEMENT

BOX 6

○ 4 (30)

BOX A (TRAFFIC BARRIER MODIFICATIONS)

BOX A

○

Offset (ft) Begin	Offset (ft) End	Top Height (in)	Post Spacing (ft)	Guardrail: Post Spacing if at Bridge End	Guardrail: Block Out	Guardrail: Rub Rail	Guardrail End Treatment: Beginning	Guardrail End Treatment: Ending
48 49	50 51	52 53	54 55	56	57	58	59	60
				1. Reduced 2. Not Reduced	1. No 2. Yes	1. No 2. Yes	1. Not Anchored (to ground or bridge) 2. Anchored (to ground or bridge) 3. Anchored Turndown (not breakaway) 4. Breakaway Terminal Design	

BOX B (CHANGES TO EXISTING GUARDRAIL)

BOX B

⊗ Beginning: (61) 1. Lengthen 2. Shorten — Ending: (62) 1. Lengthen 2. Shorten — (63 64) Change in Length (ft)

BOX C (MILE POINT OF CHANGE)

BOX C

Beginning: 00367S (65 66 67 68 69 70) — Ending: 00375S (71 72 73 74 75 76)

BOX 7

⊗ (79) 1. End of Group 2. End of Group and Program — 2 (80) IBM Card Type

Coding of Improvement Alternative No. 2 is shown on the "Roadside Hazard Improvement Form" in Figure 18.

Computer Output Listing

The listing of the computer output is shown in Figure 19. As evident, the slope improvement (Alternative No. 1) is more attractive than the guardrail improvement (Alternative No. 2) because of a lower cost-effectiveness value and a higher benefit-cost ratio. However, both improvement alternatives have a high probability of a zero hazard reduction over the same project life of 20 years. It is interesting to note that even though the guardrail improvement has a lower first cost, its hazard-index (injuries/yr) is higher.

It is important to re-emphasize that the computer program as it now stands was not programmed to handle (1) the effect of the rub rail in preventing wheel snagging, and (2) the effect of breakaway terminals in reducing the severity of end impacts.

CASE STUDY NO. 3

FIGURE 18

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard Ruby Date 10 Sept 1979

HIGHWAY

BOX 1

Highway Design Number	Highway Number	Design Speed (mph)	ADT	Hazard Number	Hazard Group Number	Improvement Alternative Number
1-03 (1 2 3)	1-015 (4 5 6 7)	65 (8 9)	03650 (10 11 12 13 14)	1	3	2

Highway Design Number: 1. DR SRL 2. DM 3. ROA 4. RC 5. RL
Highway Number: 1. US 2. N 3. I 4. SEC

COSTS

BOX 2

Capital Costs ($1,000) (15 16 17 18 19)	Collision Maintenance ($100/accid.) Hazard (20 21 22)	Collision Maintenance ($100/accid.) Improvement (23 24 25)	Normal Maintenance ($100/yr.) Hazard (26 27)	Normal Maintenance ($100/yr.) Improvement (28 29)
00034	001	001	01	01

POINT HAZARD IMPROVEMENTS

BOX 3

1 (30)	1 (31)	Alleviate Hazard	(32) 1. Remove 2. Make Breakaway and/or Relocate 3. Reconstruct Inlet to Safe Design 4. Reconstruct Cross Drainage System
1 (30)	2 (31)	Install Traffic Barrier (complete Box A)	(32 33) Descriptor Code; (34 35 36 37) Length (ft)
1 (30)	3 (31)	Install Energy Attenuator	(32 33) Descriptor Code

LONGITUDINAL HAZARD IMPROVEMENTS

BOX 4

2 (30)	1 (31)	Curb	(32) 1. Remove and Regrade 2. Install Wedge Modification
2 (30)	2 (31)	Traffic Barrier	(32) 1. Remove 2. Modify (complete Boxes A, B & C) 3. Replace with New Design (complete Boxes A, B & C); (33 34) Descriptor Code (New Design Only)
2 (30)	3 (31)	Bridgerail	(32) 1. Modify 2. Replace with New Design; (33 34) Descriptor Code

SLOPE IMPROVEMENTS

BOX 5

3 (30)	1 (31)	Install Traffic Barrier (complete Boxes A and C)				2 (32) 1. At Bridge 2. Not at Bridge				06 (33 34)	Descriptor Code
3 (30)	2 (31)	Modify (complete Box C)	Hinge Point Offset (ft) (32 33)	Front Slope (average) (34) :1	Front Slope Height (ft) (35 36)	Ditch Width (ft) (37 38)	Back Slope (average) (39) :1	Back Slope Height (ft) (40 41)	Condition of Slopes (42) 1. Smooth 2. Rough	Depth of Water (ft) (43) 1. None 2. Less than 2 ft. 3. Greater than 2 ft.	

NO IMPROVEMENT

BOX 6

4 (30)

BOX A (TRAFFIC BARRIER MODIFICATIONS)

BOX A

Offset (ft) Begin (48 49)	Offset (ft) End (50 51)	Top Height (in) (52 53)	Post Spacing (ft) (54 55)	Guardrail Post Spacing if at Bridge End (56) 1. Reduced 2. Not Reduced	Guardrail Block Out (57) 1. No 2. Yes	Guardrail Rub Rail (58) 1. No 2. Yes	Guardrail End Treatment Beginning (59)	Guardrail End Treatment Ending (60)
10	10	28	06		2	2	4	4

Guardrail End Treatment: 1 Not Anchored (to ground or bridge) 2. Anchored (to ground or bridge) 3. Anchored Turndown (not breakaway) 4. Breakaway Terminal Design

BOX B (CHANGES TO EXISTING GUARDRAIL)

BOX B

Beginning (61) 1. Lengthen 2. Shorten	Ending (62) 1. Lengthen 2. Shorten	Change in Length (ft) (63 64)

BOX C (MILE POINT OF CHANGE)

BOX C

Beginning (65 66 67 68 69 70)	Ending (71 72 73 74 75 76)
003722	003779

BOX 7

BOX 7

2 (79) 1. End of Group 2. End of Group and Program

2 (80) IBM Card Type

C O S T E F F E C T I V E N E S S P R O G R A M

UNIVERSITY OF NEBRASKA
AND
NEBRASKA DEPARTMENT OF ROADS

HIGHWAY DESIGN NUMBER = DR- 3
TYPE HIGHWAY = US- 15
DESIGN SPEED = 65 MPH
ADT = 3650
PROJECT LIFE = 20.0 YRS
INTEREST RATE = 9.000 %
DATE = 9-10-79

H A Z A R D								I M P R O V E M E N T								
HAZARD NO	GROUP NO	IDENT CODE	DESC CODE	HAZARD INDEX (INJ/YR)	SIDE OF ROAD	MILEPOST BEG	MILEPOST END	IMPR ALT	IMPR CODE	HAZARD INDEX (INJ/YR)	CLEAR RECOVERY ZONE (FT)	FIRST COST ($1000)	TOTAL ANNUAL COST ($/YR)	COST EFFECTIVE VALUE	ZERO ACCIDENT REDUCTION (%)	BENEFIT COST RATIO
1	3	7	2	0.02421	1	3.678	3.788	1	3-2-0	0.00824	30	4.2	0	28	72	1542.5
1	3	7	2	0.02421	1	3.678	3.788	2	3-1-2	0.01256	10	3.4	1	156	79	337.5

FIGURE 19. COMPUTER OUTPUT LISTING OF CASE STUDY NO. 3

SUMMARY AND CONCLUSIONS

The computer program in this study was developed to expedite the lengthy and tedious cost-effectiveness and benefit-cost calculations for making W-beam guardrail improvements on roadside fill slopes. For example, analyzing a single group consisting of 2 hazards and 4 improvement alternatives requires less than 2 minutes of computer execution time in comparision to three or four man-days of effort.

The work accomplished in this study has demonstrated that the cost-effectiveness computer program shows great potential in providing highway engineers and administrators in Nebraska with a managerial tool for evaluating spot safety improvement projects and design projects in order to realize the greatest return on the investment made to reduce injury accidents.

Future Work

The hazard inventory and improvement coding forms developed in this study for computer usage are general in scope and include most roadside hazards that are likely to be encountered by an errant vehicle. A tentative list of subroutines that could be added to the existing computer program are briefly described in Table 14.

All of the computer simulations in this study were run using a standard size automobile. Additional work should be done to include smaller size automobiles. Also, on low volume roads and in urban areas, additional work should be done on establishing (1) frequency encroachment rates, and (2) lateral offset impact distribution probabilities.

TABLE 14

TENTATIVE LIST OF ADDITIONAL COMPUTER SUBROUTINES

Subroutine Name	Subroutine Description
ENDGR	Compute severity-indicies of different guardrail end-treatments
VAULT	Compute severity-indicies of vehicle vaulting of guardrail (1) located on slopes, (2) located in depressed medians, and (3) with heights lower than standard
SNAG	Compute severity-indicies of vehicle snagging on guardrail posts
CABLE*	Compute severity-indicies of different cable guard-rail designs
BRIDGE	Compute severity-indicies of different bridgerail designs
PTHAZ	Compute severity-indicies of different types of point hazards
RUT	Compute severity-indicies of rutting or drop-offs between travelled lanes and shoulders
SOFT	Compute severity-indicies of different Fitch Module designs
CURB	Compute severity-indicies of different curb designs
UNIT	Store unit costs by district
MAIN 2	Subroutine to expand capability of computer program to handle groups containing as many as 15 hazards, i.e., Guardrail-bridgerail sites at over-passes
ORDER	Subroutine to re-arrange hazards by lateral and longitudinal distances (x-y coordinates) in order to determine exact location of hazards in relation to each other

* Current HP&R Project

Computer coding forms similar to the forms developed in this study, but of lesser detail, were subjected to extensive field testing by Weaver (1) in Texas. It is recommended that a similar field procedure be implemented in Nebraska in order to correct any unforeseen problems.

Ultimately, the computer program should be utilized to (1) develop design nomographs for the installation of guardrail similar to the nomograph presented in HRR SR 81 (19) as shown in Figure 20, and (2) to assist in establishing guardrail design policies and standards in Nebraska.

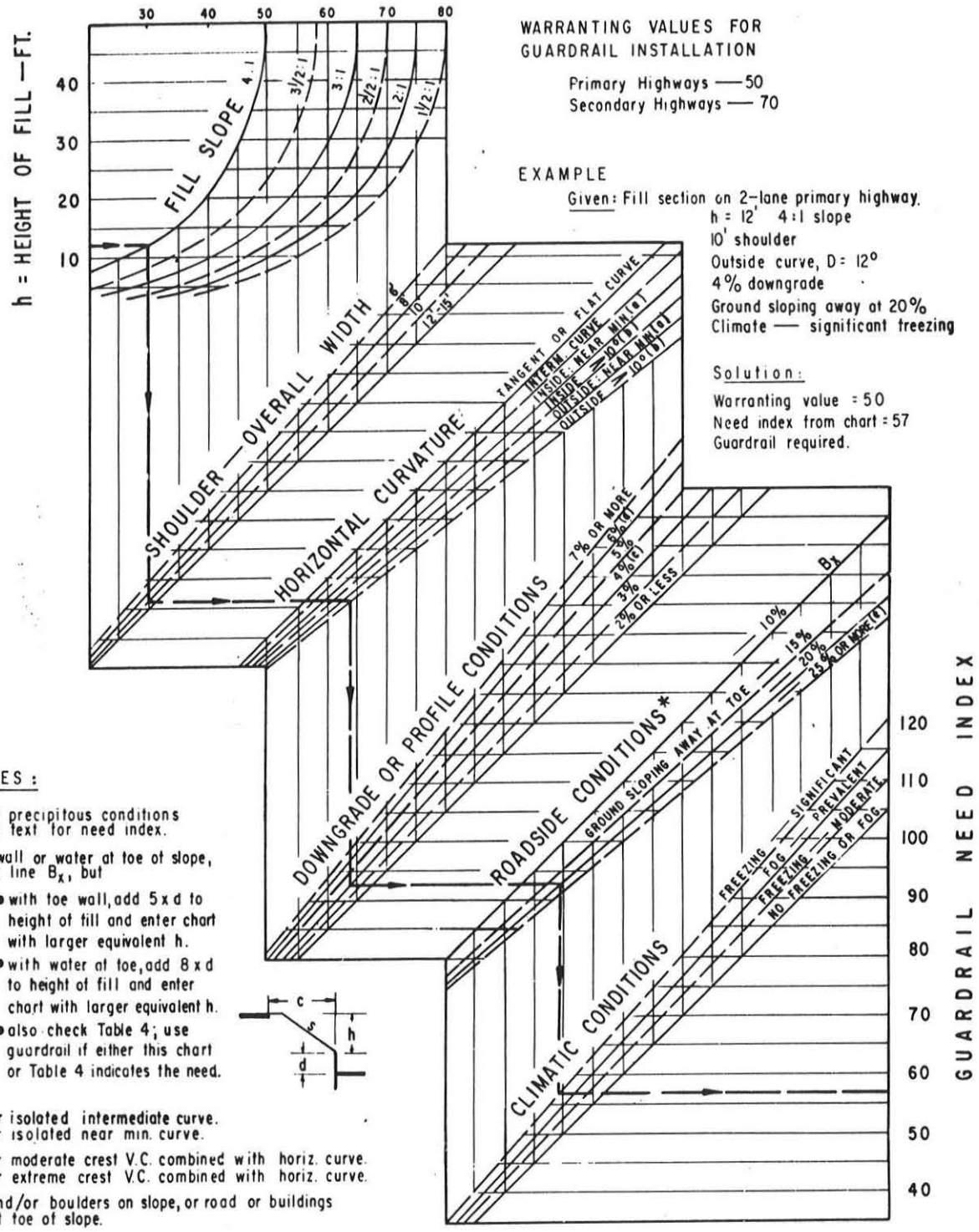


FIGURE 20. NOMOGRAPH TO COMPUTE GUARDRAIL NEED INDEX (HRR SR 81)

REFERENCES

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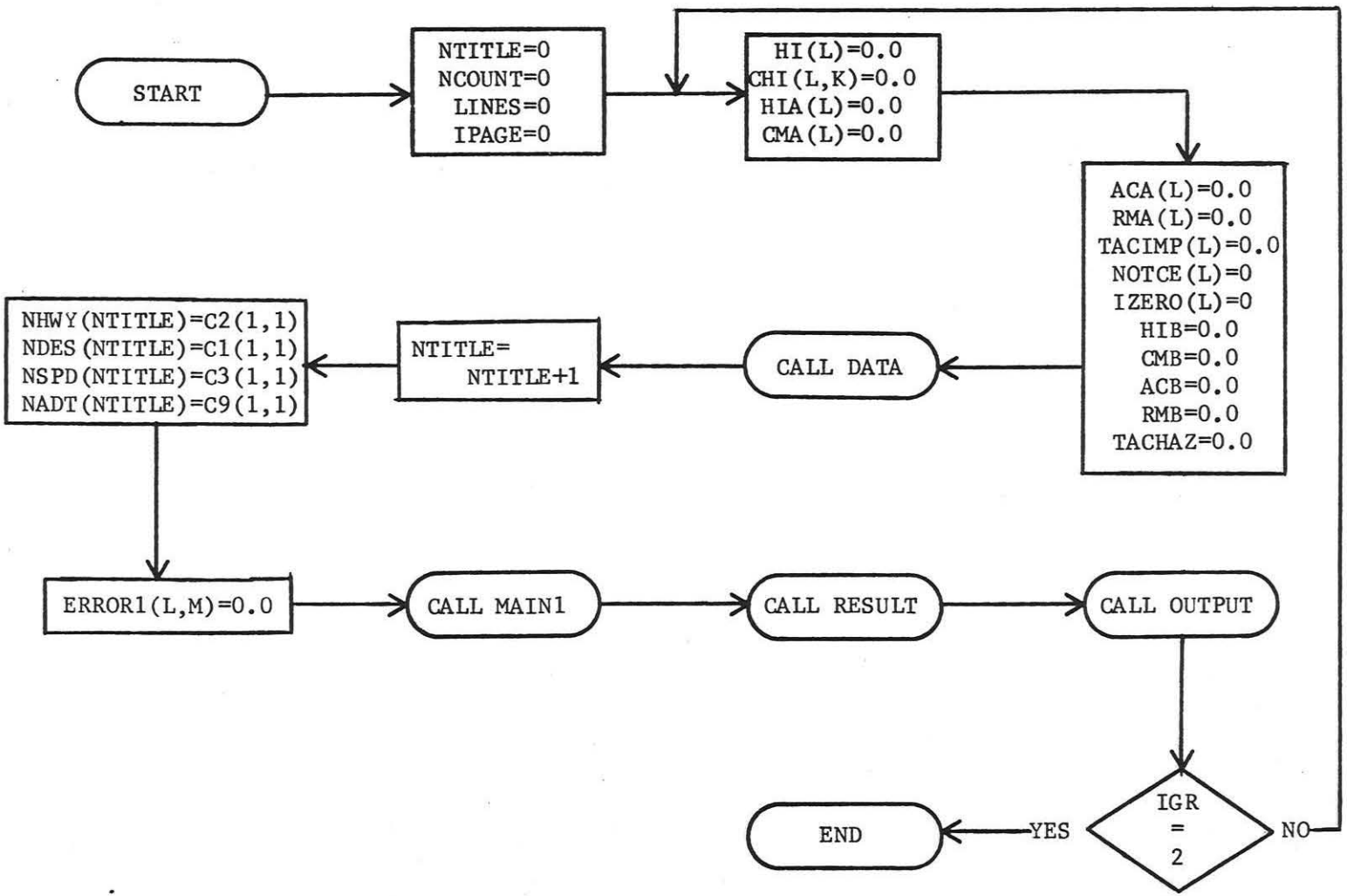
APPENDICES

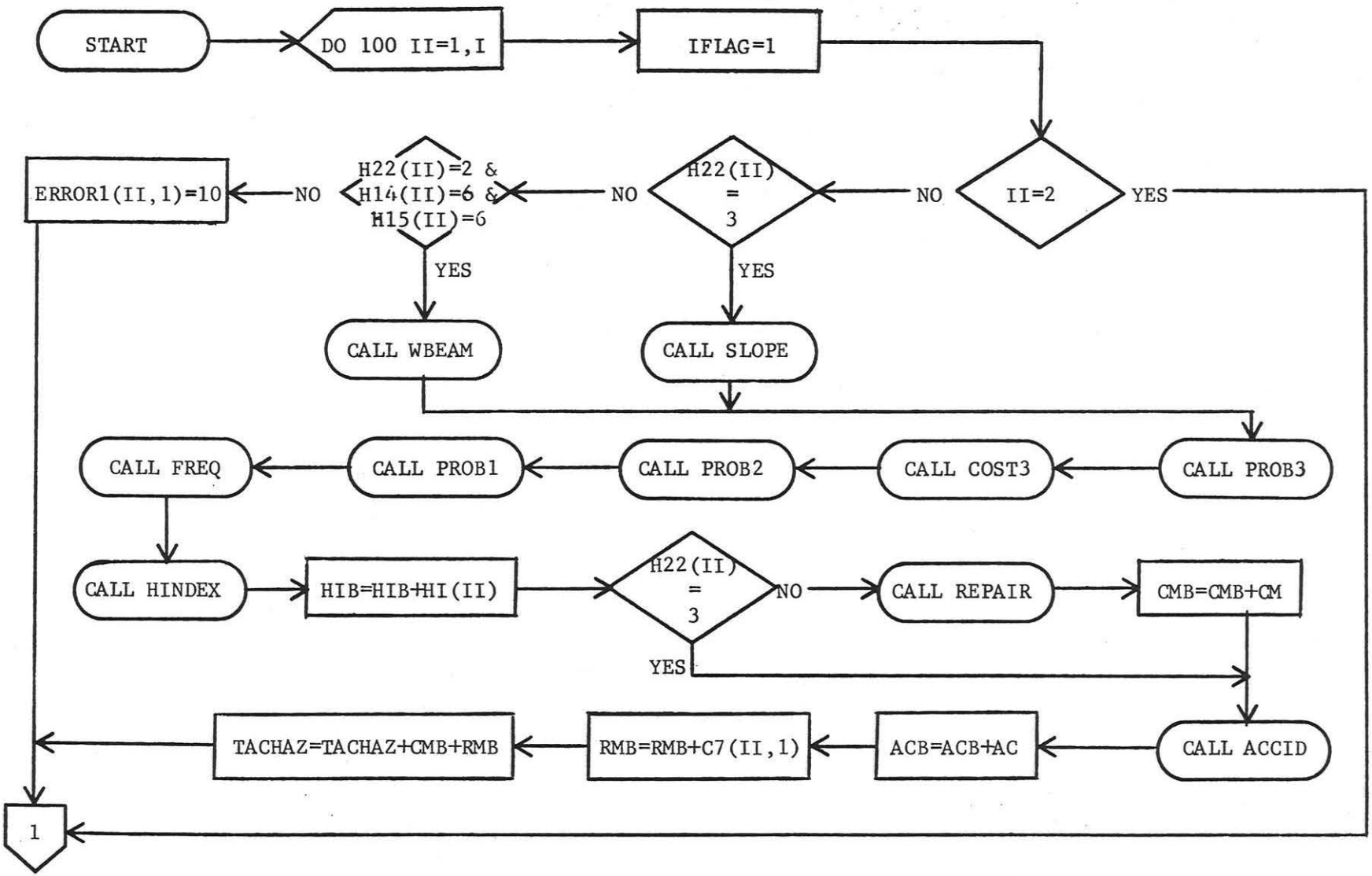
A P P E N D I X

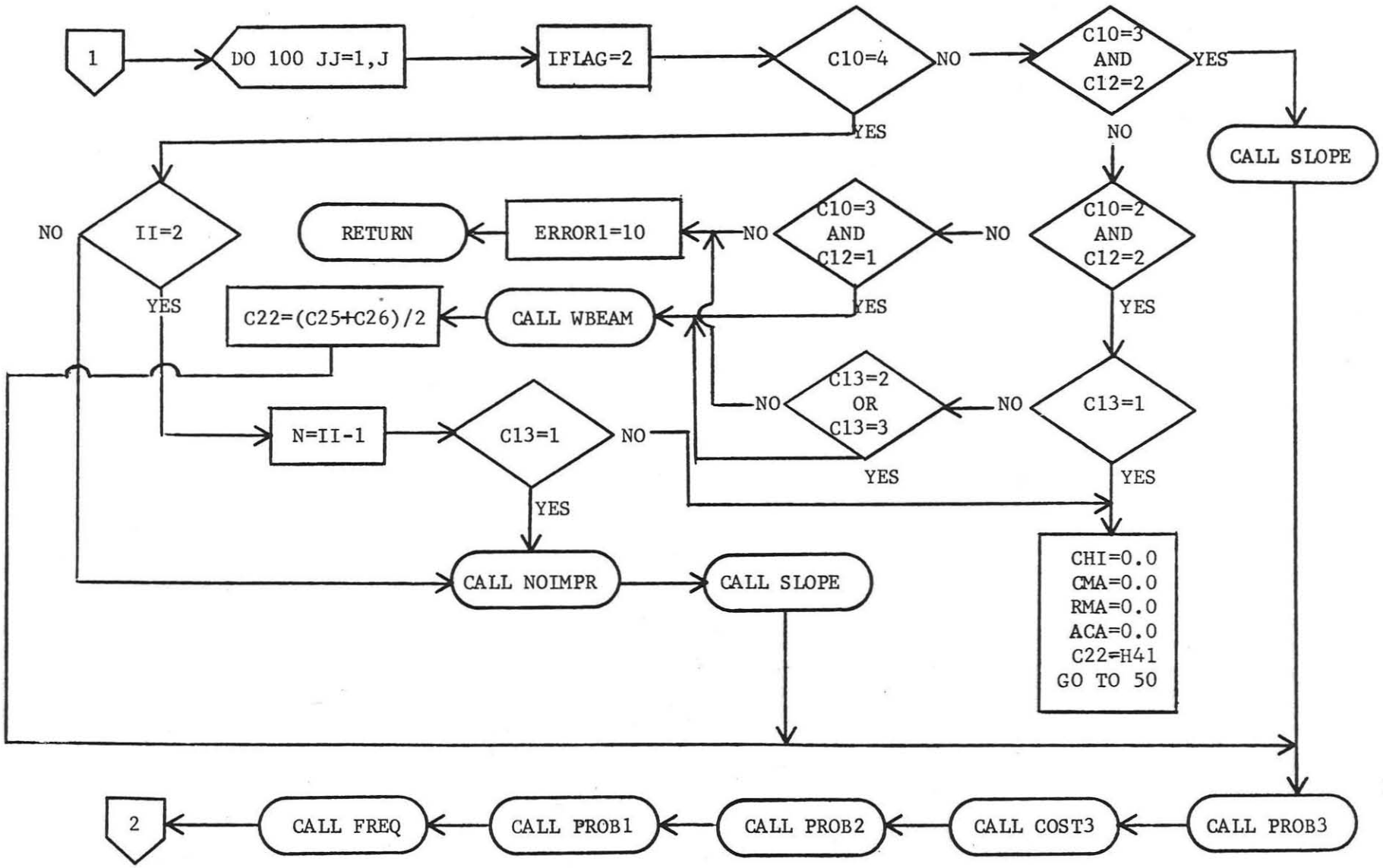
A. COMPUTER PROGRAM FLOW CHARTS

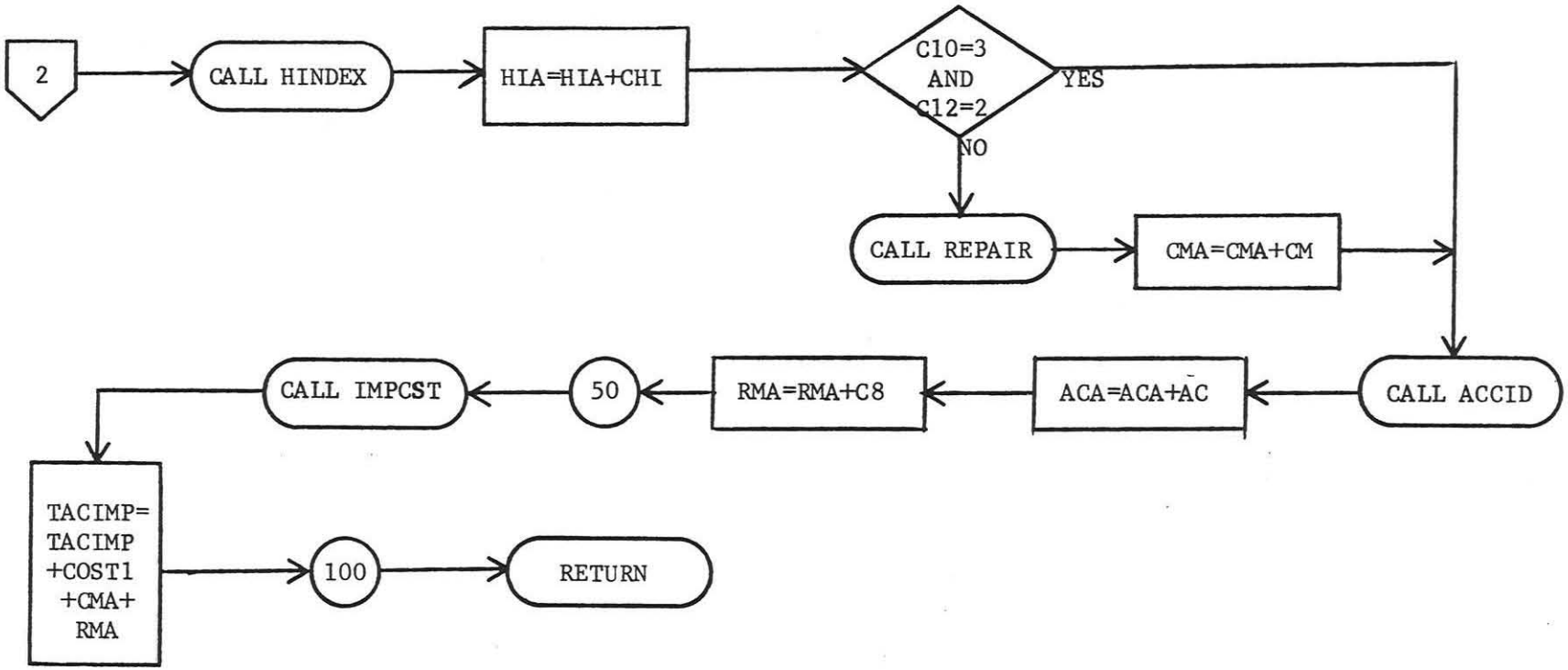
MAIN PROGRAM



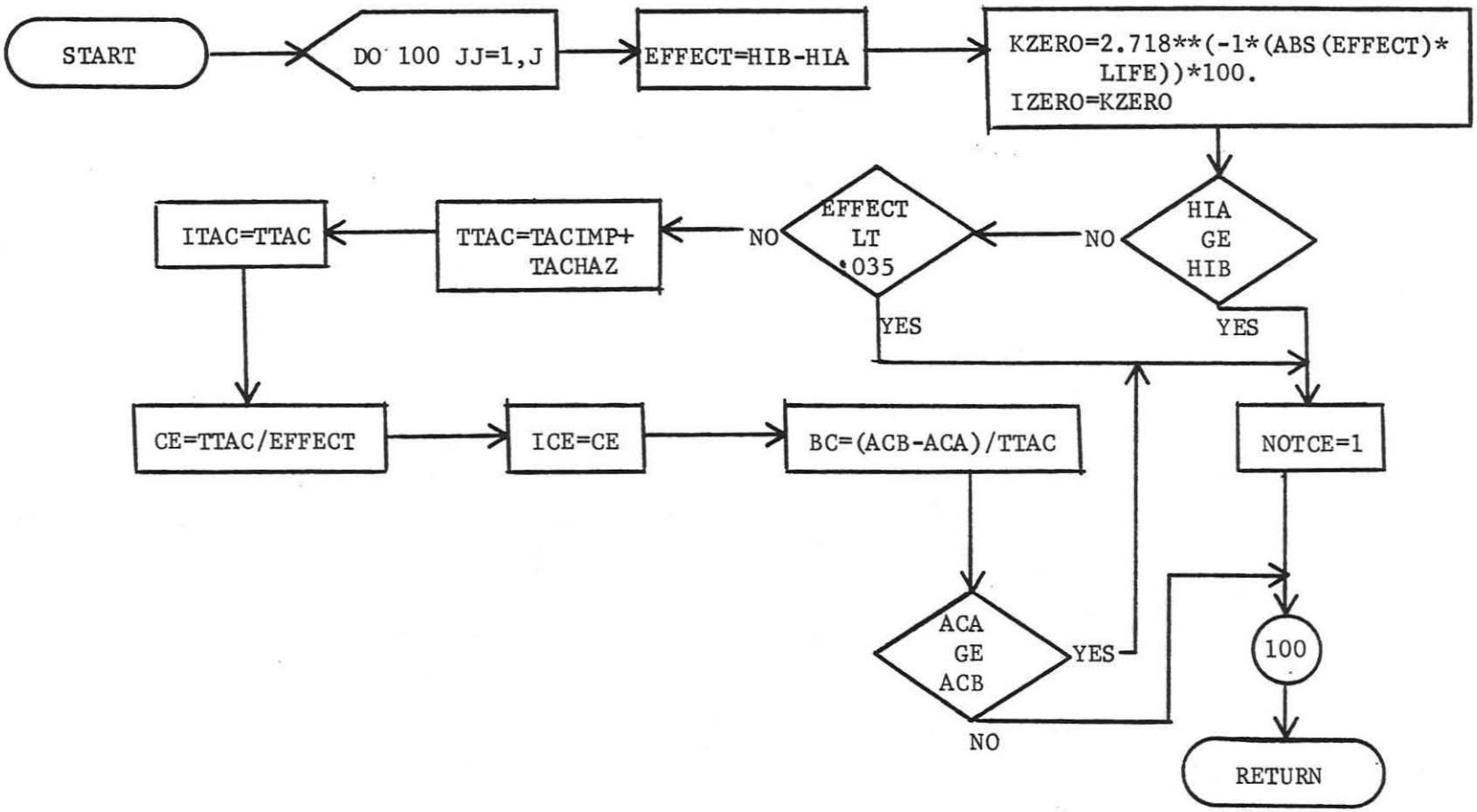
SUBROUTINE MAIN1



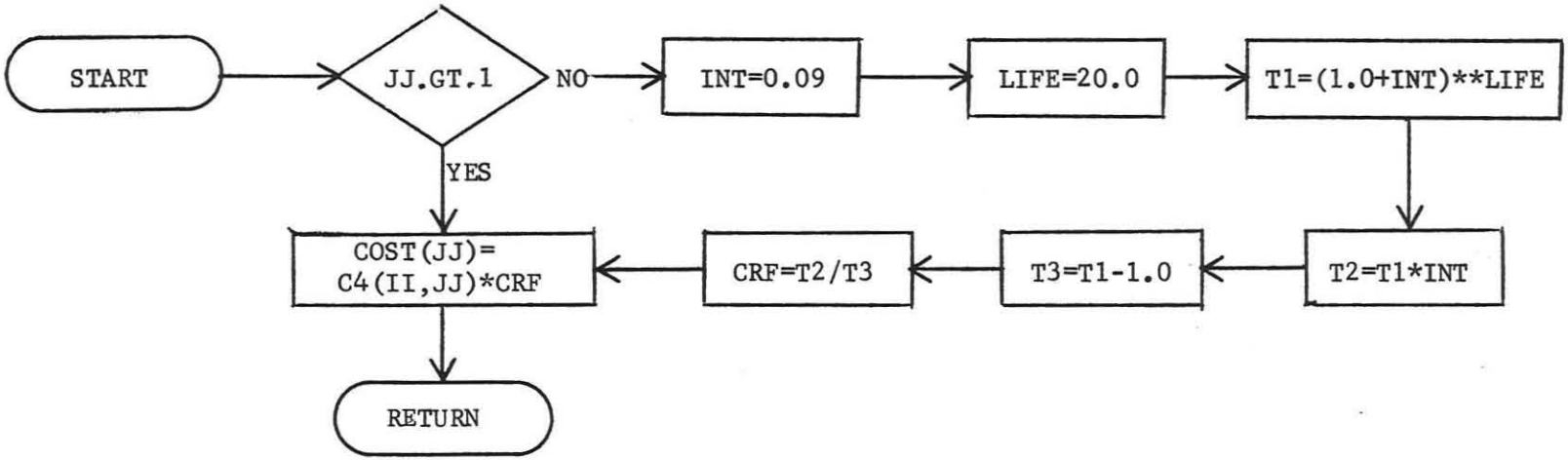

1
DO 100 JJ=1,J
IFLAG=2
C10=4
NO
C10=3 AND C12=2
YES
CALL SLOPE
YES
NO
II=2
NO
YES
RETURN
ERROR1=10
C10=3 AND C12=1
NO
C10=2 AND C12=2
NO
YES
YES
C22=(C25+C26)/2
CALL WBEAM
N=II-1
C13=1
NO
C13=2 OR C13=3
NO
C13=1
NO
YES
YES
YES
CALL NOIMPR
CALL SLOPE
CHI=0.0
CMA=0.0
RMA=0.0
ACA=0.0
C22=H41
GO TO 50
2
CALL FREQ
CALL PROB1
CALL PROB2
CALL COST3
CALL PROB3

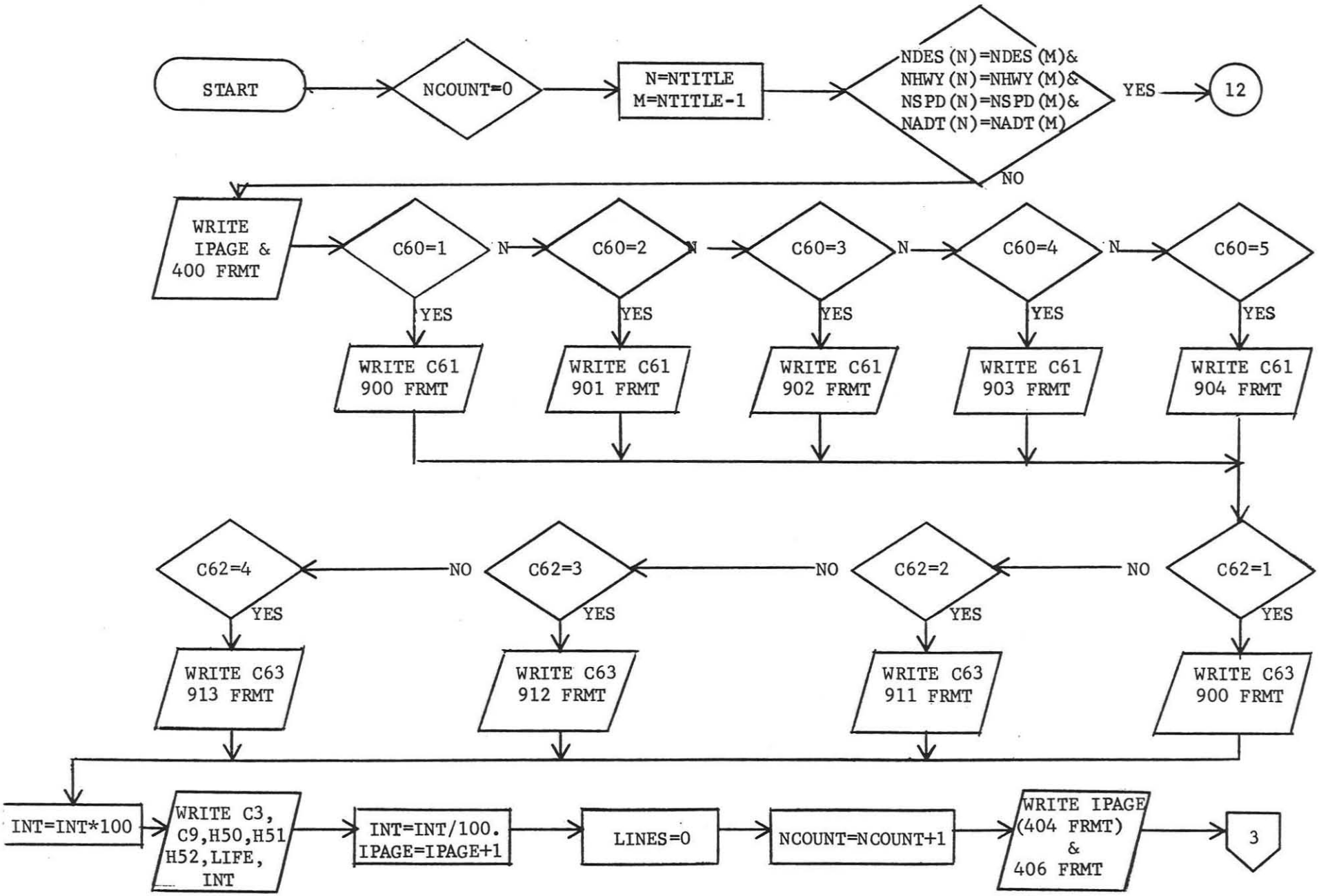

2
CALL HINDEX
HIA=HIA+CHI
C10=3 AND C12=2
YES
NO
CALL REPAIR
CMA=CMA+CM
CALL ACCID
ACA=ACA+AC
RMA=RMA+C8
50
CALL IMPCST
TACIMP= TACIMP +COST1 +CMA+ RMA
100
RETURN

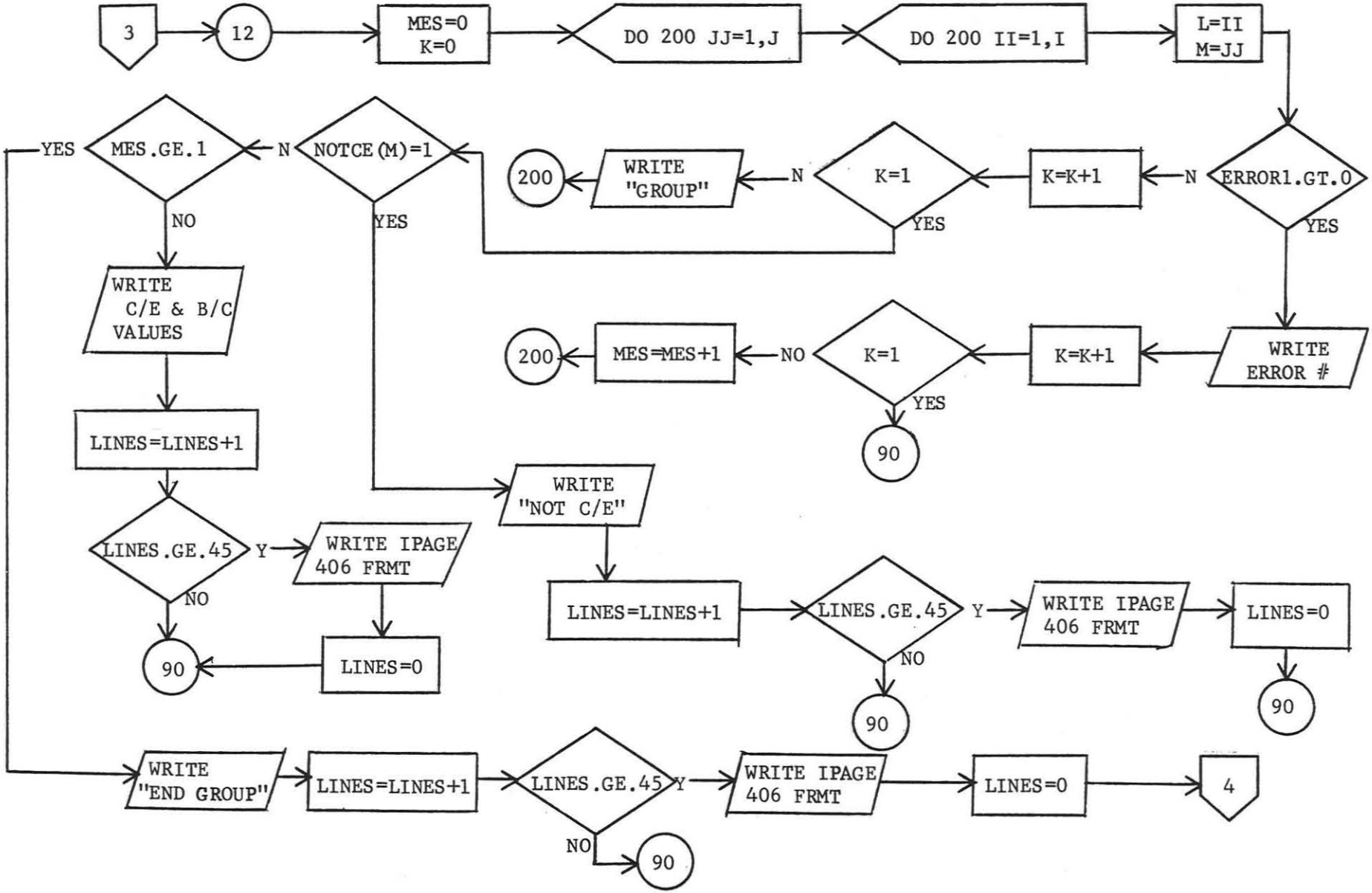
SUBROUTINE RESULT

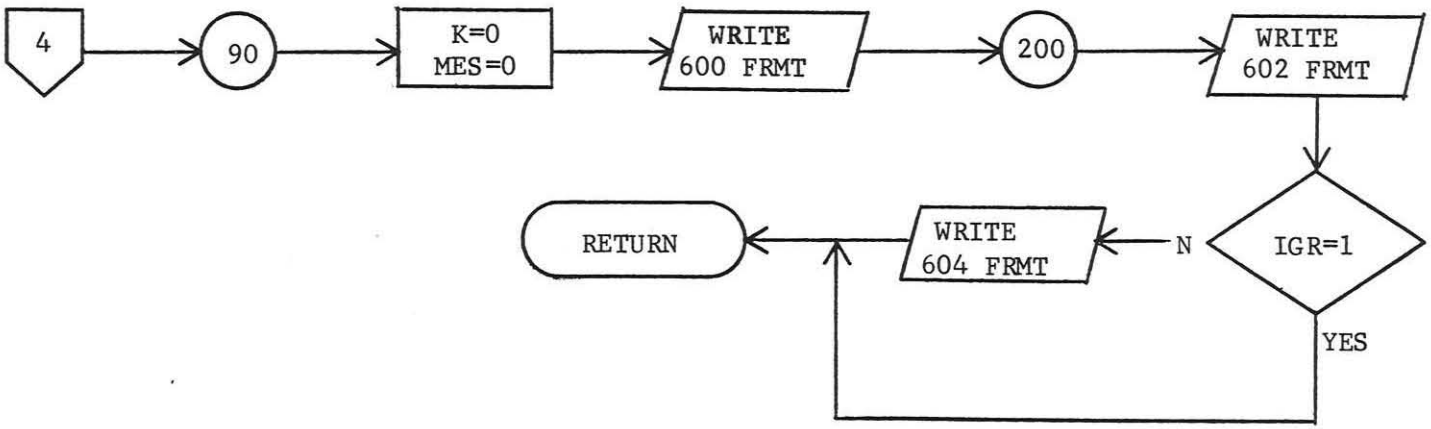


SUBROUTINE IMPCST

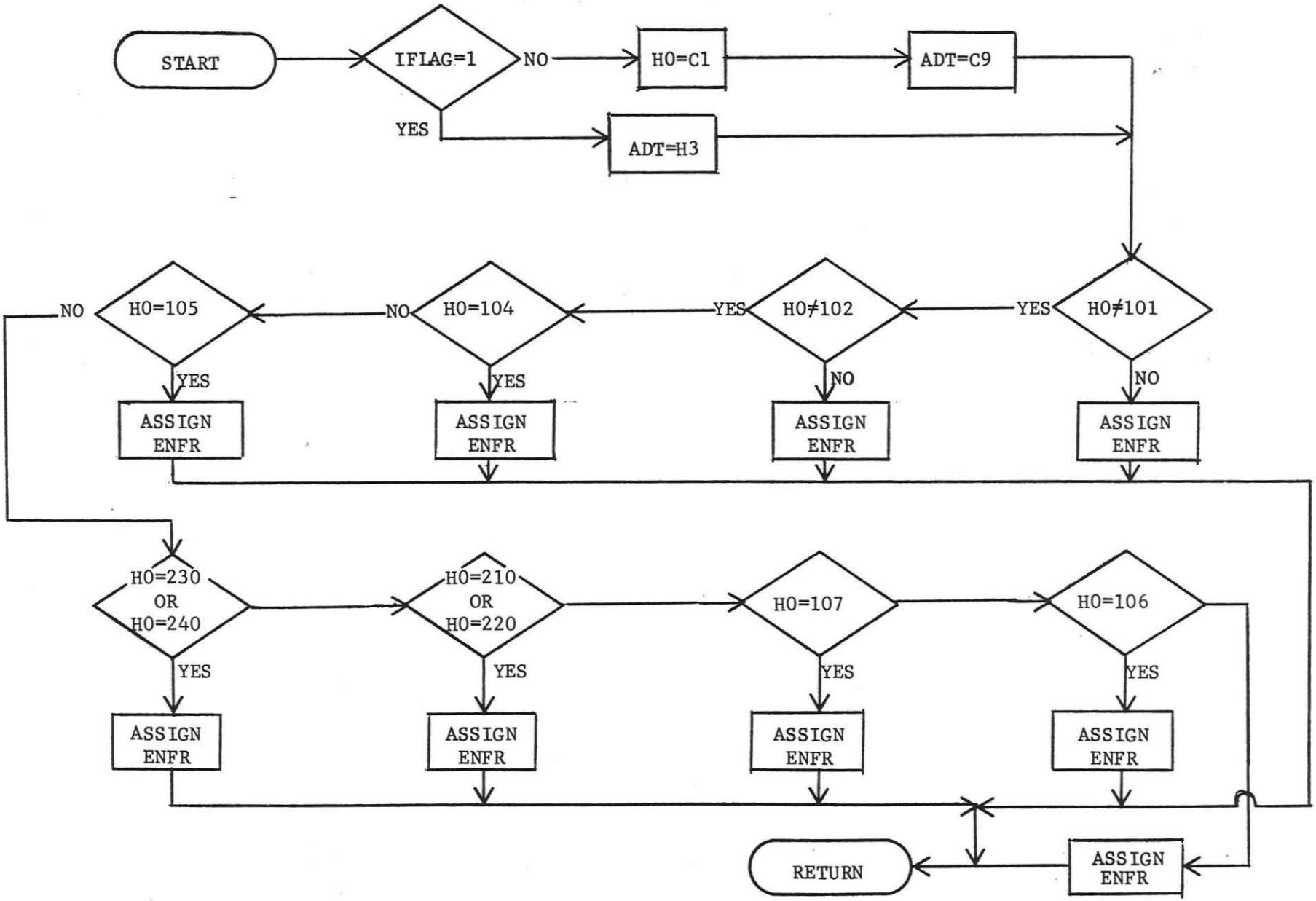


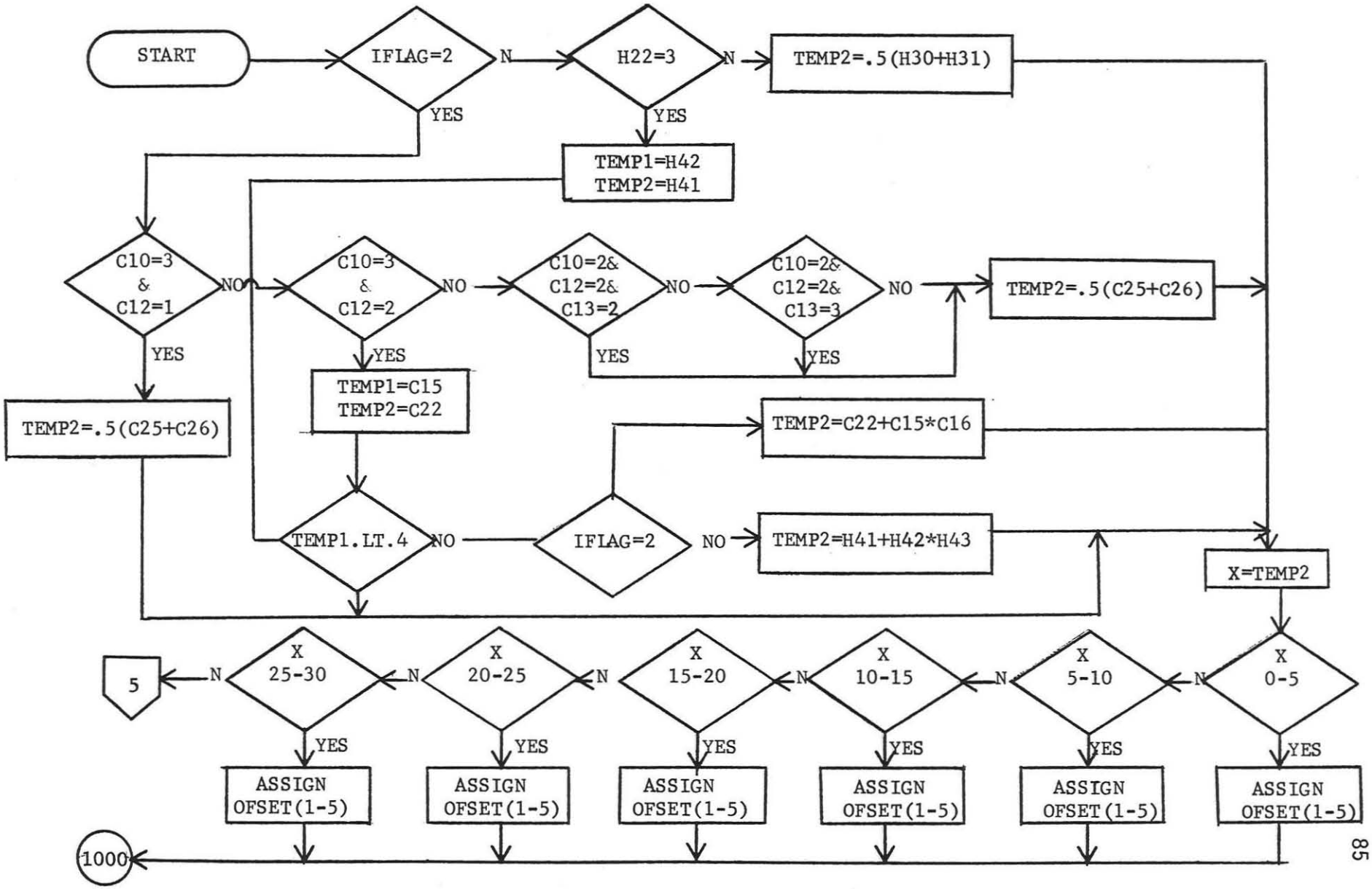

START
NCOUNT=0
N=NTITLE
M=NTITLE-1
NDES(N)=NDES(M)&
NHWY(N)=NHWY(M)&
NSPD(N)=NSPD(M)&
NADT(N)=NADT(M)
YES
12
NO
WRITE IPAGE & 400 FRMT
C60=1
N
C60=2
N
C60=3
N
C60=4
N
C60=5
YES
WRITE C61 900 FRMT
WRITE C61 901 FRMT
WRITE C61 902 FRMT
WRITE C61 903 FRMT
WRITE C61 904 FRMT
C62=4
NO
C62=3
NO
C62=2
NO
C62=1
YES
WRITE C63 913 FRMT
WRITE C63 912 FRMT
WRITE C63 911 FRMT
WRITE C63 900 FRMT
INT=INT*100
WRITE C3, C9,H50,H51 H52,LIFE, INT
INT=INT/100. IPAGE=IPAGE+1
LINES=0
NCOUNT=NCOUNT+1
WRITE IPAGE (404 FRMT) & 406 FRMT
3

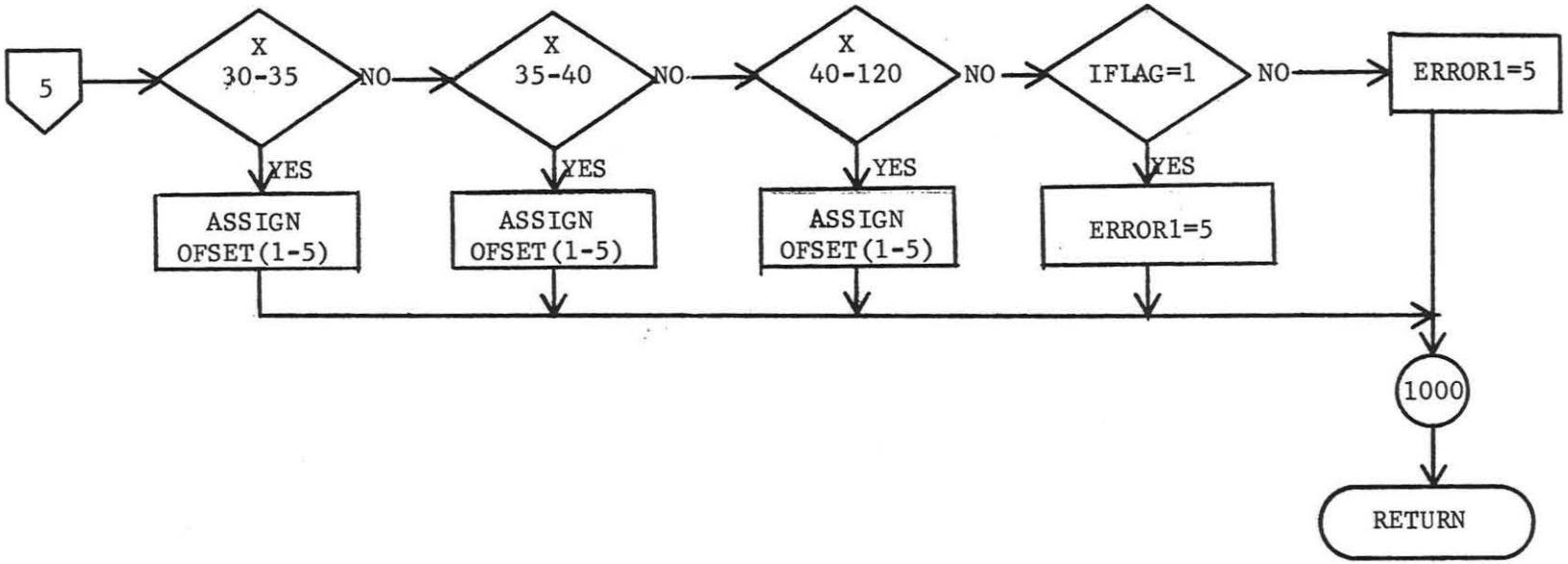

3
12
MES=0
K=0
DO 200 JJ=1,J
DO 200 II=1,I
L=II
M=JJ
ERROR1.GT.0
N
YES
K=K+1
N
K=1
YES
WRITE
"GROUP"
N
200
WRITE
ERROR #
K=K+1
K=1
NO
MES=MES+1
200
YES
90
NOTCE(M)=1
YES
N
MES.GE.1
YES
NO
WRITE
C/E & B/C
VALUES
LINES=LINES+1
LINES.GE.45
Y
NO
WRITE IPAGE
406 FRMT
90
LINES=0
WRITE
"NOT C/E"
LINES=LINES+1
LINES.GE.45
Y
NO
WRITE IPAGE
406 FRMT
LINES=0
90
90
WRITE
"END GROUP"
LINES=LINES+1
LINES.GE.45
Y
NO
WRITE IPAGE
406 FRMT
LINES=0
4
90


4
90
K=0
MES=0
WRITE
600 FRMT
200
WRITE
602 FRMT
IGR=1
N
WRITE
604 FRMT
RETURN
YES

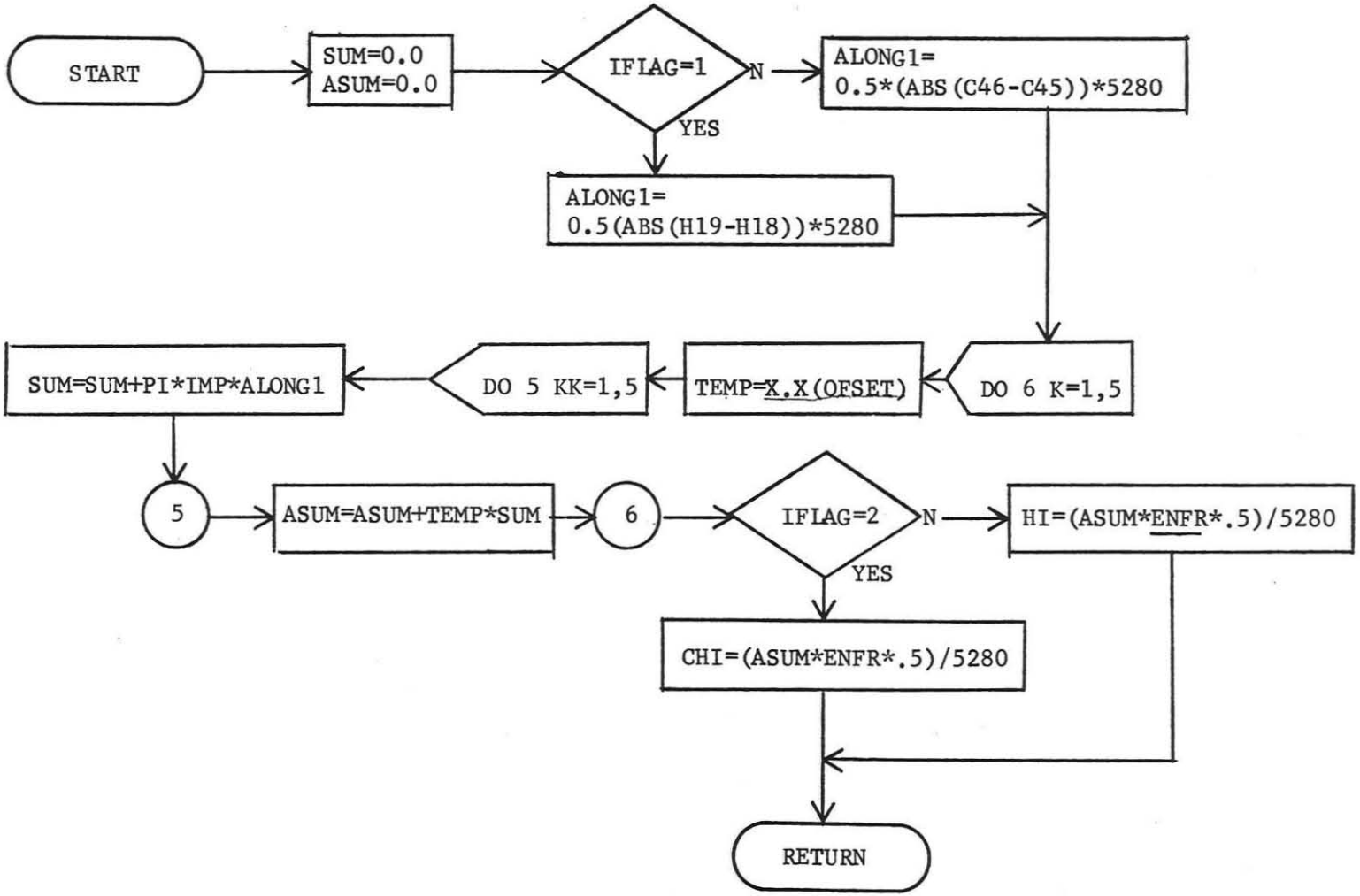
SUBROUTINE FREQ



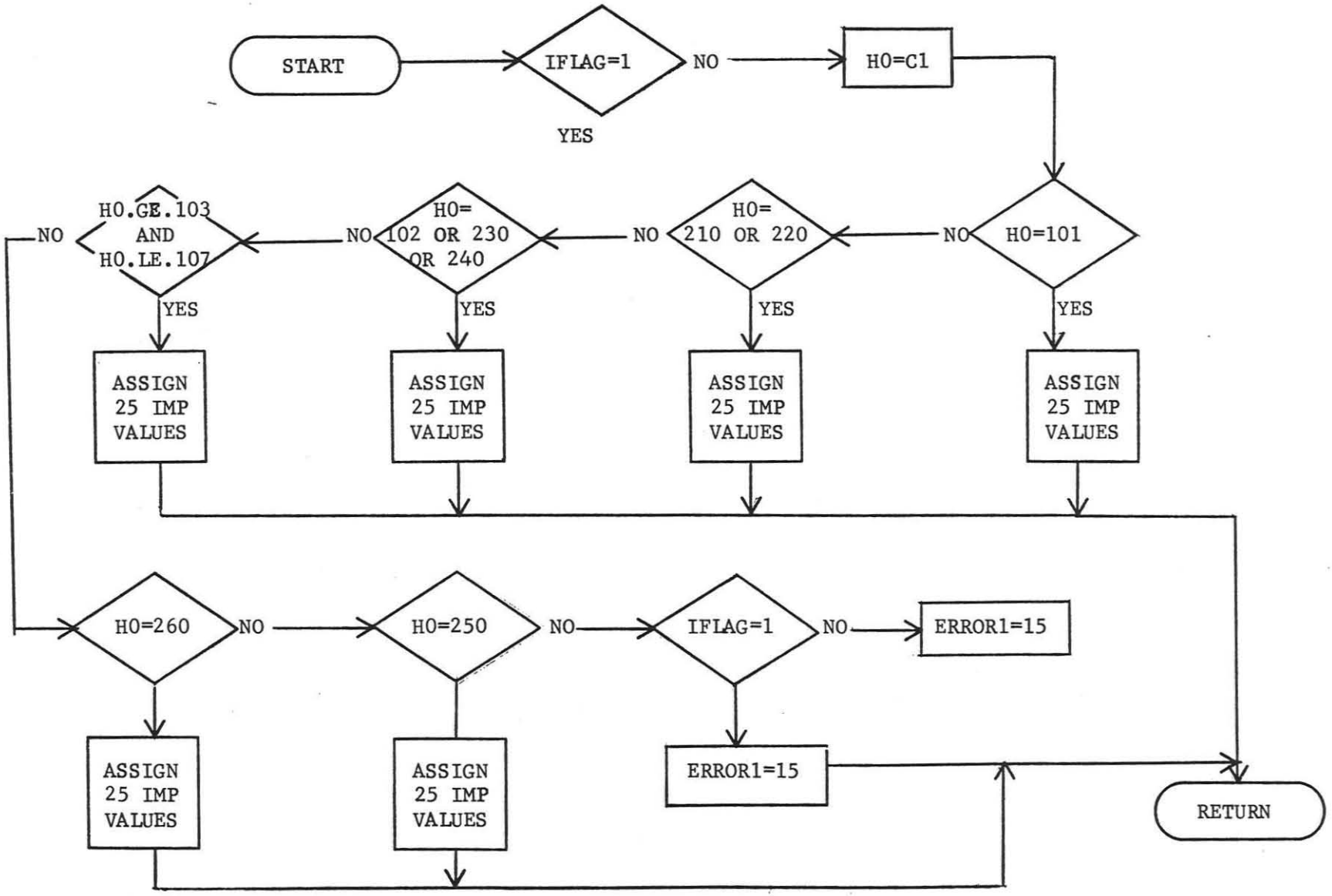

START
IFLAG=2
N
H22=3
N
TEMP2=.5(H30+H31)
YES
YES
TEMP1=H42
TEMP2=H41
C10=3 & C12=1
NO
C10=3 & C12=2
NO
C10=2& C12=2& C13=2
NO
C10=2& C12=2& C13=3
NO
TEMP2=.5(C25+C26)
YES
YES
YES
YES
TEMP1=C15
TEMP2=C22
TEMP2=.5(C25+C26)
TEMP2=C22+C15*C16
TEMP1.LT.4
NO
IFLAG=2
NO
TEMP2=H41+H42*H43
X=TEMP2
5
N
X 25-30
N
X 20-25
N
X 15-20
N
X 10-15
N
X 5-10
N
X 0-5
YES
YES
YES
YES
YES
YES
ASSIGN OFSET(1-5)
ASSIGN OFSET(1-5)
ASSIGN OFSET(1-5)
ASSIGN OFSET(1-5)
ASSIGN OFSET(1-5)
ASSIGN OFSET(1-5)
1000


5
X
30-35
NO
X
35-40
NO
X
40-120
NO
IFLAG=1
NO
ERROR1=5
YES
YES
YES
YES
ASSIGN
OFSET(1-5)
ASSIGN
OFSET(1-5)
ASSIGN
OFSET(1-5)
ERROR1=5
1000
RETURN

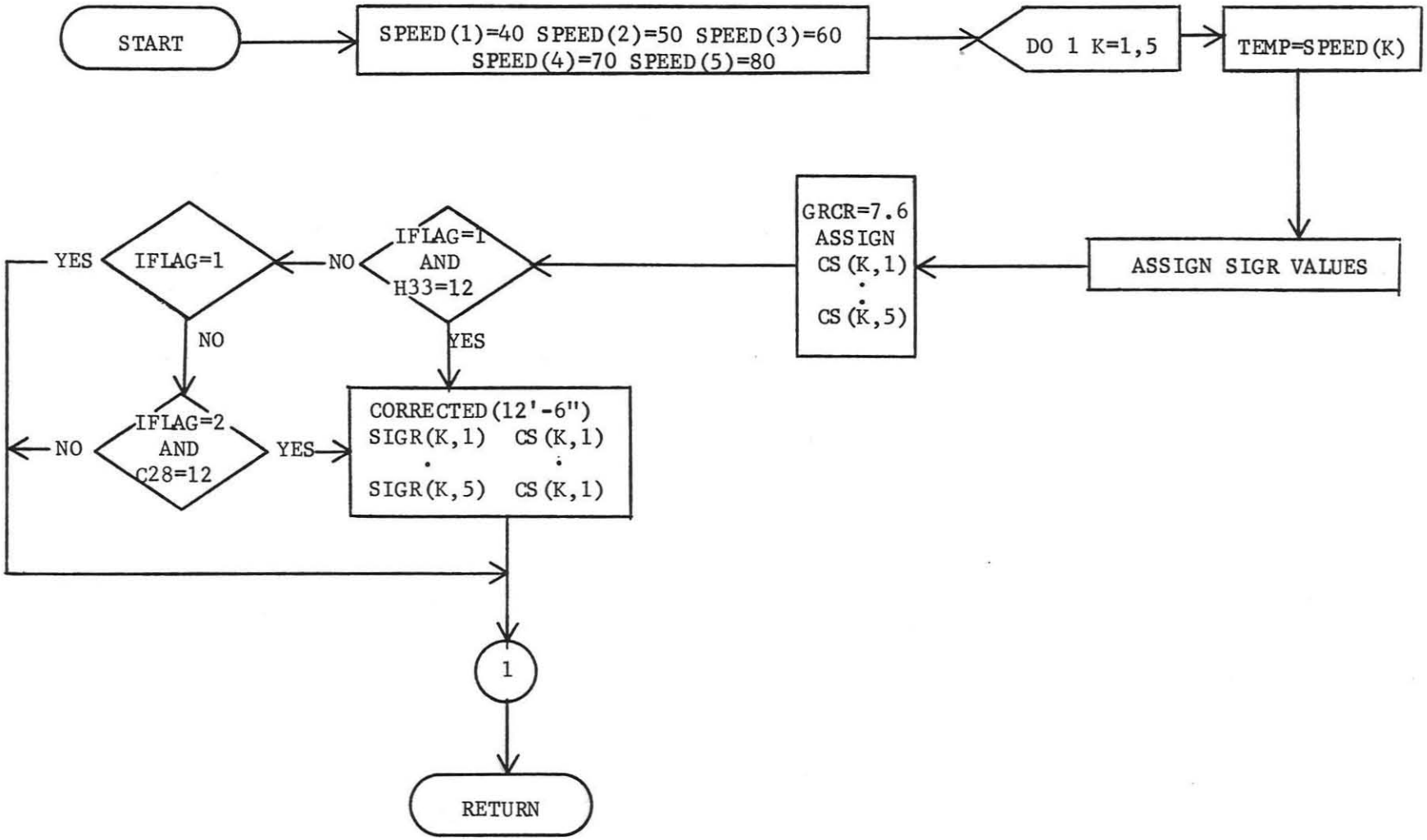
SUBROUTINE HINDEX



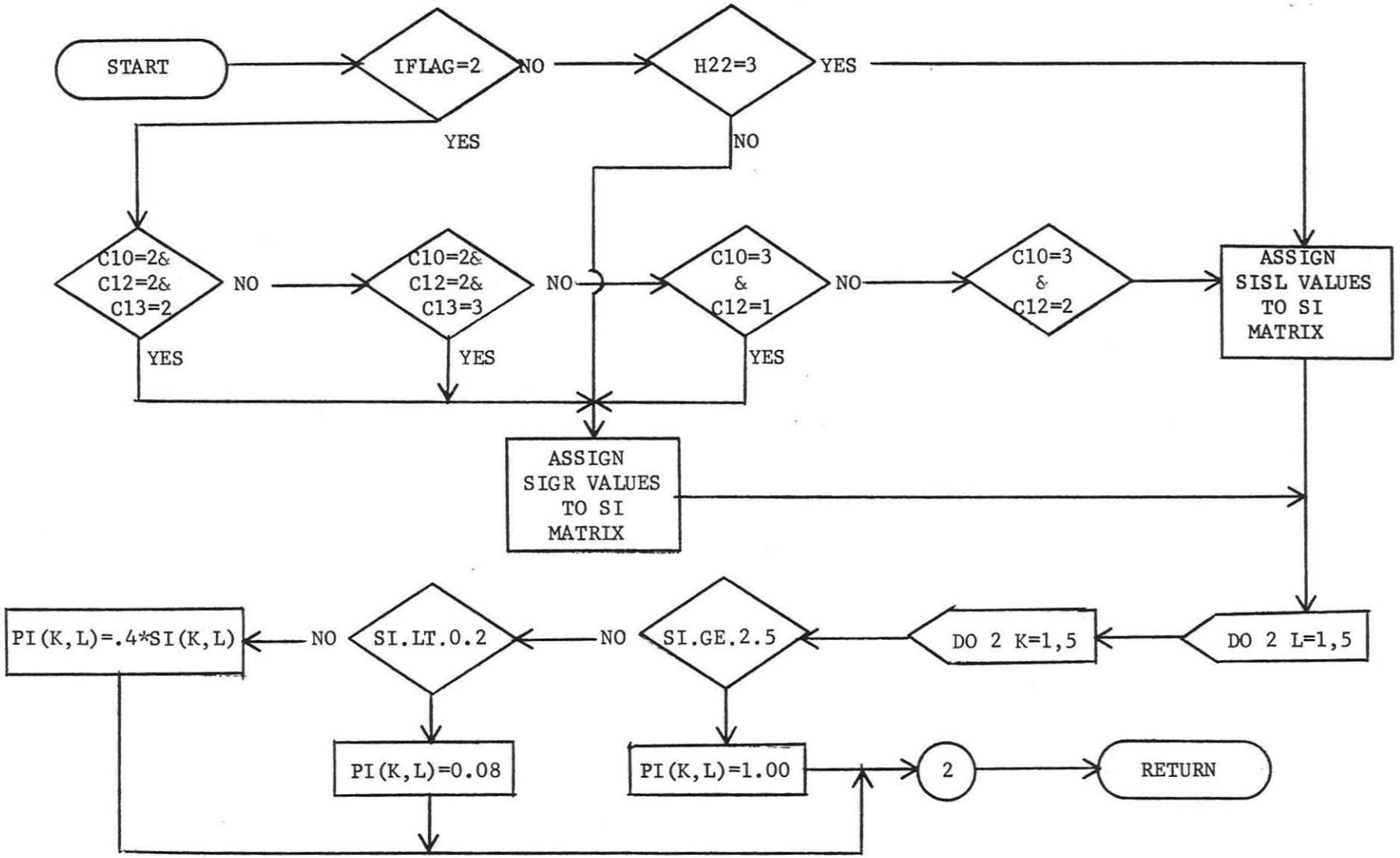
SUBROUTINE PROB2



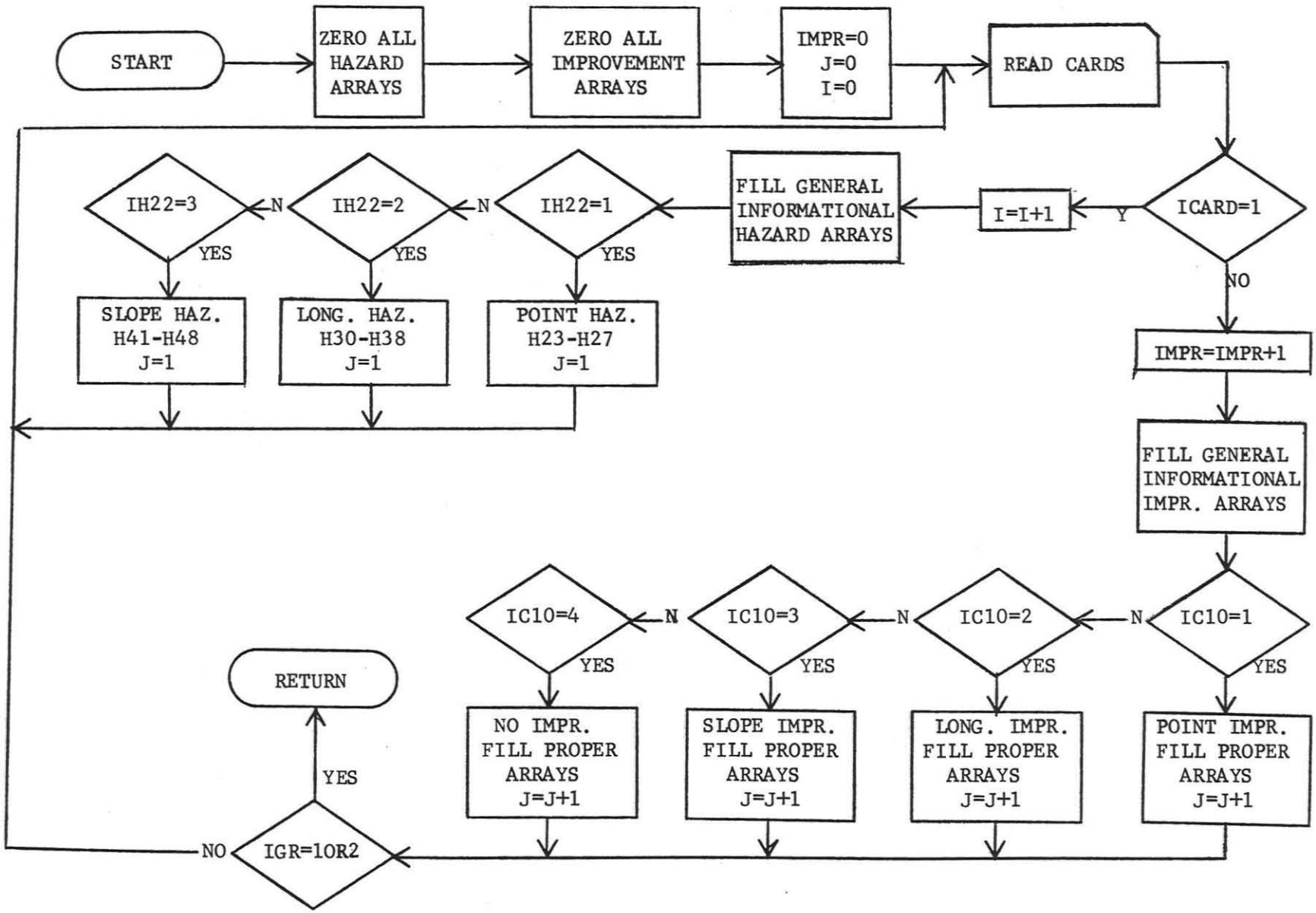
SUBROUTINE WBEAM



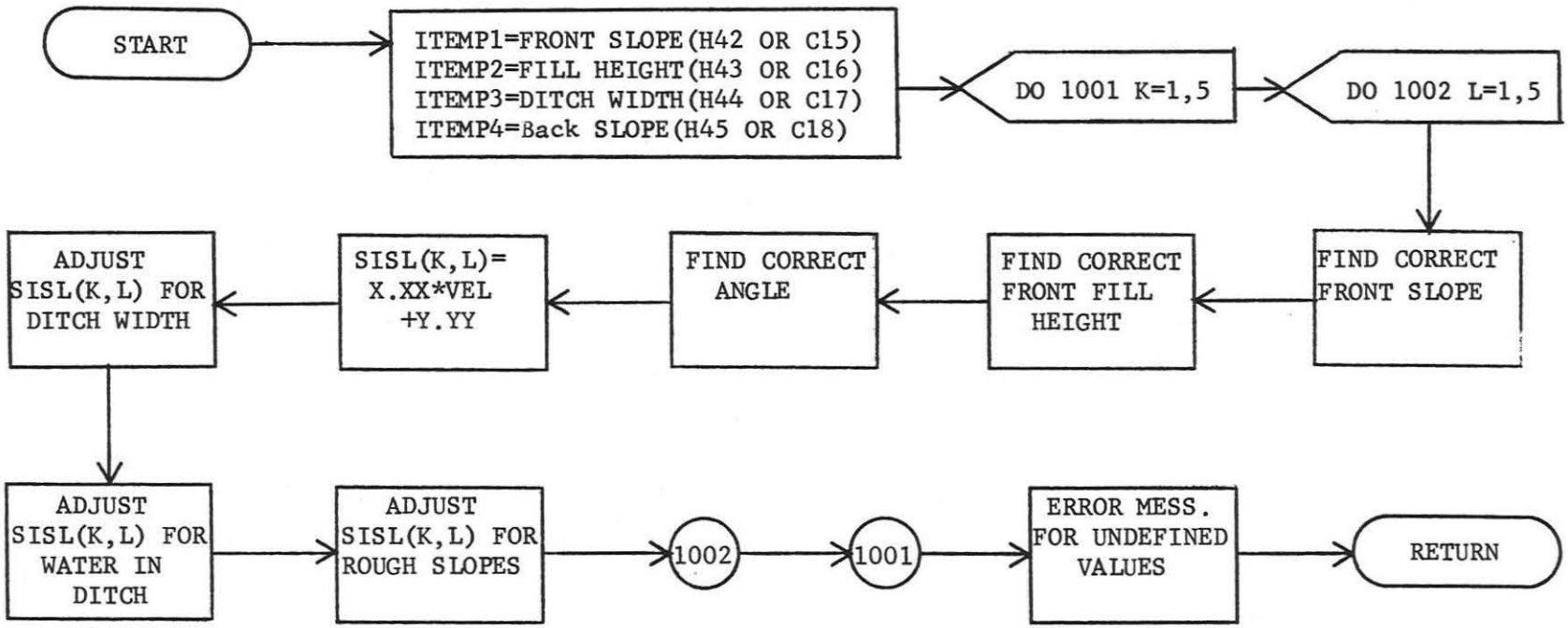
SUBROUTINE PROB3



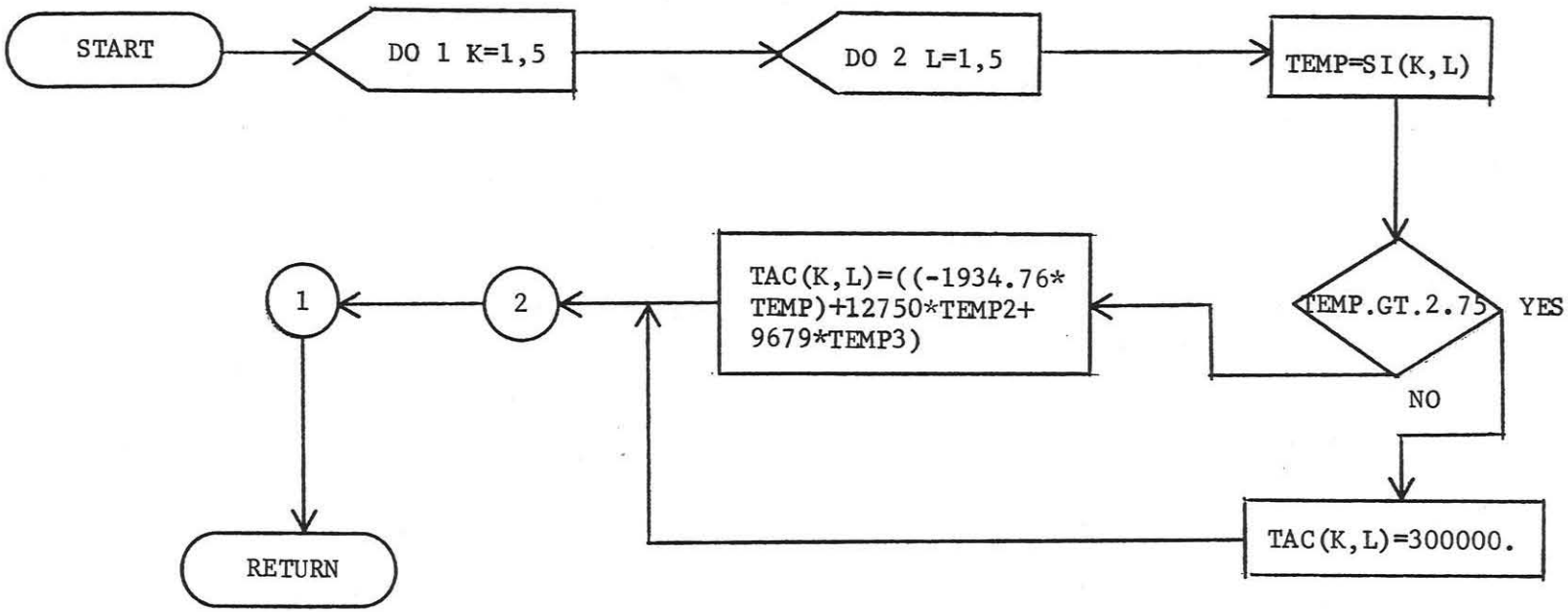
SUBROUTINE DATA



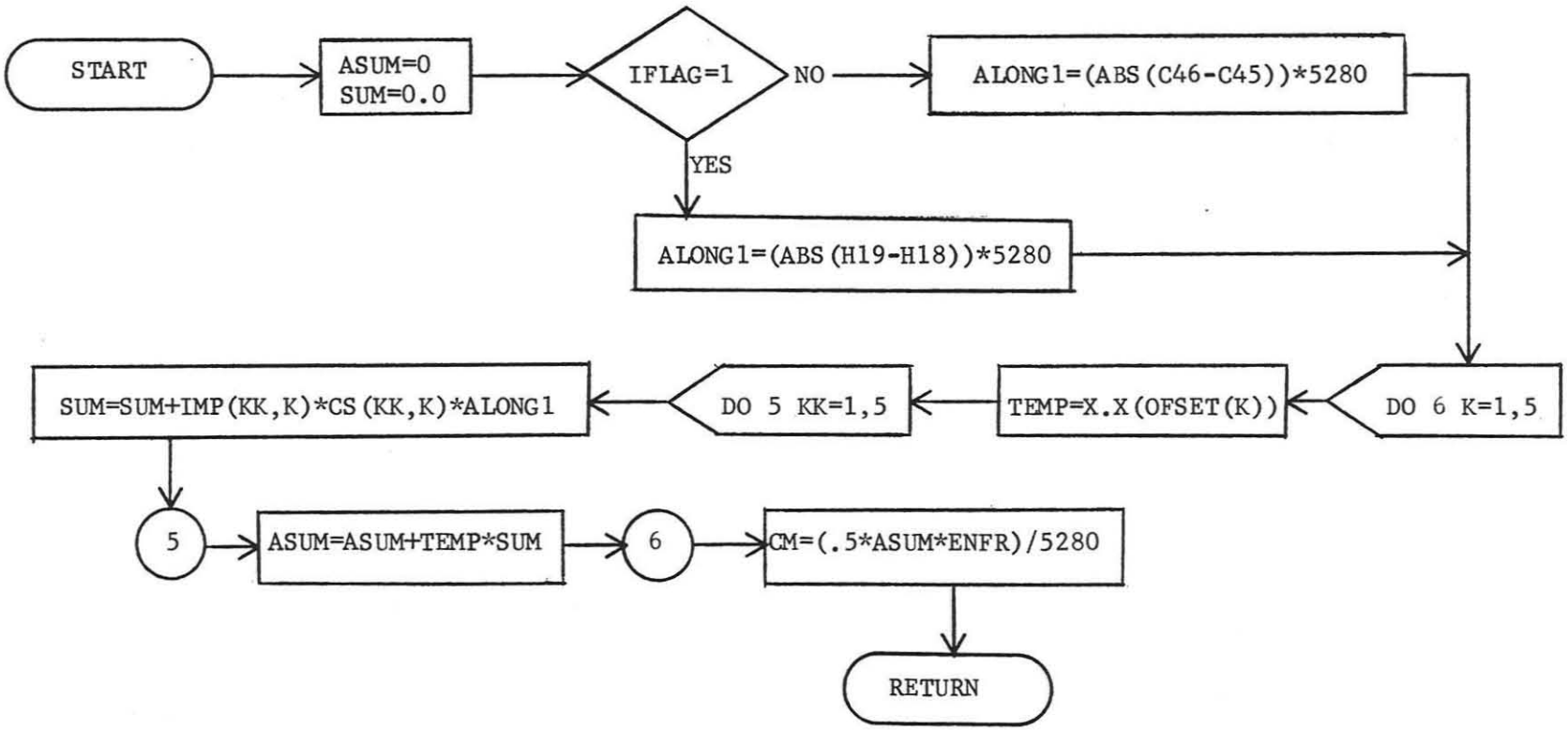
SUBROUTINE SLOPE



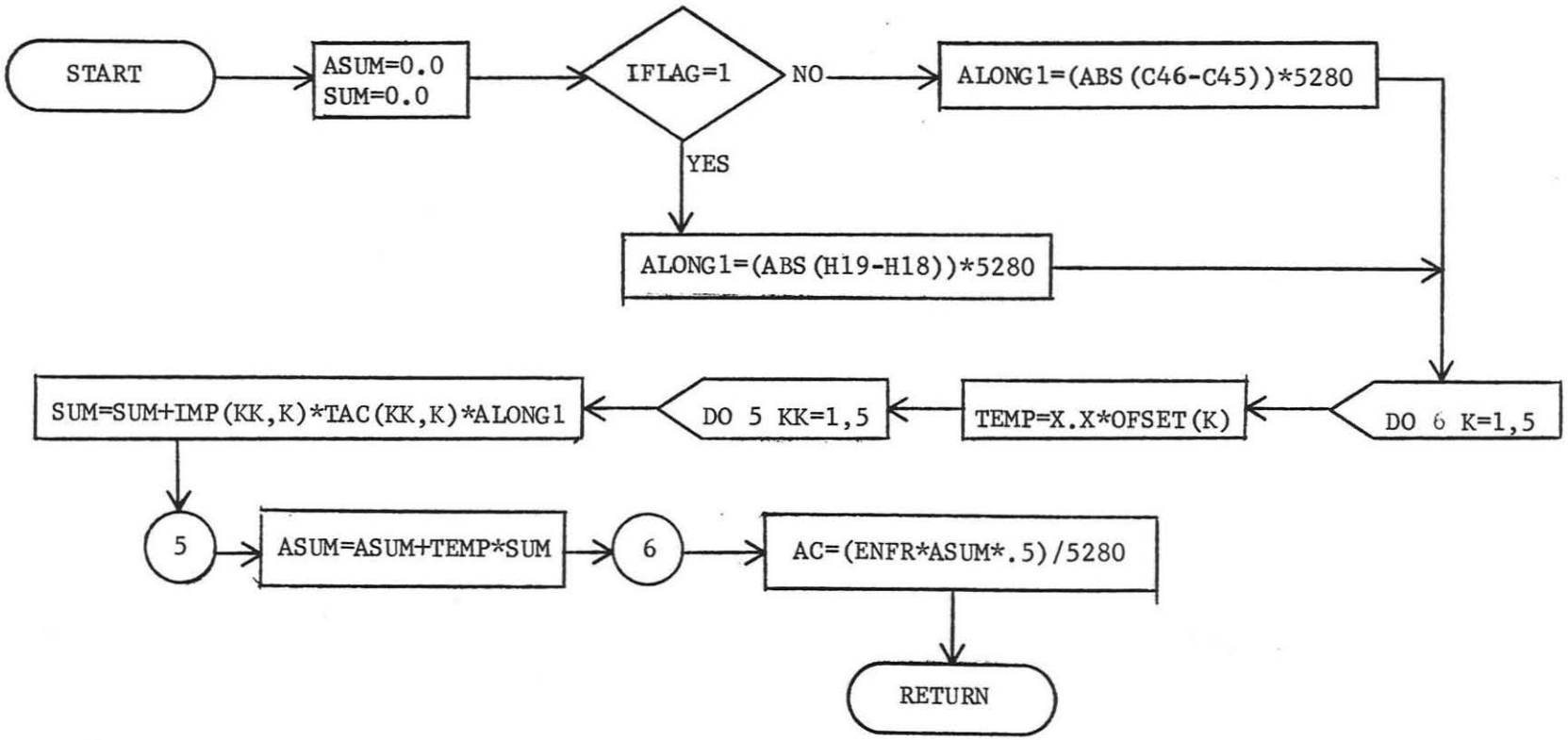
SUBROUTINE COST3



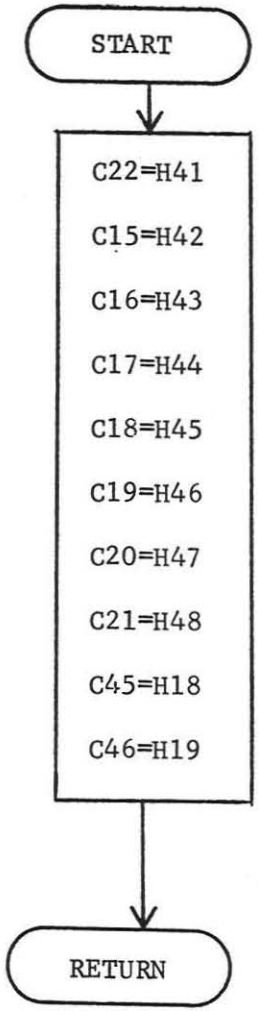
SUBROUTINE REPAIR



SUBROUTINE ACCID



SUBROUTINE NOIMPR



A P P E N D I X

B. COMPUTER PROGRAM SOURCE LISTING

```
$JOB            TIME=300
C
C*****************************************************************
C*****************************************************************
C*                  GUARDRAIL UTILIZATION: A COST-EFFECTIVENESS
C*
C*                        COMPUTER PROGRAM TO ANALYZE
C*
C*                    W-BEAM GUARDRAIL FOR USE ON FILL SLOPES
C*
C*                  A COOPERATIVE RESEARCH PROJECT BY THE NEBRASKA
C*                    DEPARTMENT OF ROADS AND THE UNIVERSITY OF
C*                     NEBRASKA, CIVIL ENGINEERING DEPARTMENT
C*****************************************************************
C*****************************************************************
C
C ***************************************************************
C
C MAIN PROGRAM
C
C ***************************************************************
C
 1        DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
         *          ERROR1(3,4),CS(5,5),IZERO(4)
 2        DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
 3        DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
 4        DIMENSION OFSET(5)
 5        DIMENSION SIGR(5,5)
 6        DIMENSION PI(5,5)
 7        DIMENSION   H0(3), H1(3), H2(3), H3(3), H4(3),H5(3),H6(3),
         *            H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
         *           H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
         *           H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
         *           H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
         *           H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
         *           H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
         *           H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
         *           H63(3)
 8        DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
         *            C6(3,4),  C7(3,4),  C8(3,4),  C9(3,4), C10(3,4),
         *           C12(3,4), C13(3,4), C14(3,4), C15(3,4), C16(3,4),
         *           C17(3,4), C18(3,4), C19(3,4), C20(3,4), C21(3,4),
         *           C25(3,4), C26(3,4), C27(3,4), C28(3,4), C29(3,4),
         *           C30(3,4), C31(3,4), C32(3,4), C33(3,4), C40(3,4),
         *           C41(3,4), C42(3,4), C45(3,4), C46(3,4), C22(3,4),
         *           C60(3,4), C61(3,4), C62(3,4), C63(3,4)
C
 9        DIMENSION IMP(5,5)
10        DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
11        DIMENSION  TAC(5,5), SI(5,5)
12        INTEGER ERROR1
13        INTEGER TEMP1,TEMP2,X
14        INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
         *         H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
         *         H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
         *         H51,H52,H60,H61,H62,H63
C
15        INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
         *         C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
         *         C40,C41,C42,C60,C61,C62,C63,C9
C
```

```
16          INTEGER SPEED,VEL
17          COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
           *                 ACA,RMA,TACIMP,IZERO,LIFE,INT
18          COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
19          COMMON/ CST1/COST1
20          COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
      C
      C
21          COMMON/ ENFRE /ENFR
      C
22          COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
23          COMMON/ LATOF /OFSET
      C
      C
      C
24          COMMON/ IMPROB /IMP
      C
25          COMMON/ GRSI /SIGR
      C
26          COMMON/ HUBT /PI,SI
      C
27          COMMON/ SLOPE1 /SISL
28          COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
           *                H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
           *            H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
           *                H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
29          COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
           *          C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
           *               C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
30          COMMON/ GRCRC / CS
31          COMMON/ ERROR /ERROR1
32          REAL IMP
33          REAL INT,LIFE
34    9999  CONTINUE
      C
      C     SET PROGRAM COUNTERS
      C
35          NTITLE = 0
36          NCOUNT = 0
37          LINES = 0
38          IPAGE = 1
      C
      C     INITIALIZE VARIABLES
      C
39      105 CONTINUE
40          DO 55 L = 1,3
41          HI(L) = 0.0
42          DO 55 K = 1,4
43          CHI(L,K) = 0.0
44     55   CONTINUE
45          DO 50 L=1,4
46          HIA(L)=0.0
47          CMA(L)=0.0
48          ACA(L)=0.0
49          RMA(L)=0.0
50          TACIMP(I)=0.0
```

```
      NOICE(I)=0
      IZERO(L)=0
   50 CONTINUE
      HIB=0.0
      CMB=0.0
      ACB=0.0
      RMB=0.0
      TACHAZ = 0.0
C
      CALL DATA
C
      NTITLE = NTITLE +1
      NDES(NTITLE) = C1(1,1)
      NHWY(NTITLE) = C2(1,1)
      NSPD(NTITLE) = C3(1,1)
      NADT(NTITLE) = C9(1,1)
C
C
C
C     INITIAL GROUP ERROR MESSAGES
C
C
C     I = NUMBER OF HAZARDS IN GROUP
C     J = NUMBER OF IMPROVEMENT ALTERNATIVES FOR GROUP
C
      DO 60 L = 1,I
      DO 60 M = 1,J
      ERROR1(I,M) = 0.0
   60 CONTINUE
      CALL MAIN1
      CALL RESULT
      CALL OUTPUT
      IF (IGR .EQ. 2) GO TO 100
      GO TO 105
  100 CONTINUE
C
      STOP
      END
C
C
C
C*****************************************************************************
C*****************************************************************************
C
      SUBROUTINE MAIN1
C
C*****************************************************************************
C
C     THIS IS THE MAIN SUBROUTINE THAT LINKS ALL SUBROUTINES
C
C*****************************************************************************
      DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
     *          ERROR1(3,4),CS(5,5),IZERO(4)
      DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
      DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
      DIMENSION OFSET(5)
      DIMENSION SIGR(5,5)
      DIMENSION PI(5,5)
      DIMENSION  H0(3),H1(3),H2(3), H3(3),H4(3),  H5(3),  H6(3),
     *           H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
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     *           H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
     *           H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
     *           H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
     *           H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
     *           H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
     *           H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
     *           H63(3)
 85       DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
     *           C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
     *           C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
     *           C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
     *           C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
     *           C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
     *           C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
     *           C61(3,4), C62(3,4), C63(3,4)
      C
 86       DIMENSION IMP(5,5)
 87       DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
 88       DIMENSION  TAC(5,5), SI(5,5)
 89       INTEGER ERROR1
 90       INTEGER TEMP1,TEMP2,X
 91       INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
     *           H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
     *           H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
     *           H51,H52,H60,H61,H62,H63
      C
 92       INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
     *           C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
     *           C40,C41,C42,C60,C61,C62,C63,C9
      C
 93       INTEGER SPEED,VEL
 94       COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
     *                    ACA,RMA,TACIMP,IZERO,LIFE,INT
 95       COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
 96       COMMON/ CST1/COST1
 97       COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
      C
      C
 98       COMMON/ ENFRE /ENFR
      C
 99       COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
100       COMMON/ LATOF /OFSET
      C
      C
      C
101       COMMON/ IMPROB /IMP
      C
102       COMMON/ GRSI /SIGR
      C
103       COMMON/ HUET /PI,SI
      C
104       COMMON/ SLOPE1 /SISL
105       COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
     *                 H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
     *                 H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
     *                 H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
106       COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
```

```
     *          C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
     *             C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
      COMMON/ GRCRC / CS
      COMMON/ ERROR /ERROR1
      REAL IMP
      C     OUTER DO-LOOP
 9999 CONTINUE
      DO 100 II=1,I
      C
      IFLAG = 1
      IF(II .EQ. 2) GO TO 10
      IF( H22(II) .EQ. 3) GO TO 12
      IF(H22(II).EQ.2.AND.H14(II).EQ.6.AND.H15(II).EQ.6) GO TO 14
      C
      ERROR1(II,1) = 10
      C
      C     ERROR = 10 ... PROGRAM VALID ONLY FOR SLOPE AND GUARDRAIL
      C     (W-BEAM ON STRONG POSTS) TYPE HAZARDS.
      C
      GO TO 10
   12 CONTINUE
      C
      CALL SLOPE
      GO TO 16
   14 CONTINUE
      CALL WBEAM
   16 CONTINUE
      CALL PROB3
      CALL COST3
      CALL PROB2
      CALL PROB1
      CALL PFREQ
      CALL HINDEX
      HIB = HIB + HI(II)
      IF(H22(II) .EQ. 3) GO TO 200
      CALL REPAIR
      CMB = CMB + CM
  200 CONTINUE
      CALL ACCID
      ACB = ACB + AC
      C
      RMB = RMB + C7(II,1)
      TACHAZ = TACHAZ + CMB + RMB
      C
   10 CONTINUE
      C     INNER DO-LOOP
      C
      DO 100 JJ=1,J
      C
      IFLAG = 2
      IF(C10(II,JJ) .EQ. 4) GO TO 20
      IF(C10(II,JJ) .EQ. 3 .AND. C12(II,JJ) .EQ. 2) GO TO 22
      IF(C10(II,JJ) .EQ. 2 .AND. C12(II,JJ).EQ. 2) GO TO 24
      IF(C10(II,JJ) .EQ. 3 .AND. C12(II,JJ) .EQ. 1) GO TO 26
      C
      ERROR1(II,JJ) = 10
      GO TO 101
   24 CONTINUE
      IF(C13(II,JJ) .EQ. 1) GO TO 28
      IF(C13(II,JJ) .EQ. 2 .OR. C13(II,JJ) .EQ. 3) GO TO 26
```

```
151           ERROR1(II,JJ) = 10
152           GO TO 101
153      20   CONTINUE
154           IF(II .EQ. 2) GO TO 21
155           GO TO 29
156      21   CONTINUE
157           N = II-1
158           IF(C13(N,JJ) .EQ. 1) GO TO 29
159           GO TO 28
160      29   CONTINUE
161           CALL NOIMPR
162      22   CONTINUE
163           CALL SLOPE
164           GO TO 40
165        26 CONTINUE
166           CALL WEEAM
167           C22(II,JJ) = (C25(II,JJ)+C26(II,JJ))/2.0
168           GO TO 40
169      28   CONTINUE
         C
         C     REMOVE HAZARD
         C
170           CHI(II,JJ) = 0.0
171           CMA(JJ) = 0.0
172           RMA(JJ) = 0.0
173           ACA(JJ) = 0.0
174           C22(II,JJ) = H41(II+1)
175           GO TO 50
176      40   CONTINUE
177           CALL PROB3
178           CALL COST3
179           CALL PROB2
180           CALL PROB1
181           CALL FREQ
182           CALL HINDEX
183           HIA(JJ) = HIA(JJ) + CHI(II,JJ)
184           IF(C10(II,JJ) .EQ.3 .AND. C12(II,JJ) .EQ. 2) GO TO 201
185           CALL REPAIR
186           CMA(JJ) = CMA(JJ) + CM
187      201  CONTINUE
188           CALL ACCID
189           ACA(JJ) = ACA(JJ) + AC
         C
190           RMA(JJ) = RMA(JJ) + C8(II,JJ)
191      50   CONTINUE
192           CALL IMPCST
193           TACIMP(JJ) = TACIMP(JJ)+COST1(JJ)+CMA(JJ)+RMA(JJ)
         C
         C     THIS IS THE END OF OUTER AND INNER DO-LOOPS
194       101 CONTINUE
195       100 CONTINUE
         C
         C
196      9998 RETURN
197           END
         C
         C
         C
         C
         C
         C
```

```
      C
      C
      C
      C  ***************************************************************
      C
  198         SUBROUTINE RESULT
      C
      C  ***************************************************************
      C
      C  SUBROUTINE CALCULATES COST-EFFECTIVENESS VALUES AND BENIFIT-COST RATI
      C
      C
  199          DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
     *              ERROR1(3,4),CS(5,5),IZERO(4)
  200          DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
  201          DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
  202          DIMENSION OFSET(5)
  203          DIMENSION SIGR(5,5)
  204          DIMENSION PI(5,5)
  205          DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
     *              H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
     *             H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
     *             H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
     *             H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
     *             H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
     *             H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
     *             H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
     *             H63(3)
  206          DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
     *             C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
     *             C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
     *             C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
     *             C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
     *             C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
     *             C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
     *             C61(3,4), C62(3,4), C63(3,4)
      C
  207          DIMENSION IMP(5,5)
  208          DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
  209          DIMENSION  TAC(5,5), SI(5,5)
  210          INTEGER ERROR1
  211          INTEGER TEMP1,TEMP2,X
  212          INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
     *             H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
     *             H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
     *             H51,H52,H60,H61,H62,H63
      C
  213          INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
     *             C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
     *             C40,C41,C42,C60,C61,C62,C63,C9
      C
  214          INTEGER SPEED,VEL
  215          COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
     *                    ACA,RMA,TACIMP,IZERO,LIFE,INT
  216          COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
  217          COMMON/ CST1/COST1
  218          COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
      C
      C
  219          COMMON/ ENFRE /ENFR
```

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      C
220           COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
221           COMMON/ LATOF /OFSET
      C
      C
      C
222           COMMON/ IMPROB /IMP
      C
223           COMMON/ GRSI /SIGR
      C
224           COMMON/ HURT /PI,SI
      C
225           COMMON/ SLOPE1 /SISL
226           COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
     *                       H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
     *                       H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
     *                       H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
227           COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
     *                  C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
     *                      C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
228           COMMON/ GRCRC / CS
229           COMMON/ ERROR /ERROR1
230           REAL IMP
231           REAL KZERO
232           REAL INT,LIFE
      C
      C
233     9999  CONTINUE
      C
      C
234           DO 100 JJ=1,J
235           EFFECT = HIB - HIA(JJ)
236           KZERO = 2.718**(-1*(ABS(EFFECT)*LIFE))*100.
237           IZERO(JJ) = KZERO
238           IF( HIA(JJ) .GE. HIB) GO TO 10
      C       IF( EFFECT .LT. 0.035) GO TO 10
239           TTAC(JJ) = TACIMP(JJ) - TACHAZ
240           ITAC(JJ) = TTAC(JJ)
241           CE(JJ) = TTAC(JJ) / EFFECT
242           ICE(JJ) = CE(JJ)
243           BC(JJ) = (ACB - ACA(JJ)) / (TTAC(JJ))
244           IF( ACA(JJ) .GE. ACB) GO TO 10
245           GO TO 100
246        10 CONTINUE
247           NOTCE(JJ) = 1
      C
      C   NOTICE=1 ... IMPROVEMENT ALTERNATIVE NOT COST-EFFECTIVE
      C
248       100 CONTINUE
      C
249      9998 RETURN
250           END
      C
      C
      C
      C*****************************************************************
```

```
C*****************************************************************
C
251         SUBROUTINE IMPCST
C
C*****************************************************************
C
C       THIS SUBROUTINE COMPUTES ANNUALIZED FIRST COSTS
C
C*****************************************************************
C
252         DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
           *          ERROR1(3,4),CS(5,5),IZERO(4)
253         DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
254         DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
255         DIMENSION OFSET(5)
256         DIMENSION SIGR(5,5)
257         DIMENSION PI(5,5)
258         DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
           *           H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
           *          H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
           *          H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
           *          H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
           *          H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
           *          H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
           *          H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
           *          H63(3)
259         DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
           *          C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
           *          C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
           *          C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
           *          C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
           *          C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
           *          C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
           *          C61(3,4), C62(3,4), C63(3,4)
C
260         DIMENSION IMP(5,5)
261         DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
262         DIMENSION  TAC(5,5), SI(5,5)
263         INTEGER ERROR1
264         INTEGER TEMP1,TEMP2,X
265         INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
           *          H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
           *          H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
           *          H51,H52,H60,H61,H62,H63
C
266         INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
           *          C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
           *          C40,C41,C42,C60,C61,C62,C63,C9
C
267         INTEGER SPEED,VEL
268         COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
           *                 ACA,RMA,TACIMP,IZERO,LIFE,INT
269         COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
270         COMMON/ CST1/COST1
271         COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
C
C
272         COMMON/ ENFRE /ENFR
C
273         COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
```

```
      C
274           COMMON/ LATOF /OFSET
      C
      C
      C
275           COMMON/ IMPROB /IMP
      C
276           COMMON/ GRSI /SIGB
      C
277           COMMON/ HUBT /PI,SI
      C
278           COMMON/ SLOPE1 /SISL
279           COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
             *                H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
             *                H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
             *                H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
280           COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
             *           C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
             *               C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
281           COMMON/ GRCRC / CS
282           COMMON/ ERROR /ERROR1
283           REAL IMP
      C
284           REAL INT,LIFE
      C
285   9999    CONTINUE
286           IF(JJ .GT. 1) GO TO 10
      C       INTEREST RATE (INT)
287           INT = 0.090
      C
      C       LIFE OF PROJECT IN YEARS (LIFE)
288           LIFE = 20.0
      C
289           T1 = (1.0 + INT)**LIFE
290           T2 = T1 * INT
291           T3 = T1 - 1.0
      C
      C       CAPITAL RECOVERY FACTOR (CRF)
      C
292           CRF = T2/T3
      C
293    10     CONTINUE
294           COST1(JJ) = C4(II,JJ) * CRF
      C
295    9998   RETURN
296           END
      C
      C
      C
      C ***************************************************************************
      C
297           SUBROUTINE OUTPUT
      C
      C ***************************************************************************
      C
      C  SUBROUTINE PRINTS OUTPUT
```

```
298         DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
           *          ERROR1(3,4),CS(5,5),IZERO(4)
299         DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
300         DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
301         DIMENSION OFSET(5)
302         DIMENSION SIGR(5,5)
303         DIMENSION PI(5,5)
304         DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
           *           H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
           *          H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
           *          H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
           *          H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
           *          H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
           *          H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
           *          H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
           *          H63(3)
305         DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
           *           C6(3,4),  C7(3,4),  C8(3,4), C9(3,4), C10(3,4),
           *          C12(3,4), C13(3,4), C14(3,4), C15(3,4), C16(3,4),
           *          C17(3,4), C18(3,4), C19(3,4), C20(3,4), C21(3,4),
           *          C25(3,4), C26(3,4), C27(3,4), C28(3,4), C29(3,4),
           *          C30(3,4), C31(3,4), C32(3,4), C33(3,4), C40(3,4),
           *          C41(3,4), C42(3,4), C45(3,4), C46(3,4), C22(3,4),
           *          C60(3,4), C61(3,4), C62(3,4), C63(3,4)
    C
306         DIMENSION IMP(5,5)
307         DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
308         DIMENSION  TAC(5,5), SI(5,5)
309         INTEGER ERROR1
310         INTEGER TEMP1,TEMP2,X
311         INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
           *         H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
           *         H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
           *         H51,H52,H60,H61,H62,H63
    C
312         INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
           *         C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
           *         C40,C41,C42,C60,C61,C62,C63,C9
    C
313         INTEGER SPEED,VEL
314         COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
           *                 ACA,RMA,TACIMP,IZERO,LIFE,INT
315         COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
316         COMMON/ CST1/COST1
317         COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
    C
    C
318         COMMON/ ENFRE /ENFR
    C
319         COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
    C
320         COMMON/ LAIOF /OFSET
    C
    C
    C
321         COMMON/ IMPROB /IMP
    C
322         COMMON/ GRSI /SIGR
    C
323         COMMON/ HURT /PI,SI
    C
```

```
      COMMON/ SLOPE1 /SISL
      COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
     *               H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
     *               H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
     *               H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
C
C
C
      COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
     *          C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
     *              C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      COMMON/ GRCRC / CS
      COMMON/ ERROR /ERROR1
      REAL INT,LIFE
      REAL IMP
 9999 CONTINUE
      IF(NCOUNT .EQ. 0) GO TO 10
C
C
      N = NTITLE
      M = NTITLE-1
      IF(NDES(N) .EQ. NDES(M) .AND. NHWY(N) .EQ. NHWY(M) .AND.
     *NSPD(N) .EQ. NSPD(M) .AND. NADT(N) .EQ. NADT(M)) GO TO 12
C
   10 CONTINUE
      WRITE(6,398) IPAGE
      WRITE(6,400)
C
      IF (C60(1,1).EQ.1) GO TO 800
      IF (C60(1,1).EQ.2) GO TO 801
      IF (C60(1,1).EQ.3) GO TO 802
      IF (C60(1,1).EQ.4) GO TO 803
      IF (C60(1,1).EQ.5) GO TO 804
C
  800 CONTINUE
      WRITE(6,900) C61(1,1)
      GO TO 905
  801 CONTINUE
      WRITE(6,901) C61(1,1)
      GO TO 905
  802 CONTINUE
      WRITE(6,902) C61(1,1)
      GO TO 905
  803 CONTINUE
      WRITE(6,903) C61(1,1)
      GO TO 905
  804 CONTINUE
      WRITE(6,904) C61(1,1)
  905 CONTINUE
      IF (C62(1,1) .EQ. 1) GO TO 810
      IF (C62(1,1) .EQ. 2) GO TO 811
      IF (C62(1,1) .EQ. 3) GO TO 812
      IF (C62(1,1) .EQ. 4) GO TO 813
  810 CONTINUE
      WRITE(6,910) C63(1,1)
      GO TO 915
  811 CONTINUE
      WRITE(6,911) C63(1,1)
      GO TO 915
  812 CONTINUE
      WRITE(6,912) C63(1,1)
```

```
371          GO TO 915
372      813 CONTINUE
373          WRITE(6,913) C63(1,1)
374      915 CONTINUE
375          INT = INT*100.0
376          WRITE(6,815) C3(1,1), C9(1,1), LIFE,INT,H50(1),H51(1),
            *H52(1)
377          INT = INT/100.0
378          IPAGE = IPAGE + 1
379          LINES = 0
380          NCOUNT = NCOUNT + 1
381          WRITE(6,404) IPAGE
382          WRITE(6,406)
383       12 CONTINUE
384          MES = 0
385          K = 0
     C
386          DO 200 JJ=1,J
387          DO 200 II=1,I
     C
388          L = II
389          M = JJ
390          IF(ERROR1(L,M) .GT. 0) GO TO 80
391          K = K + 1
392          IF(K .EQ. I) GO TO 60
     C    WRITE "GROUP"
393          WRITE(6,500) H13(L), H17(L), H14(L), H15(L),HI(L),
            *H16(L), H18(L), H19(L), M, C10(L,M), C12(L,M), C13(L,M),
            *CHI(L,M), C22(L,M), C4(L,M)
394          GO TO 200
395       80 CONTINUE
     C    WRITE "ERROR MESSAGE NUMBER"
396          WRITE(6,502) H13(L), H17(L), H14(L), H15(L),HI(L),
            *H16(L), H18(L), H19(L), M, C10(L,M), C12(L,M), C13(L,M),
            *CHI(L,M), C22(L,M), C4(L,M), ERROR1(L,M)
397          K = K + 1
398          IF(K .EQ. I) GO TO 90
399          MES = MES + 1
400          GO TO 200
     C
401       60 CONTINUE
402          IF( NOTCE(M) .EQ. 1) GO TO 70
403          IF( MES .GE. 1) GO TO 85
     C    WRITE "COST-EFFECTIVENESS VALUE" AND "BENEFIT-COST RATIO"
404          WRITE(6,504) H13(L), H17(L), H14(L), H15(L), HI(L),
            *H16(L), H18(L), H19(L), M, C10(L,M), C12(L,M), C13(L,M),
            *CHI(L,M), C22(L,M), C4(L,M), ITAC(M), ICE(M), IZERO(M),BC(M)
     C
     C    LINE COUNTER
     C
405          LINES = LINES + 1
406          IF( LINES .GE. 45) GO TO 92
407          GO TO 90
408       92 CONTINUE
409          WRITE(6,404)IPAGE
410          WRITE(6,406)
411          LINES = 0
412          GO TO 90
413       70 CONTINUE
     C    WRITE "NOT COST-EFFECTIVE"
414          WRITE(6,506) H13(L), H17(L), H14(L), H15(L), HI(L),
```

```
     *H16(L), H18(L), H19(L), M, C10(L,M), C12(L,M), C13(L,M),
     *CHI(L,M), C22(L,M), C4(L,M)
C
C  LINE COUNTER
C
415       LINES = LINES + 1
416       IF( LINES .GE. 45) GO TO 93
417       GO TO 90
418    93 CONTINUE
419       WRITE(6,404) IPAGE
420       WRITE(6,406)
421       LINES = 0
422       GO TO 90
C
423    85 CONTINUE
C  WRITE "END GROUP"
424       WRITE(6,508) H13(L), H17(L), H14(L), H15(L),HI(L),
     *H16(L), H18(L), H19(L), M, C10(L,M), C12(L,M), C13(L,M),
     *CHI(L,M), C22(L,M), C4(L,M)
C
C  LINE COUNTER
C
425       LINES = LINES + 1
426       IF( LINES .GE. 45) GO TO 94
427       GO TO 90
428    94 CONTINUE
429       WRITE(6,404) IPAGE
430       WRITE(6,406)
431       LINES = 0
432    90 CONTINUE
433       K = 0
434       MES = 0
435       WRITE(6,600)
436   200 CONTINUE
437       WRITE(6,602)
C
438       IF (IGR .EQ. 1) GO TO 300
439       WRITE(6,604)
440   300 CONTINUE
C
C **** FORMAT STATEMENTS ****
C
441   400 FORMAT(      ////////, T42, 'C O S T   E F F E C T I V E N E S S
     * P R O G R A M', ///, T57, 'UNIVERSITY OF NEBRASKA', /, T67,
     * 'AND', /, T54, 'NEBRASKA DEPARTMENT OF ROADS', /////)
C
C
442    404  FORMAT(1H1,/,T122,'PAGE = ',I2,///,T22,'H   A   Z   A   R   D',
     *T78,'I   M   P   R   O   V   E   M   E   N   T',/)
C
C
C
C
443    406  FORMAT(I2,'HAZARD',T9,'GROUP',T15,'IDENT',T21,'DESC',T27,
     *'HAZARD',T35,'SIDE',T42,'MILE-POST',T59,'IMPR',T65,'IMPR',
     *T72,'HAZARD',T81,'CLEAR',T90,'FIRST',T98,'TOTAL',T107,'COST',
     *T117,'ZERO',T125,'BENEFIT',/,T4,'NO',T11,'NO',T16,'CODE',T21,
     *'CODE',T28,'INDEX',T36,'OF',T60,'ALT',T65,'CODE',T73,'INDEX',
     *T80,'RECOVERY',T91,'COST',T98,'ANNUAL',T105,'EFFECTIVE',T115,
     *'ACCIDENT',T126,'COST',/,T35,'ROAD',T41,'BEG',T49,'END',T82,
     *'ZONE',T99,'COST',T107,'VALUE',T115,'REDUCTION',T126,'RATIO',
```

```
     */,T26,'(INJ/YR)',T71,'(INJ/YR)',T82,'(FT)',T89,'($1000)',
     *T98,'($/YR)',T118,'(%)',/)
C
444   500  FORMAT(T3,I4,T10,I3,T17,I2,T22,I2,T25,F8.5,T36,I1,T39,F7.3,
     *T47,F7.3,T61,I1,T65,I1,T66,'-',T67,I1,T68,'-',T69,I1,T71,F8.5,
     *T83,I2,T90,F6.1,T97,'***************GROUP**************')
C
445   502  FORMAT(T3,I4,T10,I3,T17,I2,T22,I2,T25,F8.5,T36,I1,T39,F7.3,
     *T47,F7.3,T61,I1,T65,I1,T66,'-',T67,I1,T68,'-',T69,I1,T71,F8.5,
     *T83,I2,T90,F6.1,T97,'*********ERROR MESSAGE = 'I2,'********')
C
446   504  FORMAT(T3,I4,T10,I3,T17,I2,T22,I2,T25,F8.5,T36,I1,T39,F7.3,
     *T47,F7.3,T61,I1,T65,I1,T66,'-',T67,I1,T68,'-',T69,I1,T71,F8.5,
     *T83,I2,T90,F6.1,T98,I6,T106,I6,T117,I4,T126,F6.1)
C
447   506  FORMAT(T3,I4,T10,I3,T17,I2,T22,I2,T25,F8.5,T36,I1,T39,F7.3,
     *T47,F7.3,T61,I1,T65,I1,T66,'-',T67,I1,T68,'-',T69,I1,T71,F8.5,
     *T83,I2,T90,F6.1,T97,'---------NOT COST-EFFECTIVE--------')
C
448   508  FORMAT(T3,I4,T10,I3,T17,I2,T22,I2,T25,F8.5,T36,I1,T39,F7.3,
     *T47,F7.3,T61,I1,T65,I1,T66,'-',T67,I1,T68,'-',T69,I1,T71,F8.5,
     *T83,I2,T90,F6.1,T97,'************END GROUP************')
C
449   600  FORMAT(/)
C
450   602  FORMAT(//)
C
451   604  FORMAT(//,T61,'*****END OF PROGRAM*****'/1H1)
C
452   398  FORMAT(1H1,/,T122,'PAGE = ',T128,I2)
C
453   900  FORMAT(T52,'HIGHWAY DESIGN NUMBER = DR-',I2)
C
454   901  FORMAT(T52,'HIGHWAY DESIGN NUMBER = DM-',I2)
C
455   902  FORMAT(T52,'HIGHWAY DESIGN NUMBER = ROA-',I2)
C
456   903  FORMAT(T52,'HIGHWAY DESIGN NUMBER = RC-',I2)
C
457   904  FORMAT(T52,'HIGHWAY DESIGN NUMBER = RL-',I2)
C
458   910  FORMAT(T61,'TYPE HIGHWAY = US-',I3)
C
459   911  FORMAT(T61,'TYPE HIGHWAY = NH-',I3)
C
460   912  FORMAT(T61,'TYPE HIGHWAY = IS-',I3)
C
461   913  FORMAT(T61,'TYPE HIGHWAY = RUR-',I3)
C
462   815  FORMAT(T61,'DESIGN SPEED = ',T76,I2,T79,'MPH',/,T70,
     *'ADT = ',T76,I5,/,T61,'PROJECT LIFE = ',T76,F4.1,T81,'YRS',
     */,T60,'INTEREST RATE = ',T76,F5.3,T82,'%',/,T69,'DATE = ',
     *T76,I2,T78,'-',T79,I2,T81,'-',T82,I2,////)
C
463   9998 RETURN
464        END
C
C
C
C*********************************************************************
C*********************************************************************
```

```
C                                                                       *
C                                                                       *
      SUBROUTINE FREQ
C                                                                       *
C                                                                       *
C***********************************************************************
C                                                                       *
C --- THIS SUEROUTINE CALCULATES THE ENCROACHMENT FREQUENCY OF A GIVEN  *
C     ROADWAY.  TWO PARAMETEES ARE REQUIRED FROM THE INPUT FORM,        *
C        HIGHWAY DESIGN NUMBER--HO                                      *
C        RURAL OR URBAN CLASS---H3                                      *
C     THE ENCROACHMENT FREQUENCY'S ARE EXPRESSED IN #/MILE-YEAR         *
C                                                                       *
C --- NOTE  THE FOLLOWING ROADWAY TYPES WILL HAVE A CORRECTION FACTOR   *
C           APPLIED TO THE DHV BASED ON WHETHER THE ROADWAY IS RURAL OR*
C           URBAN                                                       *
C ----- DR01-------RURAL INTERSTATE-DHV IS 15 PERCENT OF ADT           *
C       DR02-------MULTILANE-IF RURAL, DHV IS 15 PERCENT OF ADT.  IF    *
C                  URBAN, DHV IS 10 PERCENT OF ADT.                     *
C       DR04-DR07--RURAL TWO LANE-DHV IS 15 PERCENT OF ADT              *
C       DM10-DM20--URBAN INTERSTATE-DHV IS 10 PERCENT OF ADT            *
C       DM30-DM40--MULTILANE-IF RURAL, DHV IS 15 PERCENT OF ADT.  IF    *
C                  URBAN, DHV IS 10 PERCENT OF ADT.                     *
C                                                                       *
C     SOURCE  AASHO,1965.  AASHTO,1973                                  *
C     SOURCE OF ADT AND DHV VALUES:  MINIMUM DESIGN STANDARDS,NEBRASKA  *
C                                                                       *
C     FOR DM10, DM20, DM30, AND DM40 ARE ASSUMED TO BE FOUR LANES,      *
C     TWO LANES IN EACH DIRECTION WITH SIGNAL CONTROL                   *
C                                                                       *
C***********************************************************************
C***********************************************************************
C
C
      DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
     *          ERROR1(3,4),CS(5,5),IZERO(4)
      DIMENSION ITAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
      DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
      DIMENSION OFSET(5)
      DIMENSION SIGR(5,5)
      DIMENSION PI(5,5)
      DIMENSION  H0(3),H1(3),H2(3),H3(3), H4(3),  H5(3),  H6(3),
     *           H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
     *          H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
     *          H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
     *          H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
     *          H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
     *          H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
     *          H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
     *          H63(3)
      DIMENSION  C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
     *          C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
     *          C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
     *          C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
     *          C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
     *          C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
     *          C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
     *          C61(3,4), C62(3,4), C63(3,4)
C
      DIMENSION IMP(5,5)
```

```
475           DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
476           DIMENSION  TAC(5,5), SI(5,5)
477           INTEGER ERROR1
478           INTEGER TEMP1,TEMP2,X
479           INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
             *         H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
             *         H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
             *         H51,H52,H60,H61,H62,H63
      C
480           INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
             *         C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
             *         C40,C41,C42,C60,C61,C62,C63,C9
      C
481           INTEGER SPEED,VEL
482           COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
             *                 ACA,RMA,TACIMP,IZERO,LIFE,INT
483           COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
484           COMMON/ CST1/COST1
485           COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
      C
      C
486           COMMON/ ENFRE /ENFR
      C
487           COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
488           COMMON/ LATOF /OFSET
      C
      C
      C
489           COMMON/ IMPROB /IMP
      C
490           COMMON/ GRSI /SIGR
      C
491           COMMON/ HURT /PI,SI
      C
492           COMMON/ SLOPE1 /SISL
493           COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
             *                H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
             *                H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
             *                H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
494           COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
             *           C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
             *               C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
495           COMMON/ GRCRC / CS
496           COMMON/ ERROR /ERROR1
497           REAL IMP
498     9999  CONTINUE
499           IF(IFLAG .EQ. 1) GO TO 49
500           H0(II) = C1(II,JJ)
501           ADT = C9(II,JJ)
502           GO TO 51
503      49   ADT = B3(II)
      C
      C
      C
      C
      C --- CHECK FOR HIGHWAY DESIGN NUMBER AND ASSIGN ENCROACHMENT FREQUENCY
```

```
      C      VALUE WHICH IS CORRECTED FOR RURAL OR URBAN CLASSIFICATION.
      C
      C --- IS HIGHWAY DR01?
504    51    IF(H0(II).NE.101)GO TO 10
      C
505          ENFR = 0.00090*ADT
506          GO TO 1000
      C
      C --- IS HIGHWAY DR02?
507       10 IF(H0(II).NE.102)GO TO 20
      C
      C
      C
      C
508          ENFR = 0.00090*ADT
509          GO TO 1000
      C
      C
      C
      C --- IS HIGHWAY DR04?
510       20 IF(H0(II).EQ.104)GO TO 3
511          GO TO 30
      C
512    3     ENFR = 0.000590*ADT
513          GO TO 1000
      C
      C --- IS HIGHWAY DR05?
514       30 IF(H0(II).EQ.105)GO TO 4
515          GO TO 40
      C
516    4     ENFR = 0.000742*ADT
517          GO TO 1000
      C
      C --- IS HIGHWAY DR06?
518       40 IF(H0(II).EQ.106)GO TO 5
519          GO TO 50
      C
520    5     ENFR = 0.000742*ADT
521          GO TO 1000
      C
      C --- IS HIGHWAY DR07?
522       50 IF(H0(II).EQ.107)GO TO 6
523          GO TO 60
      C
524    6     ENFR = 0.00121*ADT
525          GO TO 1000
      C
      C --- IS HIGHWAY DM10 OR DM20
526       60 IF(H0(II).EQ.210.OR.H0(II).EQ.220)GO TO 7
527          GO TO 70
      C
528    7     ENFR = 0.00090*ADT
529          GO TO 1000
      C
      C --- IS HIGHWAY DM30 OR DM40?
      C
530    70    CONTINUE
531          ENFR = 0.00090*ADT
      C
      C
      C
```

```
      C
532    1000 CONTINUE
      C
533    9998 RETURN
534         END
      C*******************************************************************************
      C*******************************************************************************
      C

535         SUBROUTINE PROB1
      C
      C*******************************************************************************
      C
      C     THIS SUBROUTINE CALCULATES LATERAL OFFSET PROBABILITIES FOR THE
      C     FIVE DIFFERENT ENCROACHMENT ANGLES AND STORES THEM IN ARRAY OFSET.
      C     THE FOLLOWING ASSUMPTION WAS MADE:
      C         IF THE FRONT SLOPE IS 2:1 OR 3:1 IT IS A CERTAINTY THE VEHICLE
      C         WILL IMPACT DITCH BOTTOM.  THEREFORE, THE PROBABILITY OF
      C         REACHING THE HINGE POINT IS ASSIGNED.  FOR 4:1 AND 6:1 FRONT
      C         SLOPES THE PROBABILITY OF GETTING TO DITCH BOTTOM IS ASSIGNED.
      C
      C*******************************************************************************
      C*******************************************************************************
      C
      C
536         DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
     *            ERROR1(3,4),CS(5,5),IZERO(4)
537         DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
538         DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
539         DIMENSION OFSET(5)
540         DIMENSION SIGR(5,5)
541         DIMENSION PI(5,5)
542         DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
     *              H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
     *             H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
     *             H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
     *             H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
     *             H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
     *             H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
     *             H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
     *             H63(3)
543         DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
     *             C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
     *             C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
     *             C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
     *             C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
     *             C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
     *             C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
     *             C61(3,4), C62(3,4), C63(3,4)
      C
544         DIMENSION IMP(5,5)
545         DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
546         DIMENSION  TAC(5,5), SI(5,5)
547         INTEGER ERROR1
548         INTEGER TEMP1,TEMP2,X
549         INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
     *            H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
     *            H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
     *            H51,H52,H60,H61,H62,H63
      C
550         INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
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     *          C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
     *          C40,C41,C42,C60,C61,C62,C63,C9
      C
551         INTEGER SPEED,VEL
552         COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
     *                       ACA,RMA,TACIMP,IZERO,LIFE,INT
553         COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
554         COMMON/ CST1/COST1
555         COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
      C
      C
556         COMMON/ ENFRE /ENFR
      C
557         COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
558         COMMON/ LATOF /OFSET
      C
      C
      C
559         COMMON/ IMPROB /IMP
      C
560         COMMON/ GRSI /SIGR
      C
561         COMMON/ HURT /PI,SI
      C
562         COMMON/ SLOPE1 /SISL
563         COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
     *                    H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
     *                    H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
     *                    H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
564         COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
     *              C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
     *                  C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
565         COMMON/ GRCRC / CS
566         COMMON/ ERROR /ERROR1
567         REAL IMP
      C
      C
      C --- IF IFLAG IS 1--HAZARD.  IF IFLAG IS 2--IMPROVEMENT.
      C
568   9999  CONTINUE
569         IF(IFLAG.EQ.2)GO TO 20
570         IF(H22(II) .EQ. 3) GO TO 11
571         TEMP2 = (H30(II) + H31(II))/2.0
572         GO TO 31
      C
      C --- TEMP1 CONTAINS FRONT SLOPE.
      C --- TEMP2 CONTAINS LATERAL OFFSET OF HINGE POINT.
      C
573      11 TEMP1=H42(II)
574         TEMP2=H41(II)
575         GO TO 30
      C
      C --- IF C12(II,JJ) IS 1--GUARDRAIL IS SUGGESTED IMPROVEMENT.
      C --- IF C12(II,JJ) IS 2--SLOPE MODIFICATION.
      C
576      20 IF(C10(II,JJ).EQ.3.AND.C12(II,JJ).EQ.1)GO TO 21
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577         IF(C10(II,JJ).EQ.3.AND.C12(II,JJ).EQ.2)GO TO 22
578         IF(C10(II,JJ).EQ.2.AND.C12(II,JJ).EQ.2.AND.C13(II,JJ).EQ.2)GO TO
           *21
579         IF(C10(II,JJ).EQ.2.AND.C12(II,JJ).EQ.2.AND.C13(II,JJ).EQ.3)GO TO
           *21
      C --- ASSIGN OFFSET OF GUARDRAIL TO TEMP2
580      21 TEMP2=(C26(II,JJ)+C25(II,JJ))/2.0
581         GO TO 31
      C
      C
      C
      C
      C --- SLOPE MODIFICATION.  ASSIGN F.S. TO TEMP1, OFFSET TO TEMP2
      C
582      22 TEMP1=C15(II,JJ)
583         TEMP2=C22(II,JJ)
      C
      C --- SEE COMMENT ABOUT F.S. AT SUBROUTINE START.
      C
584      30 IF(TEMP1.LT.4)GO TO 31
      C
      C --- USING THE LATERAL OFFSET AT WHICH SEVERITY OCCURS, BRANCH TO
      C     APPROPRIATE SET OF EQUATIONS OF LATERAL OFFSET PROBABILITIES AND
      C     ASSIGN THE PROBABILITIES FOR EACH OF THE FIVE ENCRAOCHMENT ANGLES.
      C
585         IF(IFLAG.EQ.2)GO TO 52
586         TEMP2=H41(II)+H42(II)*H43(II)
587         GO TO 31
588      52 TEMP2=C22(II,JJ)+C15(II,JJ)*C16(II,JJ)
589      31 X=TEMP2
590         IF(X.GE.0.AND.X.LT.5)GO TO 100
591         IF(X.GE.5.AND.X.LT.10)GO TO 101
592         IF(X.GE.10.AND.X.LT.15)GO TO 102
593         IF(X.GE.15.AND.X.LT.20)GO TO 103
594         IF(X.GE.20.AND.X.LT.25)GO TO 104
595         IF(X.GE.25.AND.X.LT.30)GO TO 105
596         IF(X.GE.30.AND.X.LT.35)GO TO 106
597         IF(X.GE.35.AND.X.LT.40)GO TO 107
598         IF(X.GE.40.AND.X.LT.120)GO TO 108
599         GO TO 999
600     100 OFSET(1)=-0.0174*X+1.0
601         OFSET(2)=-0.0028*X+1.0
602         OFSET(3)=1.0
603         OFSET(4)=1.0
604         OFSET(5)=1.0
605         GO TO 1000
606     101 OFSET(1)=-0.047*X+1.148
607         OFSET(2)=-0.0224*X+1.098
608         OFSET(3)=-0.016*X+1.08
609         OFSET(4)=OFSET(3)
610         OFSET(5)=-0.0084*X+1.042
611         GO TO 1000
612     102 OFSET(1)=-0.0242*X+0.92
613         OFSET(2)=-0.017*X+1.044
614         OFSET(3)=-0.016*X+1.08
615         OFSET(4)=OFSET(3)
616         OFSET(5)=-0.0084*X+1.042
617         GO TO 1000
618     103 OFSET(1)=-0.0174*X+0.818
619         OFSET(2)=-0.0338*X+1.296
620         OFSET(3)=-0.016*X+1.08
```

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621           OFSET(4)=OFSET(3)
622           OFSET(5)=-0.0166*X+1.165
623           GO TO 1000
624       104 OFSET(1)=-0.0322*X+1.114
625           OFSET(2)=-0.031*X+1.24
626           OFSET(3)=-0.06*X+1.96
627           OFSET(4)=OFSET(3)
628           OFSET(5)=-0.0334*X+1.501
629           GO TO 1000
630       105 OFSET(1)=-0.0282*X+1.014
631           OFSET(2)=-0.0254*X+1.10
632           OFSET(3)=-0.024*X+1.06
633           OFSET(4)=OFSET(3)
634           OFSET(5)=-0.0582*X+2.121
635           GO TO 1000
636       106 OFSET(1)=-0.0094*X+0.45
637           OFSET(2)=-0.0084*X+0.59
638           OFSET(3)=-0.016*X+0.82
639           OFSET(4)=OFSET(3)
640           OFSET(5)=-0.0084*X+0.627
641           GO TO 1000
642       107 OFSET(1)=-0.0054*X+0.31
643           OFSET(2)=-0.0056*X+0.492
644           OFSET(3)=-0.004*X+0.40
645           OFSET(4)=OFSET(3)
646           OFSET(5)=0.3333
647           GO TO 1000
648       108 OFSET(1)=-0.00118*X+0.141
649           OFSET(2)=-0.00335*X+0.402
650           OFSET(3)=-0.003*X+0.36
651           OFSET(4)=OFSET(3)
652           OFSET(5)=-0.00416*X+0.4995
653           GO TO 1000
654        999 CONTINUE
655           IF(IFLAG .EQ. 1) GO TO 60
656           ERROR1(II,JJ) = 5
657           GO TO 1000
658        60 CONTINUE
659           ERROR1(II,1) = 5
660      1000 CONTINUE
661         C
662       9998 RETURN
663           END
664         C
665         C*****************************************************************
666         C*****************************************************************
667         C
668
669           SUBROUTINE HINDEX
670         C
671         C*****************************************************************
672         C
673         C     THIS SUBROUTINE CALCULATES THE HAZARD INDEX.  IMPACTS ON THE END OF
674         C     GUARDRAIL AND THE BOTTOMING OUT OF GUARDRAIL ON BRIDGE PIERS HAS
675         C     NOT BEEN TAKEN INTO ACCOUNT.
676         C
677         C
678         C
679         C
680         C
681         C*****************************************************************
```

```
C*****************************************************************
C
C
      DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
     *          ERROR1(3,4),CS(5,5),IZERO(4)
      DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
      DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
      DIMENSION OFSET(5)
      DIMENSION SIGR(5,5)
      DIMENSION FI(5,5)
      DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
     *           H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
     *          H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
     *          H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
     *          H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
     *          H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
     *          H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
     *          H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
     *          H63(3)
      DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
     *          C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
     *          C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
     *          C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
     *          C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
     *          C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
     *          C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
     *          C61(3,4), C62(3,4), C63(3,4)
C
      DIMENSION IMP(5,5)
      DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
      DIMENSION  TAC(5,5), SI(5,5)
      INTEGER ERROR1
      INTEGER TEMP1,TEMP2,X
      INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
     *         H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
     *         H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
     *         H51,H52,H60,H61,H62,H63
C
      INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
     *         C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
     *         C40,C41,C42,C60,C61,C62,C63,C9
C
      INTEGER SPEED,VEL
      COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
     *                 ACA,RMA,TACIMP,IZERO,LIFE,INT
      COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
      COMMON/ CST1/COST1
      COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
C
C
      COMMON/ ENFRE /ENFR
C
      COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
C
      COMMON/ LATOF /OFSET
C
C
C
      COMMON/ IMPROB /IMP
C
      COMMON/ GRSI /SIGR
```

```
      C
689           COMMON/ HUNT /PI,SI
      C
690           COMMON/ SLOPE1 /SISL
691           COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
             *               H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
             *               H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
             *               H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
692           COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
             *          C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
             *              C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
693           COMMON/ GRCRC / CS
694           COMMON/ ERROR /ERROR1
695           REAL IMP
696     9999  CONTINUE
697           SUM=0.0
698           ASUM = 0.0
      C
      C --- IFLAG CHECKS TO SEE IF THE DATA IS FROM A HAZARD OR AN IMPROVEMENT
      C     ALTERNATIVE.  IFLAG = 1--HAZARD.  IFLAG = 2--IMPROVEMENT ALTERNATIV
699           IF(IFLAG.EQ.1)GO TO 17
700           ALONG1=(ABS(C46(II,JJ)-C45(II,JJ)))*5280.0
701           GO TO 21
702        17 ALONG1=(ABS(H19(II)-H18(II)))*5280.0
703        21 DO 6 K = 1,5
704           GO TO (1,2,3,4,7),K
705      1    TEMP = 0.48*OFSET(1)
706           GO TO 10
707      2    TEMP = 0.20*OFSET(2)
708           GO TO 10
709      3    TEMP = 0.12*OFSET(3)
710           GO TO 10
711      4    TEMP = 0.08*OFSET(4)
712           GO TO 10
713      7    TEMP = 0.12*OFSET(5)
714      10   DO 5 KK = 1,5
715           SUM = PI(KK,K)*IMP(KK,K)*ALONG1+SUM
716         5 CONTINUE
717           ASUM = TEMP*SUM + ASUM
718         6 CONTINUE
719           IF(IFLAG .EQ.2) GO TO 20
720           HI(II) =(ASUM*ENFR*0.50)/5280.0
721           GO TO 1000
722      20   CHI(II,JJ) =(ASUM*ENFR*0.50)/5280.0
      C --- THE DIRECTIONAL SPLIT IS ASSUMED TO BE 0.5 IN EACH CASE
723      1000 CONTINUE
724      9998 RETURN
725           END
      C*************************************************************************
      C*************************************************************************
      C
726           SUBROUTINE PROB2
      C
      C*************************************************************************
      C
      C     THIS SUBROUTINE ASSIGNS IMPACT PROBABILITIES TO THE ARRAY 'IMP'
```

```
C      BASED ON HIGHWAY DESIGN NUMBER HO GENERATED IN SUBROUTINE DATA.
C         DR01---------------RURAL INTERSTATE, STATEMENT 100
C         DM10 AND DM20------URBAN INTERSTATE, STATEMENT 200
C         DR02, DM30, DM40---MULTILANE, STATEMENT 300
C         DR04-DR07----------RURAL 2 LANE, STATEMENT 400
C
C*****************************************************************
C*****************************************************************
C
C
727        DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
          *          ERROR1(3,4),CS(5,5),IZERO(4)
728        DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
729        DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
730        DIMENSION OFSET(5)
731        DIMENSION SIGR(5,5)
732        DIMENSION PI(5,5)
733        DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
          *           H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
          *          H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
          *          H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
          *          H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
          *          H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
          *          H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
          *          H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
          *          H63(3)
734        DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
          *          C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
          *          C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
          *          C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
          *          C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
          *          C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
          *          C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
          *          C61(3,4), C62(3,4), C63(3,4)
C
735        DIMENSION IMP(5,5)
736        DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
737        DIMENSION  TAC(5,5), SI(5,5)
738        INTEGER ERROR1
739        INTEGER TEMP1,TEMP2,X
740        INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
          *          H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
          *          H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
          *          H51,H52,H60,H61,H62,H63
C
741        INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
          *          C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
          *          C40,C41,C42,C60,C61,C62,C63,C9
C
742        INTEGER SPEED,VEL
743        COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
          *                 ACA,RMA,TACIMP,IZERO,LIFE,INT
744        COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
745        COMMON/ CST1/COST1
746        COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
C
C
747        COMMON/ ENFRE /ENFR
C
748        COMMON/ IDENT /I,J,II,JJ,ICARD,IFIAG,IMPR,NTITLE
C
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749         COMMON/ LATOF /CFSET
      C
      C
      C
750         COMMON/ IMPROB /IMP
      C
751         COMMON/ GRSI /SIGR
      C
752         COMMON/ HURT /PI,SI
      C
753         COMMON/ SLOPE1 /SISL
754         COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
           *                H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
           *                H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
           *                H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
755         COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
           *           C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
           *               C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
756         COMMON/ GRCRC / CS
757         COMMON/ ERROR /ERROR1
      C
      C
      C
758         REAL IMP
      C
759   9999  CONTINUE
760         IF(IFLAG .EQ. 1) GO TO 10
761         H0(II) = C1(II,JJ)
      C
      C
      C
      C
      C
      C
      C
      C     IF STATEMENT CHECKS IF HIGHWAY DESIGN NO. IS DR01
762    10   IF(H0(II).EQ.101)GO TO 100
      C
      C     IF STATEMENT CHECKS IF HIGHWAY DESIGN NO. IS DM10 OR DM20
763         IF(H0(II).EQ.210.OR.H0(II).EQ.220)GO TO 200
      C
      C     IF STATEMENT CHECKS IF HIGHWAY DESIGN NO. IS DR02, DM30, OR DM40
764         IF(H0(II).EQ.102.OR.H0(II).EQ.230.OR.H0(II).EQ.240)GO TO 300
      C
      C     IF STATEMENT CHECKS IF HIGHWAY DESIGN NO. IS DR03-DR07
765         IF(H0(II).GE.103.AND.H0(II).LE.107)GO TO 400
      C
766         IF(IFLAG .EQ. 1) GO TO 20
767         ERROR1(II,JJ) = 15
768         GO TO 1001
769    20   CONTINUE
770         ERROR1(II,1) = 15
771         GO TO 1001
772    100  CONTINUE
773         IMP(1,1) = 0.001
774         IMP(1,2) = 0.000
775         IMP(1,3) = 0.000
```

```
776           IMP(1,4) = 0.000
777           IMP(1,5) = 0.000
778           IMP(2,1) = 0.090
779           IMP(2,2) = 0.038
780           IMP(2,3) = 0.022
781           IMP(2,4) = 0.015
782           IMP(2,5) = 0.022
783           IMP(3,1) = 0.335
784           IMP(3,2) = 0.139
785           IMP(3,3) = 0.084
786           IMP(3,4) = 0.056
787           IMP(3,5) = 0.084
788           IMP(4,1) = 0.054
789           IMP(4,2) = 0.023
790           IMP(4,3) = 0.014
791           IMP(4,4) = 0.009
792           IMP(4,5) = 0.014
793           IMP(5,1) = 0.000
794           IMP(5,2) = 0.000
795           IMP(5,3) = 0.000
796           IMP(5,4) = 0.000
797           IMP(5,5) = 0.000
798           GO TO 1000
799       200 CONTINUE
800           IMP(1,1) = 0.010
801           IMP(1,2) = 0.004
802           IMP(1,3) = 0.003
803           IMP(1,4) = 0.002
804           IMP(1,5) = 0.003
805           IMP(2,1) = 0.210
806           IMP(2,2) = 0.088
807           IMP(2,3) = 0.053
808           IMP(2,4) = 0.035
809           IMP(2,5) = 0.053
810           IMP(3,1) = 0.243
811           IMP(3,2) = 0.101
812           IMP(3,3) = 0.061
813           IMP(3,4) = 0.040
814           IMP(3,5) = 0.060
815           IMP(4,1) = 0.016
816           IMP(4,2) = 0.007
817           IMP(4,3) = 0.004
818           IMP(4,4) = 0.003
819           IMP(4,5) = 0.004
820           IMP(5,1) = 0.000
821           IMP(5,2) = 0.000
822           IMP(5,3) = 0.000
823           IMP(5,4) = 0.000
824           IMP(5,5) = 0.000
825           GO TO 1000
826       300 CONTINUE
827           IMP(1,1) = 0.016
828           IMP(1,2) = 0.007
829           IMP(1,3) = 0.004
830           IMP(1,4) = 0.003
831           IMP(1,5) = 0.004
832           IMP(2,1) = 0.271
833           IMP(2,2) = 0.113
834           IMP(2,3) = 0.068
835           IMP(2,4) = 0.045
836           IMP(2,5) = 0.068
```

```
837           IMP(3,1) = 0.188
838           IMP(3,2) = 0.078
839           IMP(3,3) = 0.047
840           IMP(3,4) = 0.031
841           IMP(3,5) = 0.047
842           IMP(4,1) = 0.005
843           IMP(4,2) = 0.002
844           IMP(4,3) = 0.001
845           IMP(4,4) = 0.001
846           IMP(4,5) = 0.001
847           IMP(5,1) = 0.000
848           IMP(5,2) = 0.000
849           IMP(5,3) = 0.000
850           IMP(5,4) = 0.000
851           IMP(5,5) = 0.000
852           GO TO 1000
853       400 CONTINUE
854           IMP(1,1) = 0.006
855           IMP(1,2) = 0.002
856           IMP(1,3) = 0.001
857           IMP(1,4) = 0.001
858           IMP(1,5) = 0.002
859           IMP(2,1) = 0.217
860           IMP(2,2) = 0.090
861           IMP(2,3) = 0.054
862           IMP(2,4) = 0.036
863           IMP(2,5) = 0.055
864           IMP(3,1) = 0.249
865           IMP(3,2) = 0.104
866           IMP(3,3) = 0.062
867           IMP(3,4) = 0.041
868           IMP(3,5) = 0.062
869           IMP(4,1) = 0.009
870           IMP(4,2) = 0.004
871           IMP(4,3) = 0.002
872           IMP(4,4) = 0.001
873           IMP(4,5) = 0.002
874           IMP(5,1) = 0.000
875           IMP(5,2) = 0.000
876           IMP(5,3) = 0.000
877           IMP(5,4) = 0.000
878           IMP(5,5) = 0.000
879      1000 CONTINUE
         C
         C
         C
880      1001 CONTINUE
881      9998 RETURN
882           END
         C*************************************************************************
         C*************************************************************************
         C

883           SUBROUTINE WBEAM
         C
         C*************************************************************************
         C
         C     THIS SUBROUTINE ASSIGNS SEVERITY INDEX VALUES TO AN ARRAY SIGR.
         C     THESE VALUES ARE COMPUTED FOR 40, 50, 60, 70, AND 80 MPH FOR
         C     ENCROACHMENT ANGLES OF 7.5, 10, 15, 20, AND 25 DEGREES.  THESE
         C     EQUATIONS WERE OBTAINED FROM BARRIER7 RUNS.
```

```
      C
      C*****************************************************************
      C*****************************************************************
      C
      C
  884          DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
     *             ERROR1(3,4),CS(5,5),IZERO(4)
  885          DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
  886          DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
  887          DIMENSION OFSET(5)
  888          DIMENSION SIGR(5,5)
  889          DIMENSION PI(5,5)
  890          DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
     *              H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
     *             H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
     *             H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
     *             H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
     *             H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
     *             H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
     *             H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
     *             H63(3)
  891          DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
     *             C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
     *             C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
     *             C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
     *             C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
     *             C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
     *             C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
     *             C61(3,4), C62(3,4), C63(3,4)
      C
  892          DIMENSION IMP(5,5)
  893          DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
  894          DIMENSION  TAC(5,5), SI(5,5)
  895          INTEGER ERROR1
  896          INTEGER TEMP1,TEMP2,X
  897          INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
     *             H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
     *             H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
     *             H51,H52,H60,H61,H62,H63
      C
  898          INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
     *             C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
     *             C40,C41,C42,C60,C61,C62,C63,C9
      C
  899          INTEGER SPEED,VEL
  900          COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
     *                    ACA,RMA,TACIMP,IZERO,LIFE,INT
  901          COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
  902          COMMON/ CST1/COST1
  903          COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
      C
      C
  904          COMMON/ ENFRE /ENFR
      C
  905          COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
  906          COMMON/ LATOF /OFSET
      C
      C
      C
  907          COMMON/ IMPROB /IMP
```

```
      C
  908         COMMON/ GBSI /SIGR
      C
  909         COMMON/ HUBT /PI,SI
      C
  910         COMMON/ SLOPE1 /SISL
  911         COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
     *                       H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
     *                       H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
     *                       H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
  912         COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
     *                  C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
     *                      C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
  913         COMMON/ GRCRC / CS
  914         COMMON/ ERROR /ERROR1
  915         REAL IMP
  916 9999    CONTINUE
  917         SPEED(1) = 40.0
  918         SPEED(2) = 50.0
  919         SPEED(3) = 60.0
  920         SPEED(4) = 70.0
  921         SPEED(5) = 80.0
      C
  922         DO 1 K = 1,5
  923         TEMP = SPEED(K)
  924         SIGR(K,1) = 0.01475*TEMP-0.2660
  925         SIGR(K,2) = 0.01228*TEMP-0.0470
  926         SIGR(K,3) = 0.01222*TEMP+0.2470
  927         SIGR(K,4) = 0.01448*TEMP+0.1678
  928         SIGR(K,5) = 0.01727*TEMP+0.1827
      C
      C     GUARDRAIL COLLISION REPAIR COSTS ($/FT)
      C
  929         GRCR = 7.60
      C
  930         X1 = SIGR(K,1)
  931         X2 = SIGR(K,2)
  932         X3 = SIGR(K,3)
  933         X4 = SIGR(K,4)
  934         X5 = SIGR(K,5)
  935         CS(K,1)=((18.87*X1)*(1.0-1.313*X1+1.373*X1*X1))*GRCR
  936         CS(K,2)=((18.87*X2)*(1.0-1.313*X2+1.373*X2*X2))*GRCR
  937         CS(K,3)=((18.87*X3)*(1.0-1.313*X3+1.373*X3*X3))*GRCR
  938         CS(K,4)=((18.87*X4)*(1.0-1.313*X4+1.373*X4*X4))*GRCR
  939         CS(K,5)=((18.87*X5)*(1.0-1.313*X5+1.373*X5*X5))*GRCR
      C
      C     ADJUSTMENT FACTOR FOR GUARDRAIL WITH 12'-6" POST SPACINGS.
  940         IF(IFLAG .EQ. 1 .AND. H33(II) .EQ. 12) GO TO 10
  941         IF(IFLAG .EQ. 1) GO TO 11
  942         IF(IFLAG .EQ. 2 .AND. C28(II,JJ) .EQ. 12) GO TO 10
  943         GO TO 11
  944   10    SIGR(K,1) = 0.89*SIGR(K,1)
  945         SIGR(K,2) = 0.91*SIGR(K,2)
  946         SIGR(K,3) = 0.93*SIGR(K,3)
  947         SIGR(K,4) = 1.06*SIGR(K,4)
  948         SIGR(K,5) = 1.06*SIGR(K,5)
  949         CS(K,1) = 1.20*CS(K,1)
```

```
950           CS(K,2) = 1.20*CS(K,2)
951           CS(K,3) = 1.20*CS(K,3)
952           CS(K,4) = 1.20*CS(K,4)
953           CS(K,5) = 1.20*CS(K,5)
954      11   CONTINUE
955       1   CONTINUE
          C
956      9998 RETURN
957           END
          C*******************************************************************************
          C*******************************************************************************
          C

958           SUBROUTINE PROB3
          C
          C*******************************************************************************
          C
          C --- THIS SUBROUTINE CALCULATES THE PROBABILITY OF INJURY GIVEN A
          C --- SEVERITY INDEX (SI) ARRAY FROM EITHER THE WBEAM1 OR WBEAM2 OR SLOPE
          C --- SUBROUTINE.  THE CALCULATED VALUES ARE STORED IN ARRAY 'PI'.
          C
          C*******************************************************************************
          C*******************************************************************************
959           DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
             *          ERROR1(3,4),CS(5,5),IZERO(4)
960           DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
961           DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
962           DIMENSION OFSET(5)
963           DIMENSION SIGR(5,5)
964           DIMENSION PI(5,5)
965           DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
             *           H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
             *           H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
             *           H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
             *           H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
             *           H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
             *           H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
             *           H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
             *           H63(3)
966           DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
             *           C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
             *           C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
             *           C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
             *           C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
             *           C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
             *           C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
             *           C61(3,4), C62(3,4), C63(3,4)
          C
967           DIMENSION IMP(5,5)
968           DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
969           DIMENSION  TAC(5,5), SI(5,5)
970           INTEGER ERROR1
971           INTEGER TEMP1,TEMP2,X
972           INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
             *           H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
             *           H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
             *           H51,H52,H60,H61,H62,H63
          C
973           INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
             *           C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
             *           C40,C41,C42,C60,C61,C62,C63,C9
```

```
      C
974           INTEGER SPEED,VEL
975           COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
     *                         ACA,RMA,TACIMP,IZERO,LIFE,INT
976           COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
977           COMMON/ CST1/COST1
978           COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
      C
      C
979           COMMON/ ENFRE /ENFR
      C
980           COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
981           COMMON/ LATOF /OFSET
      C
      C
      C
982           COMMON/ IMPROB /IMP
      C
983           COMMON/ GRSI /SIGR
      C
984           COMMON/ HUET /PI,SI
      C
985           COMMON/ SLOPE1 /SISL
986           COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
     *                       H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
     *                       H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
     *                       H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
987           COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
     *                  C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
     *                      C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
988           COMMON/ GRCRC / CS
989           COMMON/ ERROR /ERROR1
990           REAL IMP
991     9999  CONTINUE
992           IF(IFLAG .EQ. 2) GO TO 11
      C
      C
      C
      C --- H22 CHECKS TO SEE IF THE HAZARD IS LONGITUDINAL OR SLOPE
      C
993           IF(H22(II).EQ.3)GO TO 13
      C
      C --- LONGITUDINAL HAZARD
994           DO 10 L = 1,5
995           DO 14 M = 1,5
996           SI(L,M)= SIGR(L,M)
997        14 CONTINUE
998        10 CONTINUE
999           GO TO 800
      C
      C --- SLOPE HAZARD
1000       13 DO 12 L = 1,5
1001          DO 15 M = 1,5
1002          SI(L,M) = SISL(L,M)
1003       15 CONTINUE
1004       12 CONTINUE
```

```
1005          GO TO 800
1006       11 IF(C10(II,JJ).EQ.2.AND.C12(II,JJ).EQ.2.AND.C13(II,JJ).EQ.2)GO TO
              *20
1007          IF(C10(II,JJ).EQ.2.AND.C12(II,JJ).EQ.2.AND.C13(II,JJ).EQ.3)GO TO
              *20
1008          IF(C10(II,JJ).EQ.3.AND.C12(II,JJ).EQ.1)GO TO 20
1009          IF(C10(II,JJ).EQ.3.AND.C12(II,JJ).EQ.2)GO TO 30
      C
      C
      C
      C
      C
      C --- LONGITUDINAL IMPROVEMENT
1010       20 DO 40 LL = 1,5
1011          DO 41 MM = 1,5
1012          SI(LL,MM) = SIGR(LL,MM)
1013       41 CONTINUE
1014       40 CONTINUE
1015          GO TO 800
      C
      C --- SLOPE IMPROVEMENT
1016       30 DO 42 LL = 1,5
1017          DO 43 MM = 1,5
1018          SI(LL,MM) = SISL(LL,MM)
1019       43 CONTINUE
1020       42 CONTINUE
1021      800 DO 2 K = 1,5
1022          DO 2 L = 1,5
1023          IF(SI(K,L).GE.2.5)GO TO 1
1024          IF(SI(K,L).LT.0.2)GO TO 3
1025          PI(K,L) = 0.4*SI(K,L)
1026          GO TO 5
1027        3 CONTINUE
1028          PI(K,L) = 0.08
1029          GO TO 5
1030        1 CONTINUE
1031          PI(K,L) = 1.00
1032        5 CONTINUE
1033        2 CONTINUE
      C
      C
      C
      C
      C
1034     9998 RETURN
1035          END
      C
      C
      C
      C
      C
      C
      C
      C
      C*****************************************************************
      C
      C
      C*****************************************************************
      C*****************************************************************
      C
```

```
      C
1036        SUBROUTINE DATA
      C
      C
      C*****************************************************************************
      C*****************************************************************************
      C
      C     THIS SUBROUTINE READS AND STORES HAZARD AND IMPROVEMENT DATA OBTAINE
      C     IN THE FIELD.  THE MAXIMUM NUMBER OF HAZARDS IS 3.  MAXIMUM NUMBER
      C     OF IMPROVEMENT ALTERNATIVES IS 4.
      C
      C*****************************************************************************
      C
      C
1037        DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
           *          ERROR1(3,4),CS(5,5),IZERO(4)
1038        DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
1039        DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
1040        DIMENSION OFSET(5)
1041        DIMENSION SIGR(5,5)
1042        DIMENSION PI(5,5)
1043        DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
           *           H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
           *          H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
           *          H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
           *          H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
           *          H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
           *          H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
           *          H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
           *          H63(3)
1044        DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
           *          C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
           *          C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
           *          C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
           *          C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
           *          C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
           *          C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
           *          C61(3,4), C62(3,4), C63(3,4)
1045        DIMENSION IMP(5,5)
1046        DIMENSION X(78)
1047        DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
1048        DIMENSION  TAC(5,5), SI(5,5)
1049        INTEGER ERROR1
1050        INTEGER TEMP1,TEMP2
1051        INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
           *          H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
           *          H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
           *          H51,H52,H60,H61,H62,H63
      C
1052        INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
           *          C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
           *          C40,C41,C42,C60,C61,C62,C63,C9
      C
1053        INTEGER SPEED,VEL
1054        COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
           *                 ACA,RMA,TACIMP,IZERO,LIFE,INT
1055        COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
1056        COMMON/ CST1/COST1
1057        COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
      C
```

```
      C
1058          COMMON/ ENFRE /ENFR
      C
1059          COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
1060          COMMON/ LATOF /OFSET
      C
      C
      C
1061          COMMON/ IMPROB /IMP
      C
1062          COMMON/ GRSI /SIGR
      C
1063          COMMON/ HURT /PI,SI
      C
1064          COMMON/ SLOPE1 /SISL
1065          COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
             *               H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
             *               H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
             *               H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
1066          COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
             *          C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
             *              C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
1067          COMMON/ GRCRC / CS
1068          COMMON/ ERROR /ERROR1
1069          REAL IMP
      C       INITIALIZE ARRAYS TO ZERO
      C
1070    9999  CONTINUE
1071          DO 1 K = 1,3
      C
1072           H0(K) = 0
1073           H2(K) = 0
1074           H3(K) = 0
1075           H4(K) = 0
1076           H5(K) = 0
1077           H6(K) = 0
1078           H7(K) = 0
1079           H8(K) = 0
1080           H9(K) = 0
1081          H10(K) = 0
1082          H11(K) = 0
1083          H12(K) = 0
1084          H13(K) = 0
1085          H14(K) = 0
1086          H15(K) = 0
1087          H16(K) = 0
1088          H17(K) = 0
1089          H18(K) = 0.0
1090          H19(K) = 0.0
1091          H22(K) = 0
1092          H23(K) = 0
1093          H24(K) = 0
1094          H25(K) = 0
1095          H26(K) = 0
1096          H27(K) = 0
1097          H30(K) = 0
```

```
1098            H31(K) = 0
1099            H32(K) = 0
1100            H33(K) = 0
1101            H34(K) = 0
1102            H35(K) = 0
1103            H36(K) = 0
1104            H37(K) = 0
1105            H38(K) = 0
1106            H41(K) = 0
1107            H42(K) = 0
1108            H43(K) = 0
1109            H44(K) = 0
1110            H45(K) = 0
1111            H46(K) = 0
1112            H47(K) = 0
1113            H48(K) = 0
1114            H50(K) = 0
1115            H51(K) = 0
1116            H52(K) = 0
1117            H60(K) = 0
1118            H61(K) = 0
1119            H62(K) = 0
1120            H63(K) = 0
1121          1 CONTINUE
      C
1122            DO 2 L=1,3
1123            DO 2 M=1,4
      C
1124             C1(L,M) = 0
1125             C2(L,M) = 0
1126             C3(L,M) = 0
1127             C4(L,M) = 0
1128             C5(L,M) = 0
1129             C6(L,M) = 0
1130             C7(L,M) = 0
1131             C8(L,M) = 0
1132             C9(L,M) = 0
1133            C10(L,M) = 0
1134            C12(L,M) = 0
1135            C13(L,M) = 0
1136            C14(L,M) = 0
1137            C15(L,M) = 0
1138            C16(L,M) = 0
1139            C17(L,M) = 0
1140            C18(L,M) = 0
1141            C19(L,M) = 0
1142            C20(L,M) = 0
1143            C21(L,M) = 0
1144            C22(L,M) = 0
1145            C25(L,M) = 0
1146            C26(L,M) = 0
1147            C27(L,M) = 0
1148            C28(L,M) = 0
1149            C29(L,M) = 0
1150            C30(L,M) = 0
1151            C31(L,M) = 0
1152            C32(L,M) = 0
1153            C33(L,M) = 0
1154            C40(L,M) = 0
1155            C41(L,M) = 0
1156            C42(L,M) = 0
```

```
1157          C45(L,M) = 0.0
1158          C46(L,M) = 0.0
1159          C60(L,M) = 0
1160          C61(L,M) = 0
1161          C62(L,M) = 0
1162          C63(L,M) = 0
1163        2 CONTINUE
      C
      C
      C     READ VALUES FROM DATA CARDS AND INSERT IN PROPER ARRAY POSITION.
      C     IGR KEEPS TRACK OF INDIVIDUAL GROUPS. ICARD IS USED TO LABEL THE
      C     CARD AS HAZARD OR IMPROVEMENT ALTERNATIVE.
      C
      C
1164          IMPR=0
1165          J=0
1166          I=0
1167      100 CONTINUE
1168          READ(5,1000)(X(L),L=1,78),IGR,ICARD
1169          GO TO (200,205),ICARD
1170      200 CONTINUE
1171           I = I + 1
1172           H60(I)=X(1)+0.1
1173           H61(I)=10.0*X(2)+X(3)+0.1
1174           H62(I)=X(4)+0.1
1175           H63(I)=100.0*X(5)+10.0*X(6)+X(7)+0.1
1176           H0(I)=100.0*X(1)+10.0*X(2)+X(3)+0.1
1177           H2(I)=10.*X(8)+X(9)+0.1
1178           H3(I)=10000.0*X(10)+1000.0*X(11)+100.*X(12)+10.*X(13)+X(14)+0.1
1179           H4(I)=10.*X(15)+X(16)+0.1
1180           H5(I)=10.*X(17)+X(18)+0.1
1181           H6(I)=10.*X(19)+X(20)+0.1
1182           H7(I)=10.*X(21)+X(22)+0.1
1183           H8(I)=X(23)+0.1
1184           H9(I)=X(24)+0.1
1185          H10(I)=X(25)+0.1
1186          H11(I)=X(26)+0.1
1187          H12(I)=X(27)+0.1
1188          H13(I)=1000.*X(28)+100.*X(29)+10.*X(30)+X(31)+.1
1189          H14(I)=10.*X(32)+X(33)+.1
1190          H15(I)=10.*X(34)+X(35)+.1
1191          H16(I)=X(36)+.1
1192          H17(I)=10.*X(37)+X(38)+.1
1193          H18(I)=100.*X(39)+10.*X(40)+X(41)+.1*X(42)+.01*X(43)+.001*X(44)
1194          H19(I)=100.*X(45)+10.*X(46)+X(47)+.1*X(48)+.01*X(49)+.001*X(50)
1195          H50(I)=10.0*X(70)+X(71)+0.1
1196          H51(I)=10.0*X(72)+X(73)+0.1
1197          H52(I)=10.0*X(74)+X(75)+0.1
1198          H22(I)=X(51)+.1
1199          IH22=H22(I)
      C
1200          GO TO(3,4,5),IH22
      C
      C     IDENTIFICATION
      C
      C     IH22=1    POINT HAZARD
      C     IH22=2    LONGITUDINAL HAZARD
      C     IH22=3    SLOPE HAZARD
      C
1201        3 CONTINUE
1202          H23(I)=10.*X(52)+X(53)+0.1
```

```
1203          H24(I)=10.*X(54)+X(55)+0.1
1204          H25(I)=1000.*X(56)+100.*X(57)+10.*X(58)+X(59)+0.1
1205          H26(I)=10.*X(60)+X(61)+0.1
1206          H27(I)=10.*X(62)+X(63)+0.1
1207          J=1
1208          GO TO 100
      C
1209        4 CONTINUE
1210          H30(I)=10.*X(52)+X(53)+0.1
1211          H31(I)=10.*X(54)+X(55)+0.1
1212          H32(I)=10.*X(56)+X(57)+0.1
1213          H33(I)=10.*X(58)+X(59)+0.1
1214          H34(I)=X(60)+.1
1215          H35(I)=X(61)+.1
1216          H36(I)=X(62)+.1
1217          H37(I)=X(63)+.1
1218          H38(I)=X(64)+.1
1219          J=1
1220          GO TO 100
      C
1221        5 CONTINUE
1222          H41(I)=10.*X(52)+X(53)+0.1
1223          H42(I)=X(54)+0.1
1224          H43(I)=10.*X(55)+X(56)+0.1
1225          H44(I)=10.*X(57)+X(58)+0.1
1226          H45(I)=X(59)+0.1
1227          H46(I)=10.*X(60)+X(61)+0.1
1228          H47(I)=X(62)+.1
1229          H48(I)=X(63)+.1
1230          J=1
1231          GO TO 100
      C
1232      205 CONTINUE
1233          IMPR=IMPR+1
1234          C60(I,J)=X(1)+0.1
1235          C61(I,J)=10.0*X(2)+X(3)+0.1
1236          C62(I,J)=X(4)+0.1
1237          C63(I,J)=100.0*X(5)+10.0*X(6)+X(7)+0.1
1238           C1(I,J)=100.0*X(1)+10.0*X(2)+X(3)+0.1
1239           C2(I,J)=1000.0*X(4)+100.0*X(5)+10.0*X(6)+X(7)+0.1
1240           C3(I,J)=10.0*X(8)+X(9)+0.1
1241           C9(I,J)=10000.0*X(10)+1000.0*X(11)+100.0*X(12)+10.0*X(13)
             **+X(14)+0.1
1242           C4(I,J)=1000.*X(15)+100.*X(16)+10.*X(17)+X(18)+.1*X(19)
1243           C5(I,J)=100.*X(20)+10.*X(21)+X(22)+0.1
1244           C6(I,J)=100.*X(23)+10.*X(24)+X(25)+0.1
1245           C7(I,J)=10.*X(26)+X(27)+0.1
1246           C8(I,J)=10.*X(28)+X(29)+0.1
1247          C10(I,J)=X(30)+.1
1248          C12(I,J)=X(31)+.1
      C
1249          IC10=C10(I,J)
1250          IC12=C12(I,J)
1251          GO TO (6,7,8,9),IC10
      C
      C       IDENTIFICATION
      C
      C       IC10=1     POINT HAZARD IMPROVEMENT
      C       IC10=2     LONGITUDINAL HAZARD IMPROVEMENT
      C       IC10=3     SLOPE HAZARD IMPROVEMENT
      C       IC10=4     NO IMPROVEMENT
```

```
      C
1252        6 CONTINUE
1253          GO TO (10,11,12),IC12
      C
      C       IDENTIFICATION
      C
      C       IC12=1     POINT HAZARD IMPROVEMENT--ALLEVIATE HAZARD
      C       IC12=2     POINT HAZARD IMPROVEMENT--INSTALL TRAFFIC BARRIER
      C       IC12=3     POINT HAZARD IMPROVEMENT--INSTALL ENERGY ATTENUATOR
      C
1254       10 CONTINUE
1255          C13(I,J)=X(32)+.1
1256          IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
1257          J=J+1
1258          GO TO 100
      C
1259       11 CONTINUE
1260          C13(I,J)=10.*X(32)+X(33)+.1
1261          C14(I,J)=1000.*X(34)+100.*X(35)+10.*X(36)+X(37)+0.1
1262          GO TO 400
      C
1263       12 CONTINUE
1264          C13(I,J)=10.*X(32)+X(33)+.1
1265          IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
1266          J=J+1
1267          GO TO 100
      C
1268        7 CONTINUE
1269          GO TO (13,14,15),IC12
      C
      C       IDENTIFICATION
      C
      C       IC12=1     LONGITUDINAL IMPROVEMENT--CURB
      C       IC12=2     LONGITUDINAL IMPROVEMENT--TRAFFIC BARRIER
      C       IC12=3     LONGITUDINAL IMPROVEMENT--BRIDGERAIL
      C
1270       13 CONTINUE
1271          C13(I,J)=X(32)+.1
1272          IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
1273          J=J+1
1274          GO TO 100
      C
1275       14 CONTINUE
1276          C13(I,J)=X(32)+.1
1277          C14(I,J)=10.*X(33)+X(34)+.1
      C
1278          IC13=C13(I,J)
1279          GO TO(101,500,500),IC13
      C
      C       IDENTIFICATION
      C
      C       IC13=1     DO NOT FILL OUT BOXES A AND B
      C       IC13=2     FILL OUT BOXES A AND B
      C       IC13=3     FILL OUT BOXES A AND B
      C
1280      101 CONTINUE
1281          IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
1282          J=J+1
1283          GO TO 100
      C
1284       15 CONTINUE
```

```
1285          C13(I,J)=X(32)+.1
1286          C14(I,J)=10.*X(33)+X(34)+.1
1287          IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
1288          J=J+1
1289          GO TO 100
      C
1290        8 CONTINUE
      C
      C       IDENTIFICATION
      C
      C       IC12=1    SLOPE IMPROVEMENTS--INSTALL TRAFFIC BARRIER
      C       IC12=2    SLOPE IMPROVEMENTS--MODIFY
      C
1291          GO TO(16,17),IC12
1292       16 CONTINUE
1293          C13(I,J)=X(32)+.1
1294          C14(I,J)=10.*X(33)+X(34)+.1
1295          GO TO 600
      C
1296       17 CONTINUE
1297          C22(I,J)=10.*X(32)+X(33)+0.1
1298          C15(I,J)=X(34)+0.1
1299          C16(I,J)=10.*X(35)+X(36)+0.1
1300          C17(I,J)=10.*X(37)+X(38)+0.1
1301          C18(I,J)=X(39)+0.1
1302          C19(I,J)=10.*X(40)+X(41)+0.1
1303          C20(I,J)=X(42)+.1
1304          C21(I,J)=X(43)+.1
1305          GO TO 700
      C
1306        9 CONTINUE
1307          IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
1308          J=J+1
1309          GO TO 100
      C
1310      400 CONTINUE
      C       THIS SECTION COMPLETES BOX A
1311          C25(I,J)=10.*X(48)+X(49)+0.1
1312          C26(I,J)=10.*X(50)+X(51)+0.1
1313          C27(I,J)=10.*X(52)+X(53)+0.1
1314          C28(I,J)=10.*X(54)+X(55)+0.1
1315          C29(I,J)=X(56)+.1
1316          C30(I,J)=X(57)+.1
1317          C31(I,J)=X(58)+.1
1318          C32(I,J)=X(59)+.1
1319          C33(I,J)=X(60)+.1
1320          IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
1321          J=J+1
1322          GO TO 100
      C
1323      500 CONTINUE
      C       THIS SECTION COMPLETES BOXES A AND B AND C
1324          C25(I,J)=10.*X(48)+X(49)+0.1
1325          C26(I,J)=10.*X(50)+X(51)+0.1
1326          C27(I,J)=10.*X(52)+X(53)+0.1
1327          C28(I,J)=10.*X(54)+X(55)+0.1
1328          C29(I,J)=X(56)+.1
1329          C30(I,J)=X(57)+.1
1330          C31(I,J)=X(58)+.1
1331          C32(I,J)=X(59)+.1
1332          C33(I,J)=X(60)+.1
```

```
1333          C40(I,J)=X(61)+.1
1334          C41(I,J)=X(62)+.1
1335          C42(I,J)=10.*X(63)+X(64)+0.1
1336          C45(I,J)=100.*X(65)+10.*X(66)+X(67)+.1*X(68)+.01*X(69)+.001*X(70)
1337          C46(I,J)=100.*X(71)+10.*X(72)+X(73)+.1*X(74)+.01*X(75)+.001*X(75)
1338          IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
1339          J=J+1
1340          GO TO 100
      C
1341        600 CONTINUE
      C       THIS SECTION COMPLETES BOXES A AND C
1342          C25(I,J)=10.*X(48)+X(49)+0.1
1343          C26(I,J)=10.*X(50)+X(51)+0.1
1344          C27(I,J)=10.*X(52)+X(53)+0.1
1345          C28(I,J)=10.*X(54)+X(55)+0.1
1346          C29(I,J)=X(56)+.1
1347          C30(I,J)=X(57)+.1
1348          C31(I,J)=X(58)+.1
1349          C32(I,J)=X(59)+.1
1350          C33(I,J)=X(60)+.1
1351          C45(I,J)=100.*X(65)+10.*X(66)+X(67)+.1*X(68)+.01*X(69)+.001*X(70)
1352          C46(I,J)=100.*X(71)+10.*X(72)+X(73)+.1*X(74)+.01*X(75)+.001*X(76)
1353          IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
1354          J=J+1
1355          GO TO 100
      C
1356        700 CONTINUE
      C       THIS SECTION COMPLETES BOX C
1357          C45(I,J)=100.*X(65)+10.*X(66)+X(67)+.1*X(68)+.01*X(69)+.001*X(70)
1358          C46(I,J)=100.*X(71)+10.*X(72)+X(73)+.1*X(74)+.01*X(75)+.001*X(76)
1359          IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
1360          J=J+1
1361          GO TO 100
1362        300 CONTINUE
1363       1000 FORMAT(78F1.0,2I1)
1364       9998 RETURN
1365          END
      C
      C
      C*****************************************************************
      C*****************************************************************
      C
1366          SUBROUTINE SLOPE
      C
      C*****************************************************************
      C
      C       THIS SUBROUTINE DETERMINES THE SEVERITY INDEX FOR VEHICLES TRAVERSIN
      C       VARIOUS TYPES OF DITCHES.  THE VARIABLES OF THE TERRAIN ENTERED INCL
      C       H42--FRONTSLOPE--2,3,4,6 TO 1 ONLY.  H45--BACKSLOPE--0,2,4 TO 1 ONLY
      C       H43--FILL HEIGHT--50 FEET OR LESS.  H44--DITCH WIDTH--FROM 0 TO 12 F
      C
      C*****************************************************************
      C
      C
      C
      C
      C
1367          DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
     *                  ERROR1(3,4),CS(5,5),IZERO(4)
1368          DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
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1369          DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
1370          DIMENSION OFSET(5)
1371          DIMENSION SIGR(5,5)
1372          DIMENSION PI(5,5)
1373          DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
             *            H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
             *           H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
             *           H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
             *           H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
             *           H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
             *           H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
             *           H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
             *           H63(3)
1374          DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
             *           C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
             *           C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
             *           C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
             *           C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
             *           C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
             *           C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
             *           C61(3,4), C62(3,4), C63(3,4)
      C
1375          DIMENSION IMP(5,5)
1376          DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
1377          DIMENSION  TAC(5,5), SI(5,5)
1378          INTEGER ERROR1
1379          INTEGER TEMP1,TEMP2,X
1380          INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
             *         H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
             *         H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
             *         H51,H52,H60,H61,H62,H63
      C
1381          INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
             *         C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
             *         C40,C41,C42,C60,C61,C62,C63,C9
      C
1382          INTEGER SPEED,VEL
1383          COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
             *                 ACA,RMA,TACIMP,IZERO,LIFE,INT
1384          COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
1385          COMMON/ CST1/COST1
1386          COMMON / NCONT / NCOUNT, IPAGE, LINES,NDES, NHWY, NSPD, NADT
      C
      C
1387          COMMON/ ENFRE /ENFR
      C
1388          COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
1389          COMMON/ LATOF /OFSET
      C
      C
      C
1390          COMMON/ IMPROB /IMP
      C
1391          COMMON/ GRSI /SIGR
      C
1392          COMMON/ HOST /PI,SI
      C
1393          COMMON/ SLOPE1 /SISL
1394          COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
             *               H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
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     *                H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
     *                H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
1395   CCMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
     *           C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
     *               C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
1396   CCMMON/ GRCRC / CS
1397   CCMMON/ ERROR /ERROR1
1398   REAL IMP
1399   DATA SPEED(1)/40/,SPEED(2)/50/,SPEED(3)/60/,SPEED(4)/70/,
     *SPEED(5)/80/
      C
1400   DATA ANGLE(1)/7.5/,ANGLE(2)/10./,ANGLE(3)/15./,ANGLE(4)/20./,
     *ANGLE(5)/25./
      C
      C
      C
1401  9999  CCNTINUE
1402        IF(IFLAG .EQ. 1) GO TO 501
1403        IF(IFLAG .EQ. 2) GO TO 502
1404        CCNTINUE
1405   501  ITEMP1 = H42(II)
1406        ITEMP2 = H43(II)
1407        ITEMP3 = H44(II)
1408        ITEMP4 = H45(II)
1409        GO TO 503
1410   502  ITEMP1 = C15(II,JJ)
1411        ITEMP2 = C16(II,JJ)
1412        ITEMP3 = C17(II,JJ)
1413        ITEMP4 = C18(II,JJ)
1414   503  CCNTINUE
      C
      C
      C
      C
      C
      C
      C
1415        DO 1001 K=1,5
1416        DO 1002 L=1,5
      C
1417        VEL=SPEED(K)
1418        ANG=ANGLE(L)
      C
1419        GO TO (1,2,3,4,1,6),ITEMP1
      C
1420    1   GO TO 1003
      C
      C
1421    2   IF(ITEMP4 .EQ. 0) GO TO 7
1422        IF(ITEMP4 .EQ. 4) GO TO 8
1423        IF(ITEMP4 .EQ. 2) GO TO 9
1424        GO TO 1004
      C
1425    3   IF(ITEMP4 .EQ. 0) GO TO 10
1426        IF(ITEMP4 .EQ. 4) GO TO 11
1427        IF(ITEMP4 .EQ. 2) GO TO 12
1428        GO TO 1004
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1429     4     IF(ITEMP4 .EQ. 0) GO TO 13
1430           IF(ITEMP4 .EQ. 4) GO TO 14
1431           IF(ITEMP4 .EQ. 2) GO TO 15
1432           GO TO 1004
1433     6     IF(ITEMP4 .EQ. 0) GO TO 16
1434           IF(ITEMP4 .EQ. 4) GO TO 17
1435           IF(ITEMP4 .EQ. 2) GO TO 18
1436           GO TO 1004
       C
       C
       C
1437     7     IF(ITEMP2 .GT. 15) GO TO 200
1438           IF(ANG .LT. 22.5) GO TO 100
1439           SISI(K,L)=0.010*VEL+0.900
1440           GO TO 1000
1441     100   IF(ANG .LT. 17.5) GO TO 101
1442           SISI(K,L)=0.028*VEL-0.400
1443           GO TO 1000
1444     101   IF(ANG .LT. 12.5) GO TO 102
1445           SISI(K,L)=0.045*VEL-1.633
1446           GO TO 1000
1447     102   IF(ANG .LE. 7.5) GO TO 103
1448           SISI(K,L)=0.015*VEL-0.190
1449           GO TO 1000
1450     103   IF(ANG .LT. 0.0) GO TO 104
1451           SISI(K,L)=0.000*VEL+0.533
1452           GO TO 1000
1453     104   CONTINUE
       C
       C
1454     200   IF(ITEMP2 .GT. 25) GO TO 201
1455           IF(ANG .LT. 22.5) GO TO 105
1456           SISI(K,L)=0.075*VEL-2.433
1457           GO TO 1000
1458     105   IF(ANG .LT. 17.5) GO TO 106
1459           SISI(K,L)=0.0485*VEL-1.365
1460           GO TO 1000
1461     106   IF(ANG .LT. 12.5) GO TO 107
1462           SISI(K,L)=0.020*VEL-0.200
1463           GO TO 1000
1464     107   IF(ANG .LE. 7.5) GO TO 108
1465           SISI(K,L)=0.0095*VEL+0.405
1466           GO TO 1000
1467     108   IF(ANG .LT. 0.0) GO TO 109
1468           SISI(K,L)=0.005*VEL+0.667
1469           GO TO 1000
1470     109   CONTINUE
       C
       C
1471     201   IF(ITEMP2 .GT. 40) GO TO 202
1472           IF(ANG .LT. 22.5) GO TO 110
1473           SISI(K,L)=0.020*VEL+0.033
1474           GO TO 1000
1475     110   IF(ANG .LT. 17.5) GO TO 111
1476           SISI(K,L)=0.0095*VEL+0.543
1477           GO TO 1000
1478     111   IF(ANG .LT. 12.5) GO TO 112
1479           SISI(K,L)=0.000*VEL+1.000
1480           GO TO 1000
1481     112   IF(ANG .LE. 7.5) GO TO 113
1482           SISI(K,L)=0.000*VEL+1.170
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1483          GO TO 1000
1484     113  IF(ANG .LT. 0.0) GO TO 114
1485          SISL(K,L)=0.000*VEL+1.267
1486          GO TO 1000
1487     114  CONTINUE
         C
         C
1488     202  GO TO 1005
         C
         C
         C
1489     8    IF(ITEMP2 .GT. 15) GO TO 203
1490          IF(ANG .LT. 22.5) GO TO 115
1491          SISI(K,L)=-0.0194*VEL+4.0456
1492          GO TO 1000
1493     115  IF(ANG .LT. 17.5) GO TO 116
1494          SISL(K,L)=0.0029*VEL+1.9126
1495          GO TO 1000
1496     116  IF(ANG .LT. 12.5) GO TO 117
1497          SISI(K,L)=0.0243*VEL-0.1942
1498          GO TO 1000
1499     117  IF(ANG .LE. 7.5) GO TO 118
1500          SISL(K,I)=0.0165*VEL-0.0485
1501          GO TO 1000
1502     118  IF(ANG .LT. 0.0) GO TO 119
1503          SISL(K,I)=0.0097*VEI+0.0000
1504          GO TO 1000
1505     119  CONTINUE
         C
         C
1506     203  IF(ITEMP2 .GT. 25) GO TO 204
1507          IF (ANG .LT. 22.5) GO TO 120
1508          SISI(K,L)=0.1117*VEI-3.4631
1509          GO TO 1000
1510     120  IF(ANG .LT. 17.5) GO TO 121
1511          SISI(K,L)=0.0738*VEL-2.2524
1512          GO TO 1000
1513     121  IF(ANG .LT. 12.5) GO TO 122
1514          SISL(K,L)=0.0485*VEL-1.4563
1515          GO TO 1000
1516     122  IF(ANG .LE. 7.5) GO TO 123
1517          SISL(K,L)=0.0233*VEL-0.2330
1518          GO TO 1000
1519     123  IF(ANG .LT. 0.0) GO TO 124
1520          SISI(K,L)=0.0049*VEL+0.6476
1521          GO TO 1000
1522     124  CONTINUE
         C
         C
1523     204  IF(ITEMP2 .GT. 40) GO TO 205
1524          IF(ANG .LT. 22.5) GO TO 125
1525          SISI(K,L)=0.0680*VEL-1.6505
1526          GO TO 1000
1527     125  IF(ANG .LT. 17.5) GO TO 126
1528          SISL(K,L)=0.0325*VEL+0.3078
1529          GO TO 1000
1530     126  IF(ANG .LT. 12.5) GO TO 127
1531          SISL(K,L)=0.0097*VEI+1.5534
1532          GO TO 1000
1533     127  IF(ANG .LE. 7.5) GO TO 128
1534          SISL(K,L)=0.0068*VEL+1.1553
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1535          GO TO 1000
1536    128   IF(ANG .LT. 0.0) GO TO 129
1537          SISL(K,L)=0.0049*VEL+0.9058
1538          GO TO 1000
1539    129   CONTINUE
      C
      C
1540    205   GO TO 1005
      C
      C
      C
1541    9     IF(ITEMP2 .GT. 15) GO TO 206
1542          IF(ANG .LT. 22.5) GO TO 130
1543          SISL(K,L)=-0.020*VEL+4.167
1544          GO TO 1000
1545    130   IF(ANG .LT. 17.5) GO TO 131
1546          SISL(K,L)=0.003*VEL+1.970
1547          GO TO 1000
1548    131   IF(ANG .LT. 12.5) GO TO 132
1549          SISL(K,L)=0.025*VEL-0.200
1550          GO TO 1000
1551    132   IF(ANG .LE. 7.5) GO TO 133
1552          SISL(K,L)=0.0170*VEL-0.050
1553          GO TO 1000
1554    133   IF(ANG .LT. 0.0) GO TO 134
1555          SISL(K,L)=0.010*VEL+0.000
1556          GO TO 1000
1557    134   CONTINUE
      C
      C
1558    206   IF(ITEMP2 .GT. 25) GO TO 207
1559          IF(ANG .LT. 22.5) GO TO 135
1560          SISL(K,L)=0.115*VEL-3.567
1561          GO TO 1000
1562    135   IF(ANG .LT. 17.5) GO TO 136
1563          SISL(K,L)=0.076*VEL-2.320
1564          GO TO 1000
1565    136   IF(ANG .LT. 12.5) GO TO 137
1566          SISL(K,L)=0.050*VEL-1.500
1567          GO TO 1000
1568    137   IF(ANG .LE. 7.5) GO TO 138
1569          SISL(K,L)=0.024*VEL-0.240
1570          GO TO 1000
1571    138   IF(ANG .LT. 0.0) GO TO 139
1572          SISL(K,L)=0.005*VEL+0.667
1573          GO TO 1000
1574    139   CONTINUE
      C
      C
1575    207   IF(ITEMP2 .GT. 40) GO TO 208
1576          IF(ANG .LT. 22.5) GO TO 140
1577          SISL(K,L)=0.070*VEL-1.700
1578          GO TO 1000
1579    140   IF(ANG .LT. 17.5) GO TO 141
1580          SISL(K,L)=0.0335*VEL+0.317
1581          GO TO 1000
1582    141   IF(ANG .LT. 12.5) GO TO 142
1583          SISL(K,L)=0.010*VEL+1.600
1584          GO TO 1000
1585    142   IF(ANG .LE. 7.5) GO TO 143
1586          SISL(K,L)=0.007*VEL+1.190
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1587          GO TO 1000
1588     143  IF(ANG .LT. 0.0) GO TO 144
1589          SISL(K,L)=0.005*VEL+0.933
1590          GO TO 1000
1591     144  CONTINUE
         C
         C
1592     208  GO TO 1005
         C
         C
         C
1593     10   IF(ITEMP2 .GT. 15) GO TO 209
1594          IF(ANG .LT. 22.5) GO TO 145
1595          SISL(K,L)=0.050*VEL-2.133
1596          GO TO 1000
1597     145  IF(ANG .LT. 17.5) GO TO 146
1598          SISL(K,L)=0.026*VEL-0.897
1599          GO TO 1000
1600     146  IF(ANG .LT. 12.5) GO TO 147
1601          SISL(K,L)=0.000*VEL+0.467
1602          GO TO 1000
1603     147  IF(ANG .LE. 7.5) GO TO 148
1604          SISL(K,L)=0.000*VEL+0.370
1605          GO TO 1000
1606     148  IF(ANG .LT. 0.0) GO TO 149
1607          SISL(K,L)=0.000*VEL+0.300
1608          GO TO 1000
1609     149  CONTINUE
         C
         C
1610     209  IF(ITEMP2 .GT. 25) GO TO 210
1611          IF(ANG .LT. 22.5) GO TO 150
1612          SISL(K,L)=0.015*VEL-0.100
1613          GO TO 1000
1614     150  IF(ANG .LT. 17.5) GO TO 151
1615          SISL(K,L)=0.010*VEL+0.700
1616          GO TO 1000
1617     151  IF(ANG .LT. 12.5) GO TO 152
1618          SISL(K,L)=0.005*VEL-0.233
1619          GO TO 1000
1620     152  IF(ANG .LE. 7.5) GO TO 153
1621          SISL(K,L)=0.003*VEL+0.373
1622          GO TO 1000
1623     153  IF(ANG .LT. 0.0) GO TO 154
1624          SISL(K,L)=0.000*VEL+0.567
1625          GO TO 1000
1626     154  CONTINUE
         C
         C
1627     210  IF(ITEMP2 .GT. 40) GO TO 211
1628          IF(ANG .LT. 22.5) GO TO 155
1629          SISL(K,L)=0.015*VEL-0.067
1630          GO TO 1000
1631     155  IF(ANG .LT. 17.5) GO TO 156
1632          SISL(K,L)=0.006*VEL+0.457
1633          GO TO 1000
1634     156  IF(ANG .LT. 12.5) GO TO 157
1635          SISL(K,L)=-0.005*VEL+1.033
1636          GO TO 1000
1637     157  IF(ANG .LE. 7.5) GO TO 158
1638          SISL(K,L)=-0.005*VEL+0.967
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1639          GO TO 1000
1640     158  IF(ANG .LT. 0.0) GO TO 159
1641          SISL(K,L)=-0.005*VEL+0.933
1642          GO TO 1000
1643     159  CONTINUE
      C
      C
1644     211  GO TO 1005
      C
      C
      C
1645      11  IF(ITEMP2 .GT. 15) GO TO 212
1646          IF(ANG .LT. 22.5) GO TO 160
1647          SISL(K,L)=0.060*VEL-2.400
1648          GO TO 1000
1649     160  IF(ANG .LT. 17.5) GO TO 161
1650          SISL(K,L)=0.0305*VEL-1.000
1651          GO TO 1000
1652     161  IF(ANG .LT. 12.5) GO TO 162
1653          SISL(K,L)=0.020*VEL-0.533
1654          GO TO 1000
1655     162  IF(ANG .LE. 7.5) GO TO 163
1656          SISL(K,L)=0.009*VEL-0.027
1657          GO TO 1000
1658     163  IF(ANG .LT. 0.0) GO TO 164
1659          SISL(K,L)=0.005*VEL+0.133
1660          GO TO 1000
1661     164  CONTINUE
      C
      C
1662     212  IF(ITEMP2 .GT. 25) GO TO 213
1663          IF(ANG .LT. 22.5) GO TO 165
1664          SISL(K,L)=0.030*VEL-0.600
1665          GO TO 1000
1666     165  IF(ANG .LT. 17.5) GO TO 166
1667          SISL(K,L)=0.0235*VEL-0.407
1668          GO TO 1000
1669     166  IF(ANG .LT. 12.5) GO TO 167
1670          SISL(K,L)=0.020*VEL-0.367
1671          GO TO 1000
1672     167  IF(ANG .LE. 7.5) GO TO 168
1673          SISL(K,L)=0.0025*VEL+0.697
1674          GO TO 1000
1675     168  IF(ANG .LT. 0.0) GO TO 169
1676          SISL(K,L)=-0.005*VEL+1.167
1677          GO TO 1000
1678     169  CONTINUE
      C
      C
1679     213  IF(ITEMP2 .GT. 40) GO TO 214
1680          IF(ANG .LT. 22.5) GO TO 170
1681          SISL(K,L)=0.025*VEL-0.033
1682          GO TO 1000
1683     170  IF(ANG .LT. 17.5) GO TO 171
1684          SISL(K,L)=0.0205*VEL+0.056
1685          GO TO 1000
1686     171  IF(ANG .LT. 12.5) GO TO 172
1687          SISL(K,L)=0.020*VEL-0.133
1688          GO TO 1000
1689     172  IF(ANG .LE. 7.5) GO TO 173
1690          SISL(K,L)=0.012*VEL+0.460
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1691          GO TO 1000
1692     173  IF(ANG .LT. 0.0) GO TO 174
1693          SISL(K,L)=0.010*VEL+0.667
1694          GO TO 1000
1695     174  CONTINUE
       C
       C
1696     214  GO TO 1005
       C
       C
       C
1697     12   IF(ITEMP2 .GT. 15) GO TO 215
1698          IF(ANG .LT. 22.5) GO TO 175
1699          SISL(K,L)=0.1020*VEL-4.080
1700          GO TO 1000
1701     175  IF(ANG .LT. 17.5) GO TO 176
1702          SISL(K,L)=0.0519*VEL-1.700
1703          GO TO 1000
1704     176  IF(ANG .LT. 12.5) GO TO 177
1705          SISL(K,L)=0.0340*VEL-0.9061
1706          GO TO 1000
1707     177  IF(ANG .LE. 7.5) GO TO 178
1708          SISL(K,L)=0.0153*VEL-0.0459
1709          GO TO 1000
1710     178  IF(ANG .LT. 0.0) GO TO 179
1711          SISL(K,L)=0.0085*VEL+0.2261
1712          GO TO 1000
1713     179  CONTINUE
       C
       C
1714     215  IF(ITEMP2 .GT. 25) GO TO 216
1715          IF(ANG .LT. 22.5) GO TO 180
1716          SISL(K,L)=0.0510*VEL-1.020
1717          GO TO 1000
1718     180  IF(ANG .LT. 17.5) GO TO 181
1719          SISL(K,L)=0.040*VEL-0.6919
1720          GO TO 1000
1721     181  IF(ANG .LT. 12.5) GO TO 182
1722          SISL(K,L)=0.0340*VEL-0.6239
1723          GO TO 1000
1724     182  IF(ANG .LE. 7.5) GO TO 183
1725          SISL(K,L)=0.0043*VEL+1.1849
1726          GO TO 1000
1727     183  IF(ANG .LT. 0.0) GO TO 184
1728          SISL(K,L)=-0.0085*VEL+1.9839
1729          GO TO 1000
1730     184  CONTINUE
       C
       C
1731     216  IF(ITEMP2 .GT. 40) GO TO 217
1732          IF(ANG .LT. 22.5)GO TO 185
1733          SISL(K,L)=0.0425*VEL-0.0561
1734          GO TO 1000
1735     185  IF(ANG .LT. 17.5) GO TO 186
1736          SISL(K,L)=0.0349*VEL+0.0952
1737          GO TO 1000
1738     186  IF(ANG .LT. 12.5) GO TO 187
1739          SISL(K,L)=0.0340*VEL-0.2261
1740          GO TO 1000
1741     187  IF(ANG .LE. 7.5) GO TO 188
1742          SISL(K,L)=0.0204*VEL+0.7820
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1743          GO TO 1000
1744     188  IF (ANG .LT. 0.0) GO TO 189
1745          SISI(K,L)=0.0170*VEL+1.1339
1746          GO TO 1000
1747     189  CONTINUE
             C
             C
1748     217  GO TO 1005
             C
             C
             C
1749      13  IF(ITEMP2 .GT.15) GO TO 218
1750          IF(ANG .LT. 22.5) GO TO 190
1751          SISI(K,L)=0.010*VEL-0.067
1752          GO TO 1000
1753     190  IF(ANG .LT. 17.5) GO TO 191
1754          SISI(K,L)=0.0075*VEL-0.007
1755          GO TO 1000
1756     191  IF(ANG .LT. 12.5) GO TO 192
1757          SISI(K,L)=0.005*VEL+0.067
1758          GO TO 1000
1759     192  IF(ANG .LE. 7.5) GO TO 193
1760          SISI(K,L)=0.0025*VEL+0.193
1761          GO TO 1000
1762     193  IF(ANG .LT. 0.0) GO TO 194
1763          SISI(K,L)=0.0015*VEL+0.233
1764          GO TO 1000
1765     194  CONTINUE
             C
             C
1766     218  IF(ITEMP2 .GT. 25) GO TO 219
1767          IF(ANG .LT. 22.5) GO TO 195
1768          SISI(K,L)=0.010*VEL+0.067
1769          GO TO 1000
1770     195  IF(ANG .LT. 17.5) GO TO 196
1771          SISI(K,L)=0.0055*VEL+0.243
1772          GO TO 1000
1773     196  IF(ANG .LT. 12.5) GO TO 197
1774          SISI(K,L)=0.005*VEL+0.167
1775          GO TO 1000
1776     197  IF(ANG .LE. 7.5) GO TO 198
1777          SISI(K,L)=0.0045*VEL+0.133
1778          GO TO 1000
1779     198  IF(ANG .LT. 0.0) GO TO 199
1780          SISI(K,L)=0.005*VEL+0.067
1781          GO TO 1000
1782     199  CONTINUE
             C
             C
1783     219  IF(ITEMP2 .GT. 40) GO TO 220
1784          IF(ANG .LT. 22.5) GO TO 300
1785          SISI(K,L)=0.000*VEL+0.767
1786          GO TO 1000
1787     300  IF(ANG .LT. 17.5) GO TO 301
1788          SISI(K,L)=0.000*VEL+0.680
1789          GO TO 1000
1790     301  IF(ANG .LT. 12.5) GO TO 302
1791          SISI(K,L)=0.000*VEL+0.600
1792          GO TO 1000
1793     302  IF(ANG .LE. 7.5) GO TO 303
1794          SISI(K,L)=0.0025*VEL+0.340
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1795          GO TO 1000
1796     303  IF(ANG .LT. 0.0) GO TO 304
1797          SISL(K,L)=0.005*VEL+0.133
1798          GO TO 1000
1799     304  CONTINUE
      C
      C
1800     220  GO TO 1005
      C
      C
      C
1801      14  IF(ITEMP2  .GT. 15) GO TO 221
1802          IF(ANG .LT. 22.5) GO TO 305
1803          SISI(K,L)=0.010*VEL+0.367
1804          GO TO 1000
1805     305  IF(ANG .LT. 17.5) GO TO 306
1806          SISI(K,L)=0.0065*VEL+0.407
1807          GO TO 1000
1808     306  IF(ANG .LT. 12.5)  GO TO 307
1809          SISI(K,L)=0.005*VEL+0.333
1810          GO TO 1000
1811     307  IF(ANG .LE. 7.5) GO TO 308
1812          SISI(K,L)=0.0075*VEL+0.087
1813          GO TO 1000
1814     308  IF(ANG .LT. 0.0) GO TO 309
1815          SISI(K,L)=0.010*VEL-0.167
1816          GO TO 1000
1817     309  CONTINUE
      C
      C
1818     221  IF(ITEMP2 .GT. 25) GO TO 222
1819          IF(ANG .LT. 22.5) GO TO 310
1820          SISI(K,L)=0.015*VEL+0.167
1821          GO TO 1000
1822     310  IF(ANG .LT. 17.5) GO TO 311
1823          SISI(K,L)=0.0115*VEL+0.303
1824          GO TO 1000
1825     311  IF(ANG .LT. 12.5) GO TO 312
1826          SISI(K,L)=0.010*VEL+0.333
1827          GO TO 1000
1828     312  IF(ANG .LE. 7.5) GO TO 313
1829          SISI(K,L)=-0.003*VEL+0.890
1830          GO TO 1000
1831     313  IF(ANG .LT. 0.0) GO TO 314
1832          SISI(K,L)=-0.005*VEL+0.833
1833          GO TO 1000
1834     314  CONTINUE
      C
      C
1835     222  IF(ITEMP2 .GT. 40) GO TO 223
1836          IF(ANG .LT. 22.5) GO TO 315
1837          SISI(K,L)=0.006*VEL+0.860
1838          GO TO 1000
1839     315  IF(ANG .LT. 17.5) GO TO 316
1840          SISI(K,L)=0.0005*VEL+1.133
1841          GO TO 1000
1842     316  IF(ANG .LT. 12.5) GO TO 317
1843          SISI(K,L)=-0.004*VEL+1.360
1844          GO TO 1000
1845     317  IF(ANG .LE. 7.5) GO TO 318
1846          SISI(K,L)=-0.0065*VEL+1.423
```

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1847          GO TO 1000
1848     318  IF(ANG .LT. 0.0) GO TO 319
1849          SISI(K,L)=-0.008*VEL+1.447
1850          GO TO 1000
1851     319  CONTINUE
      C
      C
1852     223  GO TO 1005
      C
      C
      C
1853      15  IF(ITEMP2 .GT.15) GO TO 224
1854          IF(ANG .LT. 22.5) GO TO 320
1855          SISI(K,L)=0.0170*VEL+0.6239
1856          GO TO 1000
1857     320  IF(ANG .LT. 17.5) GO TO 321
1858          SISI(K,L)=0.0111*VEL+0.6919
1859          GO TO 1000
1860     321  IF(ANG .LT. 12.5) GO TO 322
1861          SISI(K,L)=0.0085*VEL+0.5661
1862          GO TO 1000
1863     322  IF(ANG .LE. 7.5) GO TO 323
1864          SISI(K,L)=0.0128*VEL+0.1479
1865          GO TO 1000
1866     323  IF(ANG .LT. 0.0) GO TO 324
1867          SISI(K,L)=0.0170*VEL-0.2839
1868          GO TO 1000
1869     324  CONTINUE
      C
      C
1870     224  IF(ITEMP2 .GT. 25) GO TO 225
1871          IF(ANG .LT. 22.5) GO TO 325
1872          SISI(K,L)=0.0255*VEL+0.2839
1873          GO TO 1000
1874     325  IF(ANG .LT. 17.5) GO TO 326
1875          SISI(K,L)=0.0196*VEL+0.5151
1876          GO TO 1000
1877     326  IF(ANG .LT. 12.5) GO TO 327
1878          SISI(K,L)=0.0170*VEL+0.5661
1879          GO TO 1000
1880     327  IF(ANG .LE. 7.5) GO TO 328
1881          SISI(K,L)=-0.0051*VEL+1.5130
1882          GO TO 1000
1883     328  IF(ANG .LT. 0.0) GO TO 329
1884          SISI(K,L)=-0.0085*VEL+1.4161
1885          GO TO 1000
1886     329  CONTINUE
      C
      C
1887     225  IF(ITEMP2 .GT. 40) GO TO 226
1888          IF(ANG .LT. 22.5) GO TO 330
1889          SISI(K,L)=0.0102*VEL+1.4620
1890          GO TO 1000
1891     330  IF(ANG .LT. 17.5) GO TO 331
1892          SISI(K,L)=0.0009*VEL+1.9261
1893          GO TO 1000
1894     331  IF(ANG .LT. 12.5) GO TO 332
1895          SISI(K,L)=-0.0068*VEL+2.3120
1896          GO TO 1000
1897     332  IF(ANG .LE. 7.5) GO TO 333
1898          SISI(K,L)=-0.0111*VEL+2.4191
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1899          GO TO 1000
1900     333  IF(ANG .LT. 0.0) GO TO 334
1901          SISI(K,L)=-0.0136*VEL+2.4599
1902          GO TO 1000
1903     334  CONTINUE
             C
             C
1904     226  GO TO 1005
             C
             C
             C
1905      16  IF(ITEMP2 .GT. 15) GO TO 227
1906          IF(ANG .LT. 22.5) GO TO 335
1907          SISI(K,L)=0.015*VEL-0.567
1908          GO TO 1000
1909     335  IF(ANG .LT. 17.5) GO TO 336
1910          SISI(K,L)=0.009*VEL-0.250
1911          GO TO 1000
1912     336  IF(ANG .LT. 12.5) GO TO 337
1913          SISI(K,L)=0.005*VEL-0.067
1914          GO TO 1000
1915     337  IF(ANG .LE. 7.5) GO TO 338
1916          SISI(K,L)=-0.001*VEL+0.260
1917          GO TO 1000
1918     338  IF(ANG .LT. 0.0) GO TO 339
1919          SISI(K,L)=-0.005*VEL+0.467
1920          GO TO 1000
1921     339  CONTINUE
             C
             C
1922     227  IF(ITEMP2 .GT. 25) GO TO 228
1923          IF(ANG .LT. 22.5) GO TO 340
1924          SISI(K,L)=0.015*VEL-0.567
1925          GO TO 1000
1926     340  IF(ANG .LT. 17.5) GO TO 341
1927          SISI(K,L)=0.009*VEL-0.250
1928          GO TO 1000
1929     341  IF(ANG .LT. 12.5) GO TO 342
1930          SISI(K,L)=0.005*VEL-0.067
1931          GO TO 1000
1932     342  IF (ANG .LE. 7.5) GO TO 343
1933          SISI(K,L)=-0.001*VEL+0.260
1934          GO TO 1000
1935     343  IF(ANG .LT. 0.0) GO TO 344
1936          SISI(K,L)=-0.005*VEL+0.467
1937          GO TO 1000
1938     344  CONTINUE
             C
             C
1939     228  IF(ITEMP2 .GT. 40) GO TO 229
1940          IF(ANG .LT. 22.5) GO TO 345
1941          SISI(K,L)=0.015*VEL-0.567
1942          GO TO 1000
1943     345  IF(ANG .LT. 17.5) GO TO 346
1944          SISI(K,L)=0.009*VEL-0.250
1945          GO TO 1000
1946     346  IF(ANG .LT. 12.5) GO TO 347
1947          SISI(K,L)=0.005*VEL-0.067
1948          GO TO 1000
1949     347  IF(ANG .LE. 7.5) GO TO 348
1950          SISI(K,L)=-0.001*VEL+0.260
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1951          GO TO 1000
1952     348  IF(ANG .LT. 0.0) GO TO 349
1953          SISI(K,L)=-0.005*VEL+0.467
1954          GO TO 1000
1955     349  CONTINUE
              C
              C
1956     229  GO TO 1005
              C
              C
              C
1957      17  IF(ITEMP2 .GT. 15) GO TO 230
1958          IF(ANG .LT. 22.5) GO TO 350
1959          SISI(K,L)=0.020*VEL-0.367
1960          GO TO 1000
1961     350  IF(ANG .LT. 17.5) GO TO 351
1962          SISI(K,L)=0.0125*VEL-0.037
1963          GO TO 1000
1964     351  IF(ANG .LT. 12.5) GO TO 352
1965          SISI(K,L)=0.005*VEL+0.300
1966          GO TO 1000
1967     352  IF(ANG .LE. 7.5) GO TO 353
1968          SISI(K,L)=-0.001*VEL+0.560
1969          GO TO 1000
1970     353  IF(ANG .LT. 0.0) GO TO 354
1971          SISI(K,L)=-0.005*VEL+0.767
1972          GO TO 1000
1973     354  CONTINUE
              C
              C
1974     230  IF(ITEMP2 .GT. 25) GO TO 231
1975          IF(ANG .LT. 22.5) GO TO 355
1976          SISI(K,L)=0.020*VEL-0.367
1977          GO TO 1000
1978     355  IF(ANG .LT. 17.5) GO TO 356
1979          SISI(K,L)=0.0125*VEL-0.037
1980          GO TO 1000
1981     356  IF(ANG .LT. 12.5) GO TO 357
1982          SISI(K,L)=0.005*VEL+0.300
1983          GO TO 1000
1984     357  IF(ANG .LE. 7.5) GO TO 358
1985          SISI(K,L)=-0.001*VEL+0.560
1986          GO TO 1000
1987     358  IF(ANG .LT. 0.0) GO TO 359
1988          SISI(K,L)=-0.005*VEL+0.767
1989          GO TO 1000
1990     359  CONTINUE
              C
              C
1991     231  IF(ITEMP2 .GT. 40) GO TO 232
1992          IF (ANG .LT. 22.5) GO TO 360
1993          SISI(K,L)=0.020*VEL-0.367
1994          GO TO 1000
1995     360  IF(ANG .LT. 17.5) GO TO 361
1996          SISI(K,L)=0.0125*VEL-0.037
1997          GO TO 1000
1998     361  IF(ANG .LT. 12.5) GO TO 362
1999          SISI(K,L)=0.005*VEL+0.300
2000          GO TO 1000
2001     362  IF(ANG .LE. 7.5) GO TO 363
2002          SISI(K,L)=-0.001*VEL+0.560
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2003          GO TO 1000
2004     363  IF(ANG .LT. 0.0) GO TO 364
2005          SISI(K,L)=-0.005*VEL+0.767
2006          GO TO 1000
2007     364  CONTINUE
              C
              C
2008     232  GO TO 1005
              C
              C
              C
2009      18  IF(ITEMP2 .GT. 15) GO TO 233
2010          IF(ANG .LT. 22.5) GO TO 365
2011          SISI(K,L)=0.0340*VEL-0.6239
2012          GO TO 1000
2013     365  IF(ANG .LT. 17.5) GO TO 366
2014          SISI(K,L)=0.0213*VEL-0.0629
2015          GO TO 1000
2016     366  IF(ANG .LT. 12.5) GO TO 367
2017          SISI(K,L)=0.0085*VEL+0.5100
2018          GO TO 1000
2019     367  IF(ANG .LE. 7.5) GO TO 368
2020          SISI(K,L)=-0.0017*VEI+0.9520
2021          GO TO 1000
2022     368  IF(ANG .LT. 0.0) GO TO 369
2023          SISI(K,L)=-0.0085*VEL+1.3039
2024          GO TO 1000
2025     369  CONTINUE
              C
              C
2026     233  IF(ITEMP2 .GT. 25) GO TO 234
2027          IF (ANG .LT. 22.5) GO TO 370
2028          SISI(K,L)=0.0340*VEL-0.6239
2029          GO TO 1000
2030     370  IF(ANG .LT. 17.5) GO TO 371
2031          SISI(K,L)=0.0213*VEL-0.0629
2032          GO TO 1000
2033     371  IF(ANG .LT. 12.5) GO TO 372
2034          SISI(K,L)=0.0085*VEL+0.5100
2035          GO TO 1000
2036     372  IF(ANG .LE. 7.5) GO TO 373
2037          SISI(K,L)=-0.0017*VEI+0.9520
2038          GO TO 1000
2039     373  IF(ANG .LT. 0.0) GO TO 374
2040          SISI(K,L)=-0.0085*VEI+1.3039
2041          GO TO 1000
2042     374  CONTINUE
              C
              C
2043     234  IF(ITEMP2 .GT. 40) GO TO  235
2044          IF(ANG .LT. 22.5) GO TO 375
2045          SISI(K,L)=0.0340*VEL-0.6239
2046          GO TO 1000
2047     375  IF(ANG .LT. 17.5) GO TO 376
2048          SISI(K,L)=0.0213*VEL-0.0629
2049          GO TO 1000
2050     376  IF(ANG .LT. 12.5) GO TO 377
2051          SISI(K,L)=0.0085*VEL+0.5100
2052          GO TO 1000
2053     377  IF(ANG .LE. 7.5) GO TO 378
2054          SISI(K,L)=-0.0017*VEI+0.9520
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2055          GO TO 1000
2056     378  IF(ANG .LT. 0.0) GO TO 379
2057          SISI(K,I)=-0.0085*VEL+1.3039
2058          GO TO 1000
2059     379  CONTINUE
         C
         C
2060     235  GO TO 1005
         C
         C
2061     1000 CONTINUE
         C    SI ADJUSTMENT FACTORS FOR DITCH TYPES.
         C
2062          IF(ITEMP3 .GE. 8) GO TO 400
2063          IF(ITEMP3 .LT. 8 .AND. H44(II) .GT. 4) GO TO 401
2064          IF(ITEMP3 .LE. 4) GO TO 402
         C
         C
         C
2065     400  SISI(K,L)=SISI(K,L)*0.70
2066          GO TO 403
         C
2067     401  SISI(K,L)=SISI(K,L)*0.81
2068          GO TO 403
         C
2069     402  SISI(K,L)=SISI(K,L)*1.00
         C    SI ADJUSTMENT FACTORS FOR WATER IN DITCH
2070          IF(IFLAG .EQ. 1 .AND. H48(II) .EQ. 2) GO TO 800
2071          IF(IFLAG .EQ. 1) GO TO 810
2072          IF(IFLAG .EQ. 2 .AND. C21(II,JJ) .EQ. 2) GO TO 800
2073          GO TO 810
2074     800  SISI(K,L) = SISI(K,L)*1.05
2075          GO TO 811
2076     810  IF(IFLAG .EQ. 1 .AND. H48(II) .EQ. 3) GO TO 801
2077          IF(IFLAG .EQ. 1) GO TO 811
2078          IF(IFLAG .EQ. 2 .AND. C21(II,JJ) .EQ. 3) GO TO 801
2079          GO TO 811
2080     801  SISI(K,L) = SISI(K,L)*1.10
2081     811  CONTINUE
         C
2082     403  IF(SISI(K,L) .GE. 0.2) GO TO 405
2083     404  SISI(K,L)=0.200
2084     405  CONTINUE
         C
         C
         C    SI ADJUSTMENT FACTORS FOR ROUGH SLOPES
2085          IF(IFLAG .EQ. 1 .AND. H47(II) .EQ. 2) GO TO 901
2086          IF(IFLAG .EQ. 1) GO TO 905
2087          IF(IFLAG .EQ. 2 .AND. C20(II,JJ) .EQ. 2) GO TO 901
2088          GO TO 905
2089     901  IF(SISI(K,L) .GE. 0.30) GO TO 905
2090          SISI(K,I) = 0.30
2091     905  GO TO 1002
         C
         C
2092     1002 CONTINUE
         C
2093     1001 CONTINUE
2094          GO TO 1006
2095     1003 IF(IFLAG .EQ. 2) GO TO 1200
2096          ERROR1(II,1) = 20
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2097          GO TO 1006
2098     1200 ERROR1(II,JJ) = 20
2099          GO TO 1006
2100     1004 IF(IFLAG .EQ. 2) GO TO 1201
2101          ERROR1(II,1) = 21
2102          GO TO 1006
2103     1201 ERROR1(II,JJ) = 21
2104          GO TO 1006
2105     1005 IF(IFLAG .EQ. 2) GO TO 1202
2106          ERROR1(II,1) = 22
2107          GO TO 1006
2108     1202 ERROR1(II,JJ) = 22
2109     1006 CONTINUE
2110     9998 RETURN
2111          END
      C
      C
      C
      C
      C
      C
      C
      C
      C
      C
      C*****************************************************************
      C*****************************************************************
      C
2112          SUBROUTINE COST3
      C
      C*****************************************************************
      C
      C     THIS SUBROUTINE CALCULATES TOTAL ACCIDENT COST GIVEN A SEVERITY
      C     INDEX (SI).  THREE DIFFERENT TYPES OF ACCIDENTS ARE USED,  PROPERTY
      C     DAMAGE ONLY, INJURY ACCIDENT, FATAL ACCIDENT.  THE COSTS OF EACH
      C     TYPE OF ACCIDENT ARE INPUT FROM THE COST FORM.  THE SI IS INPUTTED
      C     FROM EITHER WBEAM1 OR WBEAM2 OR SLOPE SUBROUTINES.
      C
      C*****************************************************************
      C*****************************************************************
      C
      C
2113          DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
     *          ERROR1(3,4),CS(5,5),IZERO(4)
2114          DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
2115          DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
2116          DIMENSION OFSET(5)
2117          DIMENSION SIGR(5,5)
2118          DIMENSION PI(5,5)
2119          DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
     *              H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
     *             H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
     *             H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
     *             H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
     *             H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
     *             H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
     *             H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
     *             H63(3)
2120          DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
     *             C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
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     *           C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
     *           C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
     *           C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
     *           C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
     *           C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
     *           C61(3,4), C62(3,4), C63(3,4)
      C
2121          DIMENSION IMP(5,5)
2122          DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
2123          DIMENSION  TAC(5,5), SI(5,5)
2124          INTEGER ERROR1
2125          INTEGER TEMP1,TEMP2,X
2126          INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
     *           H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
     *           H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
     *           H51,H52,H60,H61,H62,H63
      C
2127          INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
     *           C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
     *           C40,C41,C42,C60,C61,C62,C63,C9
      C
2128          INTEGER SPEED,VEL
2129          COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
     *                    ACA,RMA,TACIMP,IZERO,LIFE,INT
2130          COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
2131          COMMON/ CST1/COST1
2132          COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
2133          COMMON / TAC1 / TAC
      C
2134          COMMON/ ENFRE /ENFR
      C
2135          COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
2136          COMMON/ LATOF /OFSET
      C
      C
      C
2137          COMMON/ IMPROB /IMP
      C
2138          COMMON/ GRSI /SIGR
      C
2139          COMMON/ HURT /PI,SI
      C
2140          COMMON/ SLOPE1 /SISL
2141          COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
     *                  H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
     *                  H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
     *                  H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
2142          COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
     *              C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
     *                  C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
2143          COMMON/ GRCRC / CS
2144          COMMON/ ERROR /ERROR1
2145          REAL  INJURY
2146          REAL IMP
      C
2147    9999  CONTINUE
```

```
      C     PDC = 900.00
      C     INJURY = 4900.00
      C     FATAL = 336000.00
2148        DO 1 K = 1,5
2149        DO 2 L = 1,5
2150        TEMP = SI(K,L)
      C     PRINT,1,TEMP
2151        IF(TEMP.GT.2.75) GO TO 10
2152        TAC(K,L) = ((-1934.76*TEMP)+(12750.34*(TEMP**2))
           *+(9679.45*(TEMP**3)))
      C     PRINT,2,TAC
2153        GO TO 20
2154   10   TAC(K,L) = 300000.0
2155   20   CONTINUE
2156    2   CONTINUE
2157    1   CONTINUE
      C
      C
      C
      C
2158   9998 RETURN
2159        END
      C
      C
      C
      C
      C
      C**********************************************************************
      C**********************************************************************
      C
2160        SUBROUTINE REPAIR
      C
      C**********************************************************************
      C
      C     THIS SUBROUTINE CALCULATES THE COLLISION MAINTEANCE COSTS.
      C
      C
      C
      C
2161        DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
           *          ERROR1(3,4),CS(5,5),IZERO(4)
2162        DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
2163        DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
2164        DIMENSION OFSET(5)
2165        DIMENSION SIGR(5,5)
2166        DIMENSION PI(5,5)
2167        DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
           *           H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
           *          H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
           *          H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
           *          H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
           *          H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
           *          H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
           *          H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
           *          H63(3)
2168        DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
           *          C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
           *          C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
           *          C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
           *          C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
```

```
     *           C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
     *           C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
     *           C61(3,4), C62(3,4), C63(3,4)
C
      DIMENSION IMP(5,5)
      DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
      DIMENSION  TAC(5,5), SI(5,5)
      INTEGER ERROR1
      INTEGER TEMP1,TEMP2,X
      INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
     *         H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
     *         H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
     *         H51,H52,H60,H61,H62,H63
C
      INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
     *         C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
     *         C40,C41,C42,C60,C61,C62,C63,C9
C
      INTEGER SPEED,VEL
      COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
     *                 ACA,RMA,TACIMP,IZERO,LIFE,INT
      COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
      COMMON/ CST1/COST1
      COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
C
C
      COMMON/ ENFRE /ENFR
C
      COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
C
      COMMON/ LATOF /OFSET
C
C
C
      COMMON/ IMPROB /IMP
C
      COMMON/ GRSI /SIGR
C
      COMMON/ HURT /PI,SI
C
      COMMON/ SLOPE1 /SISL
      COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
     *               H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
     *               H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
     *               H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
C
C
C
      COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
     *          C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
     *               C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
C
      COMMON/ GRCRC / CS
      COMMON/ ERROR /ERROR1
      REAL IMP
9999  CONTINUE
      ASUM = 0.0
      SUM = 0.0
C --- IFLAG CHECKS TO SEE IF THE DATA IS FROM A HAZARD OR AN IMPROVEMENT
C     ALTERNATIVE.  IFLAG = 1--HAZARD.  IFLAG = 2--IMPROVEMENT ALTERNATIVE
      IF(IFLAG.EQ.1)GO TO 17
```

```
2197          ALCNG1=(ABS(C46(II,JJ)-C45(II,JJ)))*5280.0
      C
2198          GO TO 21
2199       17 ALCNG1=(ABS(H19(II)-H18(II)))*5280.0
      C
2200       21 DO 6 K = 1,5
2201          GO TO (1,2,3,4,7),K
2202        1 TEMP = 0.48*OFSET(1)
      C
2203          GO TO 10
2204        2 TEMP = 0.20*OFSET(2)
      C
2205          GO TO 10
2206        3 TEMP = 0.12*OFSET(3)
      C
2207          GO TO 10
2208        4 TEMP = 0.08*OFSET(4)
      C
2209          GO TO 10
2210        7 TEMP = 0.12*OFSET(5)
      C
2211       10 DO 5 KK = 1,5
      C
2212          SUM = IMP(KK,K)*CS(KK,K)*ALONG1+SUM
      C
      C
2213        5 CONTINUE
2214          ASUM = TEMP*SUM + ASUM
2215        6 CONTINUE
      C
      C
2216          CM =(ASUM*ENFR*0.50)/5280.0
      C
      C
      C --- THE DIRECTIONAL SPLIT IS ASSUMED TO BE 0.5 IN EACH CASE
2217     9998 RETURN
2218          END
      C
      C
      C
      C
      C*****************************************************************************
      C*****************************************************************************
      C
2219          SUBROUTINE ACCID
      C
      C*****************************************************************************
      C
      C     THIS SUBROUTINE CALCULATES ACCIDENT COSTS.
      C
      C
      C
      C
      C
      C
      C*****************************************************************************
      C*****************************************************************************
      C
      C
```

```
2220          DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
             *          ERROR1(3,4),CS(5,5),IZERO(4)
2221          DIMENSION ITAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
2222          DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
2223          DIMENSION OFSET(5)
2224          DIMENSION SIGR(5,5)
2225          DIMENSION PI(5,5)
2226          DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
             *           H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
             *          H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
             *          H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
             *          H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
             *          H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
             *          H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
             *          H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
             *          H63(3)
2227          DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
             *          C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
             *          C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
             *          C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
             *          C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
             *          C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
             *          C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
             *          C61(3,4), C62(3,4), C63(3,4)
      C
2228          DIMENSION IMP(5,5)
2229          DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
2230          DIMENSION  TAC(5,5), SI(5,5)
2231          INTEGER ERROR1
2232          INTEGER TEMP1,TEMP2,X
2233          INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
             *          H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
             *          H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
             *          H51,H52,H60,H61,H62,H63
      C
2234          INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
             *          C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
             *          C40,C41,C42,C60,C61,C62,C63,C9
      C
2235          INTEGER SPEED,VEL
2236          COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
             *                 ACA,RMA,TACIMP,IZERO,LIFE,INT
2237          COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
2238          COMMON/ CST1/COST1
2239          COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY, NSPD, NADT
2240          COMMON / TAC1 / TAC
      C
2241          COMMON/ ENFRE /ENFR
      C
2242          COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
2243          COMMON/ LATOF /OFSET
      C
      C
      C
2244          COMMON/ IMPROB /IMP
      C
2245          COMMON/ GRSI /SIGR
      C
2246          COMMON/ HUFT /PI,SI
      C
```

```
2247          COMMON/ SLOPE1 /SISL
2248          COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
             *                H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
             *                H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
             *                H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
2249          COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
             *           C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
             *               C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
2250          COMMON/ GRCRC / CS
2251          COMMON/ ERROR /ERROR1
2252          REAL IMP
2253      9999 CONTINUE
2254          ASUM = 0.0
2255          SUM = 0.0
      C --- IFLAG CHECKS TO SEE IF THE DATA IS FROM A HAZARD OR AN IMPROVEMENT
      C     ALTERNATIVE.  IFLAG = 1--HAZARD.  IFLAG = 2--IMPROVEMENT ALTERNATIVE
2256          IF(IFLAG.EQ.1)GO TO 17
2257          ALONG1=(ABS(C46(II,JJ)-C45(II,JJ)))*5280.0
      C       PRINT,2,ALONG1
2258          GO TO 21
2259         17 ALONG1=(ABS(H19(II)-H18(II)))*5280.0
      C       PRINT,1,ALONG1
2260         21 DO 6 K = 1,5
2261          GO TO (1,2,3,4,7),K
2262          1 TEMP = 0.48*OFSET(1)
      C       PRINT,1,TEMP
2263          GO TO 10
2264          2 TEMP = 0.20*OFSET(2)
      C       PRINT,2,TEMP
2265          GO TO 10
2266          3 TEMP = 0.12*OFSET(3)
      C       PRINT,3,TEMP
2267          GO TO 10
2268          4 TEMP = 0.08*OFSET(4)
      C       PRINT,4,TEMP
2269          GO TO 10
2270          7 TEMP = 0.12*OFSET(5)
      C       PRINT,5,TEMP
2271         10 DO 5 KK = 1,5
      C       PRINT,0,SUM
2272          SUM = IMP(KK,K)*TAC(KK,K)*ALONG1+SUM
      C       PRINT,1,SUM
      C       PRINT,1,IMP,2,TAC,3,ALONG1
2273          5 CONTINUE
      C       PRINT,0,ASUM
2274          ASUM = TEMP*SUM + ASUM
      C       PRINT,1,ASUM
      C       PRINT,1,TEMP,2,SUM
2275          6 CONTINUE
      C
      C
2276          AC =(ENFR*ASUM*0.50)/5280.0
      C       PRINT,AC
      C       PRINT,1,ENFR,2,ASUM
      C --- THE DIRECTIONAL SPLIT IS ASSUMED TO BE 0.5 IN EACH CASE
2277       9998 RETURN
2278          END
```

```
      C
      C*************************************************************************
      C*************************************************************************
      C
2279        SUBROUTINE NOIMPR
      C
      C*************************************************************************
      C
      C       NO IMPROVEMENT SUBROUTINE FOR SLOPES
      C
      C*************************************************************************
2280        DIMENSION HI(3),HIA(4),CHI(3,4),CMA(4),ACA(4),RMA(4),TACIMP(4),
           *          ERROR1(3,4),CS(5,5),IZERO(4)
2281        DIMENSION TTAC(4), CE(4), BC(4), ICE(4), ITAC(4), NOTCE(4)
2282        DIMENSION COST1(4),NDES(100),NHWY(100),NSPD(100),NADT(100)
2283        DIMENSION OFSET(5)
2284        DIMENSION SIGR(5,5)
2285        DIMENSION PI(5,5)
2286        DIMENSION  H0(3),H1(3), H2(3), H3(3), H4(3), H5(3), H6(3),
           *           H7(3),  H8(3),  H9(3), H10(3), H11(3), H12(3),
           *          H13(3), H14(3), H15(3), H16(3), H17(3), H18(3),
           *          H19(3), H22(3), H23(3), H24(3), H25(3), H26(3),
           *          H27(3), H30(3), H31(3), H32(3), H33(3), H34(3),
           *          H35(3), H36(3), H37(3), H38(3), H41(3), H42(3),
           *          H43(3), H44(3), H45(3), H46(3), H47(3), H48(3),
           *          H50(3), H51(3), H52(3), H60(3), H61(3), H62(3),
           *          H63(3)
2287        DIMENSION   C1(3,4),  C2(3,4),  C3(3,4),  C4(3,4),  C5(3,4),
           *          C6(3,4),C7(3,4),C8(3,4),C9(3,4),C10(3,4),C12(3,4),
           *          C13(3,4), C14(3,4), C15(3,4), C16(3,4), C17(3,4),
           *          C18(3,4), C19(3,4), C20(3,4), C21(3,4), C25(3,4),
           *          C26(3,4), C27(3,4), C28(3,4), C29(3,4), C30(3,4),
           *          C31(3,4), C32(3,4), C33(3,4), C40(3,4), C41(3,4),
           *          C42(3,4), C45(3,4), C46(3,4), C22(3,4), C60(3,4),
           *          C61(3,4), C62(3,4), C63(3,4)
      C
2288        DIMENSION IMP(5,5)
2289        DIMENSION SPEED(5),ANGLE(5),SISL(5,5)
2290        DIMENSION  TAC(5,5), SI(5,5)
2291        INTEGER ERROR1
2292        INTEGER TEMP1,TEMP2,X
2293        INTEGER  H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,H14,H15,
           *         H16,H17,H22,H23,H24,H25,H26,H27,H30,H31,H32,H33,H34,
           *         H35,H36,H37,H38,H41,H42,H43,H44,H45,H46,H47,H48,H50,
           *         H51,H52,H60,H61,H62,H63
      C
2294        INTEGER  C1,C2,C3,C5,C6,C7,C8,C10,C12,C13,C14,C15,C16,C17,C18,
           *         C19,C20,C21,C22,C25,C26,C27,C28,C29,C30,C31,C32,C33,
           *         C40,C41,C42,C60,C61,C62,C63,C9
      C
2295        INTEGER SPEED,VEL
2296        COMMON / MAIN5 / HIB,HI,CMB,CM,ACB,AC,RMB,RM,TACHAZ,HIA,CHI,CMA,
           *                 ACA,RMA,TACIMP,IZERO,LIFE,INT
2297        COMMON / RESLT / TTAC, CE, BC, NOTCE, ICE, ITAC, IGR
2298        COMMON/ CST1/COST1
2299        COMMON / NCONT / NCOUNT, IPAGE, LINES, NDES, NHWY,NSPD, NADT
      C
      C
2300        COMMON/ ENFRE /ENFR
      C
```

```
2301          COMMON/ IDENT /I,J,II,JJ,ICARD,IFLAG,IMPR,NTITLE
      C
2302          COMMON/ LATOF /OFSET
      C
      C
      C
2303          COMMON/ IMPROB /IMP
      C
2304          COMMON/ GRSI /SIGR
      C
2305          COMMON/ HUBT /PI,SI
      C
2306          COMMON/ SLOPE1 /SISL
2307          COMMON/ DATA1 /H0,H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12,H13,
             *                H14,H15,H16,H17,H18,H19,H22,H23,H24,H25,H26,H27,
             *                H30,H31,H32,H33,H34,H35,H36,H37,H38,H41,H42,H43,
             *                H44,H45,H46,H47,H48,H50,H51,H52,H60,H61,H62,H63
      C
      C
      C
2308          COMMON/ DATA2 /C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C12,C13,C14,C15,
             *           C22,C16,C17,C18,C19,C20,C21,C25,C26,C27,C28,C29,C30,
             *               C31,C32,C33,C40,C41,C42,C45,C46,C60,C61,C62,C63
      C
2309          COMMON/ GRCRC / CS
2310          COMMON/ ERROR /ERROR1
2311          REAL IMP
2312    9999  CONTINUE
2313          C22(II,JJ) = H41(II)
2314          C15(II,JJ) = H42(II)
2315          C16(II,JJ) = H43(II)
2316          C17(II,JJ) = H44(II)
2317          C18(II,JJ) = H45(II)
2318          C19(II,JJ) = H46(II)
2319          C20(II,JJ) = H47(II)
2320          C21(II,JJ) = H48(II)
2321          C45(II,JJ) = H18(II)
2322          C46(II,JJ) = H19(II)
2323     9998 RETURN
2324          END

      $ENTRY
```

A P P E N D I X

C. HVOSM SAMPLE COMPUTER SIMULATIONS

UNL-NDR GUARDRAIL STUDY HVOSM SIMULATIONS ON EMBANKMENT FILLS
70 MPH AND 15 DEG ENCROACHMENT (RUN NO. 130) F.S.=3:1, B.S.=4:1

INITIAL CONDITIONS

PHI0 =	2.761	DEGREES	XC0' =	264.000	INCHES	P0 =	0.0	DEG/SEC
THETA0=	-0.741	''	YC0' =	168.000	''	Q0 =	0.0	''
PSI0 =	15.000	''	ZC0' =	92.232	''	R0 =	0.0	''
PHIR0 =	0.0	''	DELTA1=	0.0	''	D(PHIR)/DT=	0.0	''
PSIFI0=	0.0	''	DELTA2=	0.0	''	D(PSIF)/DT=	0.0	RAD/SC
			DELTA3=	0.0	''			

U0	=1232.000	IN/SEC
V0	= 0.0	''
W0	= 0.0	''
D(DEL1)/DT=	0.0	''
D(DEL2)/DT=	0.0	''
D(DEL3)/DT=	0.0	''

TIRE DATA

KT	1098.000	LB/IN
SIGMAT =	3.000	
LAMBDAT =	10.000	
A0	=4400.000	
A1	= 8.276	
A2	=2900.000	
A3	= 1.780	
A4	=3900.000	
AMU =	0.200	
ONEGT =	1.000	

TERRAIN TABLE ARGUMENTS

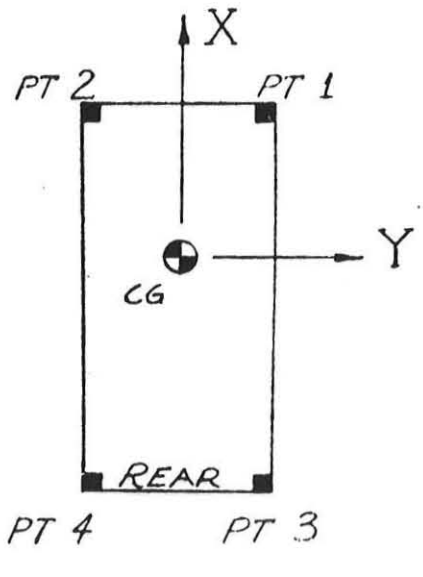
SOIL DAMPING= 0.001 SPI
SOIL FRICT. = 0.250
SSTIFF = 4000. LB/IN
NO.X TEMPS. = 2
NO.Y TEMPS. = 5
NO. VAR AMU = 1
TABLES

COEFF. OF TIRE FRICTION
VS.
(SPEED AND LOAD) DATA

ALPHA=	0.0	1/(LB-MPH)
XKVTH=	0.0	1/ MPH
XKL=	0.0	1/LB

VEHICLE MONITOR POINTS

	X (IN.)	Y (IN.)	Z (IN.)
POINT 1	81.517	39.500	12.138
POINT 2	81.517	-39.500	12.138
POINT 3	-117.483	39.000	8.138
POINT 4	-117.483	-39.000	8.138



UNL-NDR GUARDRAIL STUDY HVOSM SIMULATIONS ON EMBANKMENT FILLS
70 MPH AND 15 DEG ENCROACHMENT (RUN NO. 130) F.S.=3:1, B.S.=4:1

PROGRAM CONTROL DATA

START TIME	=	0.0	SEC
END TIME	=	3.100	
INCR FOR INTEGRATION	=	0.0050	''
PRINT INTERVAL	=	0.010	''
THETA MAX (TO SWITCH)	=	70.000	DEG
UVWMIN(STOP)	=	0.0	
PQRMIN(STOP)	=	0.0	
INDCRB	=	-1	(=0.NO CURB,=1 CURB,=-1 STEER DEG.OF FREEDOM)
MODE OF INTEGRATION	=	1	(=0 VAR.ADAMS-MOULT.,=1 RUNGE-KUTTA,=2FIX.AM)
DTCMP1	=	0.	(=1.0 SUPPLY INITIAL POSITION)
			(=0.0 CAR RESTS ON TERRAIN)

ACCELEROMETER POSITIONS

X1	=	-34.480	INCHES
Y1	=	0.0	''
Z1	=	4.000	''
X2	=	-5.983	''
Y2	=	-16.500	''
Z2	=	3.138	''

DIMENSIONS

A	=	54.5170	INCHES
B	=	64.4830	''
TF	=	61.0000	''
TR	=	60.0000	''
ZF	=	10.1380	''
ZR	=	12.0880	''
RHO	=	-2.0000	''
RW	=	14.0000	''

KF	=	100.000	LB./IN.
KR	=	105.000	LB./IN.
CF'	=	30.000	LBS.
CR'	=	45.000	LBS.
EPSILONF	=	0.001	IN./SEC.
EPSILONR	=	0.001	IN./SEC.
CF	=	3.500	LB-SEC/IN
CR	=	3.900	LB-SEC/IN

AKFC	=	300.000	LB/IN
AKFCP	=	2.000	LB/IN3
OMEGFC	=	-3.000	IN
AKFE	=	300.000	LB/IN
AKFEP	=	2.000	LB/IN3
OMEGFE	=	5.000	IN

SUSPENSION DATA

LAMBDAF	=	0.500	
LAMBDAR	=	0.500	
OMEGAF	=	3.000	INCHES
OMEGAR	=	4.000	INCHES
TS	=	46.500	INCHES
RR	=	32500.0	LB-IN/RAD
RF	=	98500.0	LB-IN/RAD
KRS	=	0.070	ROLL STEER COEFF.
AKRC	=	300.000	LB/IN
AKRCP	=	2.000	LB/IN3
OMEGRC	=	-4.000	IN
AKRE	=	300.000	LB/IN
AKREP	=	2.000	LB/IN3
OMEGRE	=	4.500	IN

INERTIAL DATA

MS	=	8.4402	LB.-SEC.**2/IN
MUF	=	0.5507	''
MUR	=	0.8952	''
IX	=	6200.0	LB.-SEC.**2-IN
IY	=	34400.0	''
IZ	=	36000.0	''
IXZ	=	-192.000	''
IR	=	600.00	''
G	=	386.400	IN/SEC.**2

UNL-NDF GUARDRAIL STUDY HVOSM SIMULATIONS ON EMBANKMENT FILLS
70 MPH AND 15 DEG ENCROACHMENT (RUN NO. 130) F.S.=3:1, B.S.=4:1

TIME SEC.	STEERING INPUT DEG.	SPRUNG MASS CG ACCEL. G-UNITS LONG.		LAT.		VERT.		ANGULAR VELOCITIES DEG./SEC. ROLL	PITCH	YAW	FORWARD SPEED FT./SEC.
1.0200	3.24	0.103		0.254		-0.466		-20.97	3.36	2.58	104.67
1.0300	3.32	0.104		0.270		-0.596		-13.20	2.30	2.85	104.71
1.0400	3.40	0.104		0.285		-0.664		-4.68	0.62	3.14	104.75
1.0500	3.47	0.101		0.278		-0.482		3.52	-0.98	3.44	104.78
1.0600	3.53	0.097		0.264		-0.241		10.21	-2.02	3.77	104.82
1.0700	3.58	0.093		0.257		-0.085		15.41	-2.59	4.14	104.85
1.0800	3.62	0.091		0.256		-0.011		19.72	-2.98	4.52	104.88
1.0900	3.65	0.089		0.260		0.025		23.53	-3.36	4.91	104.92
1.1000	3.68	0.087		0.268		0.046		27.04	-3.74	5.32	104.95
1.1100	3.70	0.085		0.280		0.072		30.31	-4.15	5.72	104.98
1.1200	3.72	0.083		0.294		0.108		33.28	-4.52	6.10	105.02
1.1300	3.73	0.082		0.305		0.150		35.92	-4.82	6.48	105.05
1.1400	3.73	0.082		0.282		0.194		38.25	-5.03	6.84	105.08
1.1500	3.73	0.063		0.276		0.242		40.60	-5.17	7.15	105.11
1.1600	3.73	0.032		0.231		0.214		42.55	-5.17	7.47	105.13
1.1700	3.72	0.016		0.139		0.149		44.05	-4.93	7.64	105.15
1.1800	3.71	0.013		0.104		0.057		44.59	-4.37	7.65	105.16
1.1900	3.70	0.023		0.118		-0.030		43.67	-3.49	7.64	105.17
1.2000	3.69	0.038		0.146		-0.087		41.31	-2.38	7.64	105.18
1.2100	3.68	0.046		0.161		-0.295		37.60	-1.07	7.67	105.20
1.2200	3.66	0.015		0.099		-1.400		26.43	2.50	7.58	105.22
1.2330	3.65	-0.543		-0.784		-1.455		14.16	6.53	7.04	105.19
1.2430	3.64	-1.572		-2.709		-4.609		-7.08	15.30	3.29	104.89
1.2530	3.66	-2.055		-3.250		-6.218		-58.25	34.47	-1.91	104.38
1.2629	3.69	-2.527	1.7	-4.519	2.5	-5.986	3.9	-102.60	51.63	-7.59	103.76
1.2729	3.71	-1.698		-1.868		-3.065		-126.27	60.03	-10.09	103.18
1.2829	3.75	-1.460		-1.558		-1.830		-152.40	67.50	-10.56	102.71
1.2929	3.80	-1.143		-1.216		-1.509		-175.38	72.96	-10.64	102.31
1.3029	3.85	-0.722		-0.656		-1.060		-195.65	75.60	-10.08	102.04
1.3129	3.92	-0.310		-0.300		-0.817		-208.23	76.93	-8.88	101.89
1.3229	3.99	-0.013		-0.157		-0.487		-214.39	77.51	-7.42	101.85
1.3329	4.06	-0.014		-0.095		-0.317		-216.61	77.66	-5.75	101.83
1.3429	4.14	-0.025		-0.065		-0.249		-217.81	77.68	-3.78	101.79
1.3499	4.19	-0.041		-0.106		-0.187		-218.39	77.67	-2.24	101.75
1.3599	4.26	-0.055		-0.140		-0.092		-218.70	77.52	0.19	101.67
1.3709	4.33	-0.086		0.506		-2.029		-210.36	71.94	1.26	101.53
1.3809	4.39	0.018		1.135		-3.328		-191.18	59.08	-0.67	101.39
1.3909	4.44	0.153		1.696		-3.973		-167.08	42.06	-5.46	101.29
1.4009	4.48	-0.672		0.156		-3.001		-152.91	31.38	-7.92	101.08
1.4109	4.52	-0.583	0.2	0.097	0.7	-3.359	2.9	-126.94	15.50	-8.89	100.85
1.4209	4.55	-0.029		0.465		-1.075		-116.07	8.08	-9.84	100.74
1.4309	4.57	-0.336		0.355		-2.843		-100.20	-1.36	-11.74	100.70
1.4409	4.58	-0.312		0.132		-2.785		-76.92	-12.93	-12.30	100.59
1.4509	4.57	-0.088		-0.043		-0.375		-66.66	-16.72	-12.38	100.53
1.4609	4.56	0.043		-0.065		-0.174		-63.61	-16.31	-12.69	100.54
1.4709	4.54	-0.014		-0.168		-0.181		-59.73	-16.12	-12.86	100.55
1.4809	4.52	-0.039		-0.172		-0.164		-55.56	-16.41	-12.97	100.54
1.4909	4.49	-0.062		-0.161		-0.120		-51.84	-17.07	-12.93	100.53
1.5009	4.46	-0.061		-0.199		-0.102		-48.90	-17.70	-12.57	100.51
1.5109	4.41	-0.063		-0.195		-0.111		-46.23	-18.13	-11.97	100.49
1.5209	4.36	-0.067		-0.186		-0.118		-43.18	-18.21	-11.29	100.47

UNL-NDR GUARDRAIL STUDY HVOSM SIMULATIONS ON EMBANKMENT FILLS
70 MPH AND 15 DEG ENCROACHMENT (RUN NO. 130) F.S.=3:1, B.S.=4:1

TIME SEC.	POSITION (INCHES)			SPRUNG MASS CG ORIENTATION (DEGREES)			VELOCITY (FT /SEC.)	
	X'	Y'	Z'	PHI	THETA	PSI	LAT.	VERT.
1.0200	1477.35	514.14	189.15	10.56	-3.78	14.91	4.95	1.26
1.0300	1489.30	517.91	190.22	10.39	-3.75	14.94	4.98	1.15
1.0400	1501.26	521.69	191.28	10.30	-3.74	14.98	5.01	0.98
1.0500	1513.21	525.49	192.31	10.29	-3.75	15.01	5.04	0.79
1.0600	1525.17	529.30	193.32	10.36	-3.77	15.04	5.07	0.64
1.0700	1537.13	533.12	194.33	10.49	-3.80	15.08	5.08	0.54
1.0800	1549.09	536.96	195.34	10.66	-3.83	15.12	5.08	0.46
1.0900	1561.05	540.80	196.35	10.88	-3.87	15.16	5.08	0.38
1.1000	1573.01	544.66	197.36	11.13	-3.91	15.21	5.07	0.31
1.1100	1584.97	548.53	198.37	11.41	-3.96	15.25	5.06	0.23
1.1200	1596.93	552.41	199.39	11.73	-4.01	15.31	5.04	0.15
1.1300	1608.89	556.30	200.41	12.07	-4.07	15.36	5.02	0.07
1.1400	1620.85	560.20	201.45	12.44	-4.13	15.42	5.00	0.01
1.1500	1632.81	564.11	202.49	12.83	-4.19	15.48	4.96	-0.05
1.1600	1644.76	568.03	203.54	13.24	-4.25	15.54	4.91	-0.11
1.1700	1656.72	571.95	204.60	13.67	-4.32	15.61	4.83	-0.18
1.1800	1668.68	575.89	205.67	14.11	-4.38	15.67	4.73	-0.27
1.1900	1680.63	579.82	206.74	14.55	-4.43	15.74	4.62	-0.37
1.2000	1692.59	583.76	207.81	14.97	-4.48	15.81	4.52	-0.48
1.2100	1704.54	587.71	208.88	15.36	-4.51	15.88	4.42	-0.59
1.2200	1716.50	591.67	209.93	15.69	-4.52	15.96	4.32	-0.89
1.2330	1732.03	596.83	211.25	15.94	-4.49	16.06	4.14	-1.08
1.2430	1743.98	600.79	212.21	15.99	-4.40	16.14	3.59	-1.56
1.2530	1755.89	604.71	213.02	15.68	-4.17	16.20	2.87	-2.77
1.2629	1767.76	608.57	213.60	14.88	-3.74	16.25	2.10	-3.42
1.2729	1779.59	612.35	214.01	13.72	-3.17	16.27	1.57	-3.35
1.2829	1791.38	616.05	214.27	12.32	-2.52	16.29	1.29	-3.19
1.2929	1803.13	619.71	214.42	10.68	-1.81	16.29	1.08	-2.73
1.3029	1814.85	623.31	214.47	8.84	-1.06	16.28	1.04	-1.89
1.3129	1826.56	626.88	214.47	6.81	-0.29	16.25	1.11	-0.82
1.3229	1838.25	630.43	214.44	4.69	0.49	16.21	1.19	0.39
1.3329	1849.95	633.97	214.39	2.54	1.26	16.15	1.23	1.69
1.3429	1861.65	637.50	214.32	0.36	2.04	16.09	1.20	3.03
1.3499	1869.85	639.96	214.27	-1.17	2.58	16.04	1.13	3.98
1.3599	1881.55	643.47	214.19	-3.36	3.35	15.96	0.93	5.35
1.3709	1894.42	647.31	214.09	-5.74	4.18	15.86	0.69	6.59
1.3809	1906.11	650.80	213.95	-7.77	4.83	15.76	0.58	7.18
1.3909	1917.79	654.30	213.71	-9.58	5.32	15.63	0.70	7.26
1.4009	1929.45	657.80	213.39	-11.19	5.66	15.48	0.74	7.27
1.4109	1941.08	661.27	212.96	-12.61	5.87	15.33	0.78	6.43
1.4209	1952.68	664.71	212.41	-13.82	5.95	15.21	0.89	6.06
1.4309	1964.27	668.16	211.79	-14.92	5.99	15.10	1.17	5.42
1.4409	1975.85	671.58	211.06	-15.82	5.84	15.01	1.39	4.22
1.4509	1987.41	674.98	210.24	-16.53	5.66	14.94	1.56	3.53
1.4609	1998.96	678.37	209.40	-17.19	5.46	14.88	1.74	3.19
1.4709	2010.52	681.77	208.55	-17.81	5.26	14.81	1.88	2.87
1.4809	2022.08	685.15	207.70	-18.39	5.06	14.75	2.02	2.55
1.4909	2033.63	688.53	206.85	-18.94	4.86	14.69	2.18	2.22
1.5009	2045.19	691.90	205.99	-19.45	4.65	14.64	2.32	1.90
1.5109	2056.74	695.26	205.14	-19.93	4.44	14.59	2.46	1.57
1.5209	2068.30	698.62	204.28	-20.38	4.23	14.55	2.59	1.24

A P P E N D I X

D. HVOSM TERRAIN LAYOUT (TYPICAL)

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UNL-NDR GUARDRAIL STUDY     HYOSM SIMULATIONS ON EMBANKMENT FILLS
60 MPH AND 10 DEG ENCROACHMENT     (RUN NO. 5)

INPUT PRESET IN SUBROUTINE STD

          1
      10.818        0.608        0.945      386.400     6000.000    30000.000    36000.000     -192.000      600.000
      54.517       64.483       61.000       60.000       10.138       12.088       -2.000       14.000     4400.000
     131.000        0.500        3.000        3.500       55.000        0.001   266000.000
     192.000        0.500        4.000        3.900       50.000        0.001    61900.000       46.500        0.070
    1098.000        3.000       10.000        8.276     2900.000        1.780        0.800        1.000     3900.000
       0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
     -34.480        0.0          4.000       -5.983      -16.500        3.138
      -5.000        5.000        1.000

PHIC(I),I=1,11
  -3.550    -2.550    -1.800    -1.300    -0.950    -0.550    -0.300    -0.300    -0.400    -0.550    -0.800
     492.000        600.000        0.400     5000.000        0.075        1.500
           4     4000.000        0.001        0.250
XVP(I),YVP(I),ZVP(I),I=1,4
      81.517       39.500       12.138
      81.517      -39.500       12.138
    -117.483       39.000        8.138
    -117.483      -39.000        8.138

     300.000        2.000       -3.000      300.000        2.000        3.000
     300.000        2.000       -4.000      300.000        2.000        4.000

INPUT READ BY CALSVA

0.0       6.80      0.005     0.0       0.01      70.0      0.0       0.0       -1.0              1
8.4402    0.5507    0.8952    386.4     6200.0    34400.0   36000.0   -192.0    600.0             3
100.0     0.50      3.0       3.5       30.0      0.001     98500.0                               5
105.0     0.50      4.0       3.9       45.0      0.001     32500.0   46.5      0.070             6
1098.0    3.0       10.0      8.276     2900.0    1.78      0.2       1.0       3900.0            7
0.0       0.0       10.0      0.0       0.0       0.0       0.0       0.0                         8
264.0     168.0               1056.0    0.0       0.0                                           9
2.0       6.0       1.0                                                                         14
XGP(I,1),YGP(I,J),ZGP(I,J),I=1, 2 J=1, 6
      0.0          0.0          0.000       20.000      10.000      40.000      20.000      44.000      20.000      84.000      10.0

   104.000      10.000
   600.000       0.0          9.000       20.000      10.000      40.000      20.000      44.000      20.000      84.000      10.0

   104.000      10.000

XGP(I,1),AMUXY(I,J),I=1, 2 J=1, 6  NMUXY =  1
      0.0          0.600        0.200       0.200       0.200       0.200       0.200
    600.000        0.200        0.200       0.200       0.200       0.200       0.200
300.0    2.0       -3.0       300.0    2.0       5.00                                            26
300.0    2.0       -4.0       300.0    2.0       4.50                                            27
                                                                                                9999
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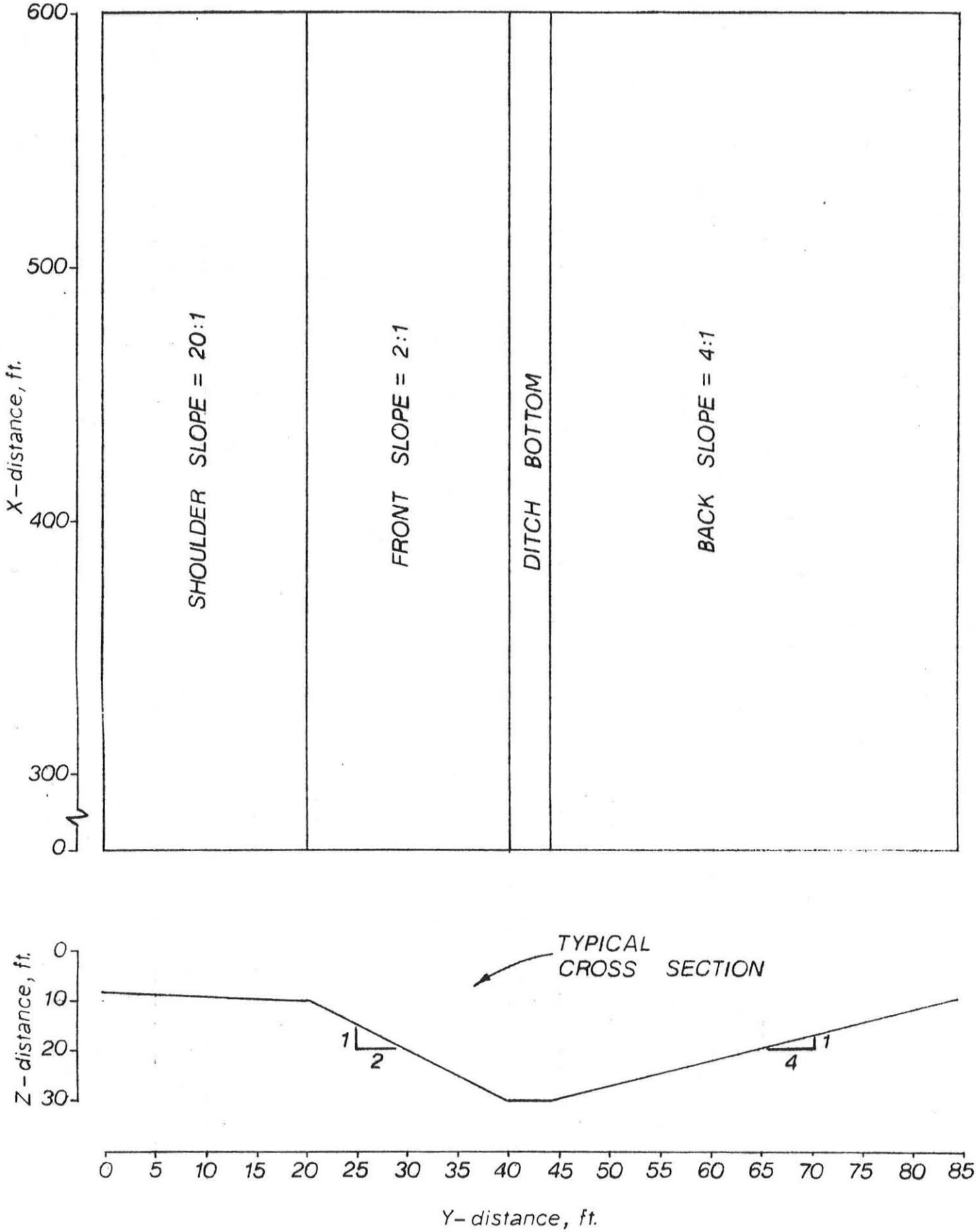
PLAN VIEW OF TERRAIN



A P P E N D I X

E. HVOSM EMBANKMENT SIMULATION RESULTS

50 mph. – 7½ degrees

HVOSM Simulations on Embankment Fills

Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	ACCELERATIONS: Front Slope to Ditch Long. (G)	Lat. (G)	Vert. (G)	SI	Ditch to Back Slope Long. (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Heading @ Ditch Contact (deg)	Injury Prob. (%)
1	3:1	10	A	0:1	0.3	0.2	1.8	0.3									
2	↓	20	↓	↓	1.1	0.4	3.2	0.6									
3	↓	30	↓	↓	1.4	0.8	3.7	0.7									
4	3:1	10	A	4:1	1.1	0.9	2.1	0.4	0.2	0.2	1.5	0.3					
5	↓	20	↓	↓	2.5	1.4	4.8	0.9	0.0	0.1	1.3	0.2					
6	↓	30	↓	↓	3.9	2.1	5.8	1.2	0.3	0.1	1.3	0.2					
7	4:1	10	A	0:1	0.1	0.4	1.4	0.3									
8	↓	20	↓	↓	0.3	0.2	1.9	0.3									
9	↓	30	↓	↓	0.8	0.2	2.4	0.4									
10	4:1	10	A	4:1	0.2	0.3	1.7	0.3	0.1	0.1	1.0	0.2					
11	↓	20	↓	↓	1.5	1.1	3.2	0.6	0.1	0.2	1.4	0.2					
12	↓	30	↓	↓	7.0	1.3	9.5	*1.1	0.3	0.1	1.3	0.2					
13	6:1	10	A	0:1	0.1	0.4	1.2	0.2									
14	↓	20	↓	↓													
15	↓	30	↓	↓													
16	6:1	10	A	4:1	1.0	0.9	2.5	0.5	0.1	0.3	1.4	0.2					
17	↓	20	↓	↓													
18	↓	30	↓	↓													

50 mph. - 15 degrees

HVOSM Simulations on Embankment Fills

Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	ACCELERATIONS: Front Slope to Ditch Long. (G)	Lat. (G)	Vert. (G)	SI	Ditch to Back Slope Long. (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Heading @ Ditch Contact (deg)	Injury Prob. (%)
19	3:1	10	A	0:1	0.2	0.3	2.9	0.5									
20	↓	20	↓	↓	0.1	0.4	3.0	0.5									
21	↓	30	↓	↓	0.5	2.0	4.5	0.8									
22	3:1	10	A	4:1	0.5	1.3	2.2	0.5	0.1	0.2	3.5	0.6					
23	↓	20	↓	↓	0.6	1.3	3.4	0.6	0.3	0.4	2.9	0.5					
24	↓	30	↓	↓	2.5	1.3	3.9	0.8	1.7	1.8	4.7	0.9					
25	4:1	10	A	0:1	0.1	0.5	1.7	0.3									
26	↓	20	↓	↓	0.7	0.2	2.2	0.4									
27	↓	30	↓	↓	1.1	0.4	3.2	0.6									
28	4:1	10	A	4:1	1.2	1.0	2.9	0.6	0.2	0.5	2.1	0.4					
29	↓	20	↓	↓	1.2	1.3	4.6	0.8	0.3	0.4	1.7	0.3					
30	↓	30	↓	↓	3.6	1.7	6.4	1.2	0.2	0.3	3.5	0.6					
31	6:1	10	A	0:1	0.1	0.3	1.0	0.2									
32	↓	20	↓	↓													
33	↓	30	↓	↓													
34	6:1	10	A	4:1	0.8	1.4	3.3	0.6									
35	↓	20	↓	↓													
36	↓	30	↓	↓													

50 mph - 25 degrees

HVOSM Simulations on Embankment Fills

Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	ACCELERATIONS: Front Slope to Ditch Long. (G)	Lat. (G)	Vert. (G)	SI	Ditch to Back Slope Long. (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Heading @ Ditch Contact (deg)	Injury Prot. (%)
37	3:1	10	A	0:1	0.5	0.5	2.4	0.4					+28 -10		52.5	+25	
38	↓	20	↓	↓	1.1	0.4	3.6	0.6					+28 -5		55.2	+34	
39	↓	30	↓	↓	1.6	0.6	3.9	0.7					+28 -5		57.3	+44	
40	3:1	10	A	4:1	2.0	1.8	4.0	0.8	0.2	0.2	1.7	0.3	+28 -21		52.5	+25	
41	↓	20	↓	↓	2.3	1.3	4.9	0.9	1.4	0.1	1.9	0.4	+28 -17		55.2	+34	
42	↓	30	↓	↓	3.9	1.8	6.0	1.2	0.3	0.6	3.5	0.6	+28 -15		57.3	+44	
43	4:1	10	A	0:1	0.5	0.7	2.3	0.4					+19 -11		52.5	+25	
44	↓	20	↓	↓	0.7	0.3	2.8	0.5					+19 -7		54.5	+41	
45	↓	30	↓	↓	1.1	0.4	4.5	0.8					+19 -4		55.9	+56	
46	4:1	10	A	4:1	1.7	2.0	3.7	0.8	0.2	0.2	2.4	0.4	+19 -20		52.5	+25	
47	↓	20	↓	↓	3.0	1.3	4.8	0.9	0.2	0.3	2.2	0.4	+19 -13		54.5	+41	
48	↓	30	↓	↓	4.0	1.0	6.3	1.2	0.1	0.4	3.7	0.6	+19 -28		55.9	+56	
49	6:1	10	A	0:1	0.1	0.3	1.4	0.2					+13 -7		52.5	+31	
50	↓	20	↓	↓													
51	↓	30	↓	↓													
52	6:1	10	A	4:1	1.6	1.2	2.8	0.6	0.5	0.1	1.6	0.3	+13 -17		52.5	+31	
53	↓	20	↓	↓													
54	↓	30	↓	↓													

60 mph - 7½ degrees

HVOSM Simulations on Embankment Fills

Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	ACCELERATIONS: Front Slope to Ditch Long. (G)	Lat. (G)	Vert. (G)	SI	Ditch to Back Slope Long. (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Heading @ Ditch Contact (deg)	Injury Prob. (%)
55	3:1	10	A	0:1	0.3	0.1	1.7	0.3	—	—	—	—	+26 -11		62.0	+17	
56	↓	20	↓	↓	1.1	0.4	2.8	0.5	—	—	—	—	+26 -5		62.7	+36	
57	↓	30	↓	↓	1.5	0.4	3.4	0.6	—	—	—	—	+26 -5		62.7	+51	
58	3:1	10	A	4:1	0.9	0.5	2.0	0.4	0.1	0.3	1.9	0.3	+26 -21		62.0	+17	
59	↓	20	↓	↓	2.4	1.4	4.5	0.9	1.5	1.6	3.7	0.7	+26 -14		62.7	+36	
* 60	↓	30	↓	↓	3.1	1.9	6.4	1.2	1.5	1.7	2.9	0.6	+26 -9		62.7	+51	
* 61	4:1	10	A	0:1	0.1	0.2	2.2	0.4	—	—	—	—	+19 -7		62.0	+18	
* 62	↓	20	↓	↓	0.2	0.2	2.6	0.4	—	—	—	—	+19 -7		64.1	+13	
63	↓	30	↓	↓	0.5	0.2	2.2	0.4	—	—	—	—	+19 -9		66.1	+33	
64	4:1	10	A	4:1	0.9	1.0	2.4	0.5	0.3	0.3	1.8	0.3	+19 -18		62.0	+18	
65	↓	20	↓	↓	0.6	1.1	2.2	0.5	0.1	0.2	3.4	0.6	+19 -21		64.1	+13	
66	↓	30	↓	↓	2.4	1.4	5.0	0.9	0.8	1.5	3.7	0.7	+19 -16		66.1	+32	
67	6:1	10	A	0:1	0.0	0.3	1.0	0.2	—	—	—	—	+12 -6		62.0	+22	
68	↓	20	↓	↓					—	—	—	—					
69	↓	30	↓	↓					—	—	—	—					
70	6:1	10	A	4:1	0.9	0.7	2.7	0.5	0.3	0.6	1.8	0.3	+12 -21		62.0	+21	
71	↓	20	↓	↓													
72	↓	30	↓	↓													

60 mph — 10 degrees

HVOSM Simulations on Embankment Fills

Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	ACCELERATIONS: Front Slope to Ditch Long. (G)	Lat. (G)	Vert. (G)	SI	Ditch to Back Slope Long. (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Heading @ Ditch Contact (deg)	Injury Prob. (%)
	3:1	10	A	0:1	0.3	0.6	1.8	0.3	—	—	—	—	+26 -10		61.8	+13	12
	↓	20	↓	↓	1.0	0.3	3.1	0.5	—	—	—	—	+22 -06		62.9	+34	20
		30			3.2	0.0	1.5	0.6	—	—	—	—	+22 -04		61.6	+51	24
	3:1	10	A	4:1	0.5	0.8	2.2	0.4	0.1	0.2	1.4	0.2	+26 -18		61.8	+13	16
	↓	20	↓	↓	2.3	1.4	4.0	0.8	1.2	1.4	5.	0.6	+26 -14		62.9	+34	32
		30			3.4	1.2	5.1	1.0	3.0	2.4	7.0	1.3	+22 -12		63.2	+47	52
	4:1	10	A	0:1	0.1	0.1	1.5	0.3	—	—	—	—	+20 -09		62.2	+21	12
	↓	20	↓	↓	0.3	0.8	2.2	0.4	—	—	—	—	+20 -07		64.1	+16	16
		30			0.2	0.7	2.6	0.5	—	—	—	—	+20 -09		64.9	+12	20
	4:1	10	A	4:1	1.1	1.0	2.8	0.5	0.1	0.3	1.8	0.3	+20 -20		62.2	+21	20
	↓	20	↓	↓	0.8	1.5	2.9	0.6	0.0	0.0	3.5	0.6	+20 -19		64.1	+16	24
		30			1.6	2.0	4.0	0.8	0.0	0.3	4.3	0.8	+20 -21		65.0	+12	32
	6:1	10	A	0:1	0.0	0.3	0.8	0.2	—	—	—	—	+12 -08		62.2	+20	8
	↓	20	↓	↓	0.1	0.1	2.0	0.3	—	—	—	—	+13 -06		63.3	+37	12
		30															
	6:1	10	A	4:1	0.7	0.8	2.0	0.4	0.2	0.5	2.0	0.4	+12 -22		62.2	+17	16
	↓	20	↓	↓	1.9	0.9	3.5	0.7	0.8	1.2	4.1	0.7	+12 -17		63.4	+36	28
		30															

60 mph - 15 degrees

HVOSM Simulations on Embankment Fills

Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	ACCELERATIONS: Front Slope to Ditch Long. (G)	Lat. (G)	Vert. (G)	SI	Ditch to Back Slope Long. (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Heading @ Ditch Contact (deg)	Injury Prob. (%)
73	3:1	10	A	0:1	0.5	1.0	2.0	0.4	—	—	—	—	+28 -9		62.0	+14	
74	↓	20	↓	↓	0.9	0.5	2.9	0.5	—	—	—	—	+28 -8		64.1	+30	
75	↓	30	↓	↓	1.6	0.3	4.1	0.7	—	—	—	—	+28 -5		64.1	+46	
76	3:1	10	A	4:1	0.8	1.6	2.8	0.6	0.2	0.3	2.9	0.5	+28 -22		62.0	+14	
77	↓	20	↓	↓	2.5	1.8	4.6	0.9	0.8	1.2	3.2	0.6	+28 -16		64.1	+30	
78	↓	30	↓	↓	4.0	1.6	6.2	1.2	0.1	0.3	2.1	0.4	+28 -11		64.1	+46	
** 79	4:1	10	A	0:1	0.1	0.6	2.2	0.4	—	—	—	—	+19 -9		62.0	+23	
** 80	↓	20	↓	↓	0.1	0.8	2.5	0.5	—	—	—	—	+19 -8		63.4	+37	
81	↓	30	↓	↓	1.0	0.3	3.4	0.6	—	—	—	—	+19 -6		64.8	+45	
82	4:1	10	A	4:1	1.4	1.1	3.0	0.6	0.1	0.2	1.7	0.3	+19 -20		62.0	+22	
83	↓	20	↓	↓	2.7	1.5	5.1	1.0	1.1	1.1	3.6	0.7	+19 -15		63.4	+36	
84	↓	30	↓	↓	3.0	1.4	5.8	1.1	1.9	1.5	4.5	0.9	+19 -13		64.8	+45	
85	6:1	10	A	0:1	0.1	0.3	1.0	0.2	—	—	—	—	+13 -6		62.0	+19	
86	↓	20	↓	↓					—	—	—	—					
87	↓	30	↓	↓					—	—	—	—					
88	6:1	10	A	4:1	1.0	1.3	2.7	0.5	0.2	0.3	1.9	0.3	+13 -19		62.0	+20	
89	↓	20	↓	↓													
90	↓	30	↓	↓													

60 mph – 25 degrees

HVOSM Simulations on Embankment Fills

Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	ACCELERATIONS: Front Slope to Ditch Long. (G)	Lat. (G)	Vert. (G)	SI	Ditch to Back Slope Long. (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Heading @ Ditch Contact (deg)	Injury Prob. (%)
91	3:1	10	A	0:1	1.3	1.9	4.2	0.8	—	—	—	—	+29 -6		62.4	+24	
92	↓	20	↓	↓	1.5	1.4	4.8	0.9	—	—	—	—	+29 -7		64.1	+29	
93	↓	30	↓	↓	2.0	0.9	4.5	0.8	—	—	—	—	+29 -8		66.1	+42	
94	3:1	10	A	4:1	1.3	1.9	4.2	0.8	0.8	0.5	5.0	0.8	+29 -21		62.0	+24	
95	↓	20	↓	↓				*1.2									
96	↓	30	↓	↓	5.0	2.9	7.0	1.5	2.4	2.0	6.6	1.2	+29 -16		66.1	+42	
* 97	4:1	10	A	0:1	0.2	0.8	3.7	0.6	—	—	—	—	+20 -9		62.0	+27	
* 98	↓	20	↓	↓	0.2	0.9	4.5	0.8	—	—	—	—	+20 -8		64.1	+33	
99	↓	30	↓	↓	1.0	1.1	4.0	0.7	—	—	—	—	+20 -8		66.8	+31	
100	4:1	10	A	4:1	2.5	2.9	5.2	1.1	0.5	0.8	2.8	0.5	+20 -23		62.0	+26	
101	↓	20	↓	↓	2.7	2.2	5.3	1.1	0.9	0.3	3.0	0.5	+20 -19		64.1	+33	
102	↓	30	↓	↓	2.4	2.2	5.1	1.0	0.6	0.3	4.4	0.8	+20 -18		66.8	+31	
103	6:1	10	A	0:1	0.1	0.3	2.0	0.3	—	—	—	—	+13 -7		62.0	+30	
104	↓	20	↓	↓					—	—	—	—					
105	↓	30	↓	↓					—	—	—	—					
106	6:1	10	A	4:1	1.9	1.6	4.7	0.9	0.6	0.8	2.9	0.5	+13 -19		62.0	+30	
107	↓	20	↓	↓													
108	↓	30	↓	↓													

70 mph — 7½ degrees

HVOSM Simulations on Embankment Fills

Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	ACCELERATIONS: Front Slope to Ditch Long. (G)	Lat. (G)	Vert. (G)	SI	Ditch to Back Slope Long. (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Heading @ Ditch Contact (deg)	Injury Prob. (%)
109	3:1	10	A	0:1	0.2	0.2	1.9	0.3	—	—	—	—	+26 -11		71.6	+15	
110	↓	20	↓	↓	1.0	0.3	3.4	0.6	—	—	—	—	+22 -6		72.3	+33	
111	↓	30	↓	↓	1.5	0.1	3.6	0.6	—	—	—	—	+22 -5		72.3	+47	
112	3:1	10	A	4:1	0.9	0.8	2.5	0.5	0.1	0.6	1.8	0.3	+26 -21		71.6	+15	
113	↓	20	↓	↓	2.4	1.2	4.1	0.8	1.2	1.5	3.4	0.7	+26 -15		72.3	+33	
114	↓	30	↓	↓	3.4	2.8	6.9	1.4	0.2	0.5	2.4	0.4	+26 -11		72.3	+50	
* 115	4:1	10	A	0:1	0.1	0.4	2.6	0.4	—	—	—	—	+20 -8		72.3	+18	
116	↓	20	↓	↓	0.1	0.7	2.2	0.4	—	—	—	—	+20 -8		73.0	+9	
117	↓	30	↓	↓	0.1	0.6	2.7	0.5	—	—	—	—	+20 -9		74.3	+9	
118	4:1	10	A	4:1	1.1	1.0	2.6	0.5	0.3	0.4	2.0	0.3	+20 -19		71.6	+18	
119	↓	20	↓	↓	0.4	1.1	2.5	0.5	0.2	0.1	3.5	0.6	+20 -27		73.0	+9	
120	↓	30	↓	↓	0.9	2.1	4.8	0.9	0.0	0.5	5.0	0.8	+20 -26		73.6	+9	
121	6:1	10	A	0:1	0.0	0.1	0.7	0.1	—	—	—	—	+12 -8		71.6	+11	
122	↓	20	↓	↓					—	—	—	—					
123	↓	30	↓	↓					—	—	—	—					
124	6:1	10	A	4:1	0.4	0.8	2.0	0.4	0.0	0.3	1.6	0.3	+12 -23		71.6	+11	
125	↓	20	↓	↓													
126	↓	30	↓	↓													

70 mph — 15 degrees

HVOSM Simulations on Embankment Fills

Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	ACCELERATIONS: Front Slope to Ditch Long. (G)	Lat. (G)	Vert. (G)	SI	Ditch to Back Slope Long. (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Heading @ Ditch Contact (deg)	Injury Prob. (%)
127	3:1	10	A	0:1	0.2	0.5	2.9	0.5	—	—	—	—	+31 -9		71.6	+17	
128	↓	20	↓	↓	1.0	0.5	3.7	0.6	—	—	—	—	+31 -8		73.6	+28	
129	↓	30	↓	↓	1.4	0.5	4.0	0.7	—	—	—	—	+31 -6		74.3	+37	
130	3:1	10	A	4:1	1.7	2.5	3.9	0.9	0.2	0.7	2.9	0.5	+31 -22		71.4	+16	
131	↓	20	↓	↓	2.4	1.7	5.2	1.0	0.5	0.6	2.7	0.5	+31 -18		73.6	+28	
132	↓	30	↓	↓	3.7	1.9	5.9	1.2	1.9	1.9	6.4	1.2	+31 -21		74.3	+37	
133	4:1	10	A	0:1	0.1	0.9	3.5	0.6	—	—	—	—	+20 -6		71.6	+21	
134	↓	20	↓	↓	0.6	0.3	2.8	0.5	—	—	—	—	+20 -8		73.0	+33	
135	↓	30	↓	↓	0.9	0.1	3.4	0.6	—	—	—	—	+20 -6		73.0	+44	
136	4:1	10	A	4:1	1.3	1.5	3.4	0.7	0.1	0.5	2.3	0.4	+20 -14		71.6	+19	
137	↓	20	↓	↓	2.5	1.5	5.3	1.0	1.1	1.2	3.8	0.7	+20 -17		73.0	+33	
138	↓	30	↓	↓	2.8	1.3	5.9	1.1	2.2	1.8	6.2	1.1	+20 -15		73.0	+44	
139	6:1	10	A	0:1	0.1	0.4	1.5	0.3	—	—	—	—	+13 -6		72.3	+20	
140	↓	20	↓	↓					—	—	—	—					
141	↓	30	↓	↓					—	—	—	—					
142	6:1	10	A	4:1	1.2	1.6	3.3	0.7	0.2	0.3	2.7	0.5	+13 -19		72.3	+20	
143	↓	20	↓	↓													
144	↓	30	↓	↓													

70 mph — 25 degrees

HVOSM Simulations on Embankment Fills

Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	ACCELERATIONS: Front Slope to Ditch Long. (G)	Lat. (G)	Vert. (G)	SI	Ditch to Back Slope Long. (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Heading @ Ditch Contact (deg)	Injury Prob. (%)
145	3:1	10	A	0:1	2.4	3.7	6.6	1.4	—	—	—	—	+28 -9		71.6	+24	
146	↓	20	↓	↓	2.2	1.7	4.4	0.9	—	—	—	—	+19 -10		73.0	+25	
147		30						*1.0	—	—	—	—					
148	3:1	10	A	4:1	4.7	7.6	9.4	2.3	0.8	0.9	5.1	0.9	+28 -21		71.6	+24	
149	↓	20	↓	↓	4.4	4.1	6.4	1.5	0.3	3.2	9.8	1.8	+19 -24		73.0	+25	
150		30			4.1	3.0	9.1	1.7	1.8	1.4	6.0	1.1	+21 -18		75.7	+35	
151	4:1	10	A	0:1	0.1	0.4	2.6	0.4	—	—	—	—	+21 -7		71.6	+26	
152	↓	20	↓	↓	0.1	0.9	4.1	0.7	—	—	—	—	+21 -8		73.6	+31	
153		30			1.0	1.1	4.4	0.8	—	—	—	—	+21 -9		75.7	+30	
154	4:1	10	A	4:1	2.3	2.3	4.8	1.0	0.3	1.1	3.8	0.7	+21 -22		71.6	+26	
155	↓	20	↓	↓				*1.2									
156		30			2.7	2.7	6.9	1.3	0.8	0.4	4.2	0.7	+21 -19		75.7	+30	
157	6:1	10	A	0:1	0.1	0.5	2.7	0.5	—	—	—	—	+12 -7		71.6	+29	
158	↓	20	↓	↓					—	—	—	—					
159		30							—	—	—	—					
160	6:1	10	A	4:1	2.2	1.7	5.0	1.0	0.7	1.3	4.7	0.8	+12 -21		72.3	+29	
161	↓	20	↓	↓													
162		30															

HVOSM Simulations of Embankment Fills

Speed (mph)	Run No.	Front Slope	Fill Ht. (ft)	Ditch Cont	Back Slope	ACCELERATIONS: Front Slope to Ditch Long (G)	Lat. (G)	Vert. (G)	SI	Ditch to Back Slope Long (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Pitch (min)	Max. Roll Angle (deg)	Impact Speed
50	201	2:1	10	A (7.5°)	0:1	0.8	1.6	2.2	0.5									
60	202		10			0.7	1.7	3.0	0.6									
70	203		10			0.4	1.4	2.7	0.5									
50	204	2:1	10	A (15°)	0:1	0.2	0.1	4.7	0.8									
60	205		10			0.1	0.9	4.3	0.7									
70	206		10			2.8	6.8	6.2	1.7									
50	207	2:1	10	A (25°)	0:1	3.2	4.2	6.0	1.4									
60	208		10			0.7	1.0	8.8	1.5									
70	209		10			0.5	1.6	9.6	1.6									
50	210	2:1	20	A (7.5°)	0:1	0.8	2.7	4.4	0.9									
60	211		20			0.7	2.8	5.2	1.0									
70	212		20			1.6	2.4	5.2	1.0									
50	213	2:1	20	A (15°)	0:1	1.8	1.7	3.5	0.7									
60	214		20			3.2	3.3	5.6	1.2									
70	215		20			2.5	1.5	5.8	1.1									
50	216	2:1	20	A (25°)	0:1	0.2	1.3	5.3	0.9									
60	217		20			5.6	10.7	11.1	2.9									
70	218		20			4.7	8.2	9.7	2.4									

HVOSM Simulations – Embankment Fills

	Run No.	Front Slope	Fill Ht. (ft)	Ditch Depth	Back Slope	Accelerations: Front Slope to Ditch Long (G)	Lat. (G)	Vert. (G)	SI	Accelerations: Ditch to Back Slope Long. (G)	Lat. (G)	Vert. (G)	SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mi/h)	Heading @ Site Exit (deg)	Impact Angle
50	219	2:1	30	A (7.5°)	0:1	0.7	3.5	6.2	1.3									
60	220		30			0.6	3.4	6.0	1.2									
70	221		30			0.7	3.6	6.8	1.3									
50	222	2:1	30	A (15°)	0:1	2.7	1.4	5.1	1.0									
60	223		30			1.4	1.7	5.5	1.0									
70	224		30			2.4	1.6	5.3	1.0									
50	225	2:1	30	A (25°)	0:1	3.7	2.8	4.5	1.1									
60	226		30			2.5	1.9	5.1	1.1									
70	227		30			0.9	0.9	9.1	1.5									
50	228	2:1	10	A (7.5°)	2:1	0.8	1.5	2.3	0.5	0.1	1.6	2.1	0.5					
60	229		10			0.7	1.7	2.9	0.6	0.4	0.9	3.0	0.5					
70	230		10			0.4	1.7	3.5	0.7	0.2	1.0	3.4	0.6					
50	231	2:1	10	A (15°)	2:1	2.0	2.5	7.0	1.2	1.8	1.0	5.0	0.9					
60	232		10			1.3	0.5	4.5	0.8	0.1	0.4	3.5	0.6					
70	233		10			2.8	6.8	6.2	1.8	1.1	3.7	2.1	0.4					
50	234	2:1	10	A (25°)	2:1	8.8	13.4	7.3	2.2	0.5	3.7	2.5	0.9					
60	235		10			7.7	12.5	7.4	2.9	0.7	2.5	4.2	0.9					
70	236		10			7.3	11.5	7.6	2.8	0.8	0.5	10.6	1.5					

HVOSM Simulations of Embankment Fills

	Run No.	Front Slope	Fill Ht. (ft)	Ditch	Back Slope	ACCELERATIONS								Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Height of CG at Dist. Traveled (ft)	Impact Angle (deg)
						From Slope to Ditch				Ditch to Back Slope								
						Long (G)	Lat. (G)	Vert. (G)	SI	Long (G)	Lat. (G)	Vert. (G)	SI					
0	237	2:1	20	A	2:1	0.7	2.7	4.4	0.9	0.5	0.9	3.8	0.7					
0	238		20	(75)		0.7	2.8	5.2	1.0	0.5	1.0	4.5	0.8					
0	239		20			0.6	2.4	5.2	1.0	0.5	1.3	4.1	0.7					
0	240	2:1	20	A	2:1	2.9	0.4	5.2	1.0	0.1	0.1	3.4	0.6					
0	241		20	(15°)		4.0	4.5	6.2	1.5	2.7	0.2	5.0	0.9					
0	242		20			5.9	6.7	7.8	2.0	0.3	2.8	3.9	0.9					
0	243	2:1	20	A	2:1	7.3	8.3	8.7	2.4	0.1	0.3	2.9	0.5					
0	244		20	(25°)		5.6	10.7	11.1	2.9	1.1	0.5	6.0	1.0					
0	245		20			12.1	21.5	5.4	4.7	0.7	8.8	4.4	1.9					
0	246	2:1	30	A	2:1	0.8	3.5	6.1	1.2	0.2	1.4	3.8	0.7					
0	247		30	(7.5°)		0.7	3.6	6.1	1.2	0.5	1.8	6.8	1.2					
0	248		30			0.8	3.7	6.5	1.3	0.5	1.9	6.5	1.2					
0	249	2:1	30	A	2:1	7.2	5.2	9.3	2.0	4.7	1.6	6.2	1.3					
0	250		30	(15°)		6.3	4.7	10.6	2.4	6.3	4.7	10.6	2.4					
0	251		30			6.9	4.4	10.4	2.2	4.1	2.2	2.9	0.8					
0	252	2:1	30	A	2:1	5.1	4.5	6.9	1.5	3.7	0.4	8.7	1.6					
0	253		30	(25°)		10.0	9.9	9.4	2.9	6.9	3.6	9.7	1.8					
0	254		30			5.5	6.2	16.0	3.0	2.6	2.9	7.3	1.3					

A P P E N D I X

F. SLOPE SEVERITY-INDEX EQUATIONS

Severity Index Equations for Type A Ditches

Adjustment factor to type B ditches = 0.81
Adjustment factor to type C ditches = 0.70

Fill Ht.	Front Slope	Back Slope	Encr. Angle	Least Squares Equations
10	2:1	0:1	5°	SI = 0.000(v) + 0.533
			10°	SI = 0.015(v) - 0.190
			15°	SI = 0.045(v) - 1.633
			20°	SI = 0.028(v) - 0.400
			25°	SI = 0.010(v) + 0.900
20	2:1	0:1	5°	SI = 0.005(v) + 0.667
			10°	SI = 0.010(v) + 0.405
			15°	SI = 0.020(v) - 0.200
			20°	SI = 0.049(v) - 1.365
			25°	SI = 0.075(v) - 2.433
30	2:1	0:1	5°	SI = 0.000(v) + 1.267
			10°	SI = 0.000(v) + 1.170
			15°	SI = 0.000(v) + 1.000
			20°	SI = 0.010(v) + 0.543
			25°	SI = 0.020(v) + 0.033
10	2:1	4:1	5°	SI = 0.010(v) + 0.000
			10°	SI = 0.017(v) - 0.049
			15°	SI = 0.024(v) - 0.194
			20°	SI = 0.003(v) + 1.913
			25°	SI =-0.019(v) + 4.046
20	2:1	4:1	5°	SI = 0.005(v) + 0.648
			10°	SI = 0.023(v) - 0.233
			15°	SI = 0.049(v) - 1.456
			20°	SI = 0.074(v) - 2.252
			25°	SI = 0.112(v) - 3.463
30	2:1	4:1	5°	SI = 0.005(v) + 0.906
			10°	SI = 0.007(v) + 1.155
			15°	SI = 0.010(v) + 1.553
			20°	SI = 0.033(v) + 0.308
			25°	SI = 0.068(v) - 1.651
10	2:1	2:1	5°	SI = 0.010(v) + 0.000
			10°	SI = 0.017(v) - 0.050
			15°	SI = 0.025(v) - 0.200
			20°	SI = 0.003(v) + 1.970
			25°	SI =-0.020(v) + 4.167
20	2:1	2:1	5°	SI = 0.005(v) + 0.667
			10°	SI = 0.024(v) - 0.240
			15°	SI = 0.050(v) - 1.500
			20°	SI = 0.076(v) - 2.320
			25°	SI = 0.115(v) - 3.567
30	2:1	2:1	5°	SI = 0.005(v) + 0.933
			10°	SI = 0.007(v) + 1.190
			15°	SI = 0.010(v) + 1.600
			20°	SI = 0.034(v) + 0.317
			25°	SI = 0.070(v) - 1.700

Severity Index Equations for Type A Ditches

Adjustment factor to type B ditches = 0.81
Adjustment factor to type C ditches = 0.70

Fill Ht.	Front Slope	Back Slope	Encr. Angle	Least Squares Equations
10	3:1	0:1	5°	SI = 0.000(v) + 0.300
			10°	SI = 0.000(v) + 0.370
			15°	SI = 0.000(v) + 0.467
			20°	SI = 0.026(v) - 0.897
			25°	SI = 0.050(v) - 2.133
20	3:1	0:1	5°	SI = 0.000(v) + 0.567
			10°	SI = 0.003(v) + 0.373
			15°	SI = 0.005(v) - 0.233
			20°	SI = 0.010(v) + 0.700
			25°	SI = 0.015(v) - 0.100
30	3:1	0:1	5°	SI =-0.005(v) + 0.933
			10°	SI =-0.005(v) + 0.967
			15°	SI =-0.005(v) + 1.033
			20°	SI = 0.006(v) + 0.457
			25°	SI = 0.015(v) - 0.067
10	3:1	4:1	5°	SI = 0.005(v) + 0.133
			10°	SI = 0.009(v) - 0.027
			15°	SI = 0.020(v) - 0.533
			20°	SI = 0.031(v) - 1.000
			25°	SI = 0.060(v) - 2.400
20	3:1	4:1	5°	SI =-0.005(v) + 1.167
			10°	SI = 0.003(v) + 0.697
			15°	SI = 0.020(v) - 0.367
			20°	SI = 0.024(v) - 0.407
			25°	SI = 0.030(v) - 0.600
30	3:1	4:1	5°	SI = 0.010(v) + 0.667
			10°	SI = 0.012(v) + 0.460
			15°	SI = 0.020(v) - 0.133
			20°	SI = 0.021(v) + 0.056
			25°	SI = 0.025(v) - 0.033
10	3:1	2:1	5°	SI= 0.009(v) + 0.226
			10°	SI = 0.015(v) - 0.046
			15°	SI = 0.034(v) - 0.906
			20°	SI = 0.052(v) - 1.700
			25°	SI = 0.102(v) - 4.080
20	3:1	2:1	5°	SI =-0.009(v) + 1.984
			10°	SI = 0.004(v) + 1.185
			15°	SI = 0.034(v) - 0.624
			20°	SI = 0.040(v) - 0.692
			25°	SI = 0.051(v) - 1.020
30	3:1	2:1	5°	SI = 0.017(v) + 1.134
			10°	SI = 0.020(v) + 0.782
			15°	SI = 0.034(v) - 0.226
			20°	SI = 0.035(v) + 0.095
			25°	SI = 0.043(v) - 0.056

Severity Index Equations for Type A Ditches

Adjustment factor to type B ditches = 0.81
Adjustment factor to type C ditches = 0.70

Fill Ht.	Front Slope	Back Slope	Encr. Angle	Least Squares Equations
10	4:1	0:1	5°	SI = 0.002(v) + 0.233
			10°	SI = 0.003(v) + 0.193
			15°	SI = 0.005(v) + 0.067
			20°	SI = 0.008(v) - 0.007
			25°	SI = 0.010(v) - 0.067
20	4:1	0:1	5°	SI = 0.005(v) + 0.067
			10°	SI = 0.005(v) + 0.133
			15°	SI = 0.005(v) + 0.167
			20°	SI = 0.006(v) + 0.243
			25°	SI = 0.010(v) + 0.067
30	4:1	0:1	5°	SI = 0.005(v) + 0.133
			10°	SI = 0.003(v) + 0.340
			15°	SI = 0.000(v) + 0.600
			20°	SI = 0.000(v) + 0.680
			25°	SI = 0.000(v) + 0.767
10	4:1	4:1	5°	SI = 0.010(v) - 0.167
			10°	SI = 0.008(v) + 0.087
			15°	SI = 0.005(v) + 0.333
			20°	SI = 0.007(v) + 0.407
			25°	SI = 0.010(v) + 0.367
20	4:1	4:1	5°	SI =-0.005(v) + 0.833
			10°	SI =-0.003(v) + 0.890
			15°	SI = 0.010(v) + 0.333
			20°	SI = 0.012(v) + 0.303
			25°	SI = 0.015(v) + 0.167
30	4:1	4:1	5°	SI =-0.008(v) + 1.447
			10°	SI =-0.007(v) + 1.423
			15°	SI =-0.004(v) + 1.360
			20°	SI = 0.001(v) + 1.133
			25°	SI = 0.006(v) + 0.860
10	4:1	2:1	5°	SI = 0.017(v) - 0.284
			10°	SI = 0.013(v) + 0.148
			15°	SI = 0.009(v) + 0.566
			20°	SI = 0.011(v) + 0.692
			25°	SI = 0.017(v) + 0.624
20	4:1	2:1	5°	SI =-0.009(v) + 1.416
			10°	SI =-0.005(v) + 1.513
			15°	SI = 0.017(v) + 0.566
			20°	SI = 0.020(v) + 0.515
			25°	SI = 0.026(v) + 0.284
30	4:1	2:1	5°	SI =-0.014(v) + 2.460
			10°	SI =-0.011(v) + 2.419
			15°	SI =-0.007(v) + 2.312
			20°	SI = 0.001(v) + 1.926
			25°	SI = 0.010(v) + 1.462

Severity Index Equations for Type A Ditches

Adjustment factor to type B ditches = 0.81

Adjustment factor to type C ditches = 0.70

Fill Ht.	Front Slope	Back Slope	Encr. Angle	Least Squares Equations
10	6:1	0:1	5°	SI =-0.005(v) + 0.467
			10°	SI =-0.001(v) + 0.260
			15°	SI = 0.005(v) - 0.067
			20°	SI = 0.009(v) - 0.250
			25°	SI = 0.015(v) - 0.567
20	6:1	0:1	5°	SI =-0.005(v) + 0.467
			10°	SI =-0.001(v) + 0.260
			15°	SI = 0.005(v) - 0.067
			20°	SI = 0.009(v) - 0.250
			25°	SI = 0.015(v) - 0.567
30	6:1	0:1	5°	SI =-0.005(v) + 0.467
			10°	SI =-0.001(v) + 0.260
			15°	SI = 0.005(v) - 0.067
			20°	SI = 0.009(v) - 0.250
			25°	SI = 0.015(v) - 0.567
10	6:1	4:1	5°	SI =-0.005(v) + 0.767
			10°	SI =-0.001(v) + 0.560
			15°	SI = 0.005(v) + 0.300
			20°	SI = 0.013(v) - 0.037
			25°	SI = 0.020(v) - 0.367
20	6:1	4:1	5°	SI =-0.005(v) + 0.767
			10°	SI =-0.001(v) + 0.560
			15°	SI = 0.005(v) + 0.300
			20°	SI = 0.013(v) - 0.037
			25°	SI = 0.020(v) - 0.367
30	6:1	4:1	5°	SI =-0.005(v) + 0.767
			10°	SI =-0.001(v) + 0.560
			15°	SI = 0.005(v) + 0.300
			20°	SI = 0.013(v) - 0.037
			25°	SI = 0.020(v) - 0.367
10	6:1	2:1	5°	SI =-0.009(v) + 1.304
			10°	SI =-0.002(v) + 0.952
			15°	SI = 0.009(v) + 0.510
			20°	SI = 0.021(v) - 0.063
			25°	SI = 0.034(v) - 0.624
20	6:1	2:1	5°	SI =-0.009(v) + 1.304
			10°	SI =-0.002(v) + 0.952
			15°	SI = 0.009(v) + 0.510
			20°	SI = 0.021(v) - 0.063
			25°	SI = 0.034(v) - 0.624
30	6:1	2:1	5°	SI =-0.009(v) + 1.304
			10°	SI =-0.002(v) + 0.952
			15°	SI = 0.009(v) + 0.510
			20°	SI = 0.021(v) - 0.063
			25°	SI = 0.034(v) - 0.624

A P P E N D I X

G. BARRIER VII SAMPLE COMPUTER SIMULATIONS

INPUT DATA: Standard Size Auto

(50 mph/15 deg)

OUTPUT DATA: Interval Time at 140 msec

BARRIER VII - ANALYSIS OF AUTOMOBILE BARRIERS - U.C. BERKELEY, 1972

****

RUN ON CORRUGATED STEEL BEAM RAIL _ WOOD POSTS GUARDRAIL UTILIZAT

****

50 mph / 15 deg

CONTROL INFORMATION

NUMBER OF BARRIER NODES	=	97
NUMBER OF CONTROL NODES	=	4
NUMBER OF NODE GENERATIONS	=	3
NUMBER OF INTERFACES	=	1
NUMBER OF MEMBERS	=	127
NUMBER OF MEMBER GENERATIONS	=	9
NUMBER OF DIFFERENT MEMBER SERIES	=	2
NUMBER OF ADDITIONAL WEIGHT SETS	=	0
BASIC TIME STEP (SEC)	=	0.00200
LARGEST ALLOWABLE TIME STEP (SEC)	=	0.10000
MAXIMUM TIME SPECIFIED (SEC)	=	0.80000
MAX. NO. OF STEPS WITH NO CONTACT	=	100
OVERSHOOT INDEX	=	0
ROTATIONAL DAMPING MULTIPLIER	=	1.00
STEP-BY-STEP INTEGRATION TYPE	=	1

OUTPUT FREQUENCIES

AUTOMOBILE DATA	= 5
BARRIER DEFLECTIONS	= 5
BARRIER FORCES	= 10
ENERGY BALANCE	= 20
CONTACT INFORMATION	= 5
PUNCHED JOINT DATA	= 0
PUNCHED TRAJECTORY	= 0

BEAM ELEMENTS, 100 SERIES

TYPE NUMBER	=	1	2
M. OF I. (IN4)	=	2.310D 00	2.310D 00
AREA (IN2)	=	1.990D 00	1.990D 00
LENGTH (IN)	=	3.750D 01	1.875D 01
YOUNGS MODULUS (KSI)	=	3.000D 04	3.000D 04
WEIGHT (LB/FT)	=	6.820D 00	6.820D 00
YIELD FORCE (K)	=	1.075D 02	1.075D 02
YIELD MOMENT (K.IN)	=	8.880D 01	8.880D 01
YIELD ACCURACY LIMIT	=	1.000D-01	1.000D-01

POSTS, 300 SERIES

TYPE NUMBER	=	1	2
HEIGHT OF NODE I (IN)	=	2.100D 01	2.100D 01
HEIGHT OF NODE J (IN)	=	0.0	0.0
A AXIS STIFFNESS (K/IN)	=	1.500D 01	2.200D 00
B AXIS STIFFNESS (K/IN)	=	1.660D 00	1.660D 00
EFFECTIVE WEIGHT (LB)	=	7.000D 01	7.000D 01
B AXIS YIELD MOMENT (K.IN)	=	1.000D 04	2.730D 02
A AXIS YIELD MOMENT (K.IN)	=	2.184D 02	2.184D 02
YIELD ACCURACY LIMIT	=	1.000D-01	1.000D-01
A SHEAR AT FAILURE (K)	=	1.000D 04	1.300D 01
B SHEAR AT FAILURE (K)	=	1.040D 01	1.040D 01
A DEFLN AT FAILURE (IN)	=	1.000D 04	7.400D 00
B DEFLN AT FAILURE (IN)	=	7.400D 00	7.400D 00

AUTOMOBILE PROPERTIES

WEIGHT (LB)	=	3820.0
MOMENT OF INERTIA (LB.IN.SEC2)	=	36758.0
NO. OF CONTACT POINTS	=	16
NO. OF UNIT STIFFNESSES	=	3
NO. OF WHEELS	=	4
BRAKE CODE (1=ON, 0=OFF)	=	0
NO. OF OUTPUT POINTS	=	1

UNIT STIFFNESSES (K/IN/IN)

NO.	BEFORE BOTTOMING	AFTER BOTTOMING	UNLOADING	BOTTOMING DISTANCE
1	0.500	3.000	4.000	15.00
2	0.875	5.250	7.000	15.00
3	1.250	7.500	10.000	15.00

CONTACT POINT DATA

POINT	R COORD	S COORD	STIFFNESS NO.	TRIBUTARY LENGTH	INTERFACE CONTACTS			
1	-108.00	15.00	1	12.00	1	0	0	0
2	-108.00	27.00	1	12.00	1	0	0	0
3	-108.00	39.00	1	12.00	1	0	0	0
4	-96.00	39.00	1	12.00	1	0	0	0
5	-84.00	39.00	1	12.00	1	0	0	0
6	-72.00	39.00	2	30.00	1	0	0	0
7	-42.00	39.00	3	30.00	1	0	0	0
8	-12.00	39.00	3	30.00	1	0	0	0
9	18.00	39.00	3	30.00	1	0	0	0
10	48.00	39.00	2	12.00	1	0	0	0
11	60.00	39.00	1	12.00	1	0	0	0
12	72.00	39.00	1	12.00	1	0	0	0
13	84.00	39.00	1	12.00	1	0	0	0
14	84.00	27.00	1	12.00	1	0	0	0
15	84.00	15.00	1	12.00	1	0	0	0
16	84.00	3.00	1	12.00	1	0	0	0

WHEEL COORDINATES (IN), STEER ANGLES (DEG), AND DRAG FORCES (LB)

POINT	R-ORD	S-ORD	STEER ANGLE	DRAG FORCE
1	54.00	30.00	0.0	518.00
2	54.00	-30.00	0.0	518.00
3	-65.00	-30.00	0.0	437.00
4	-65.00	30.00	0.0	437.00

NITIAL POSITION AND VELOCITIES OF AUTO

PECIFIED BOUNDARY POINT	=	13
ORDINATE OF POINT	=	800.00
ORDINATE OF POINT	=	0.0
NGLE FROM X AXIS TO R AXIS (DEG)	=	15.00
ELOCITY IN R DIRECTION (M.P.H)	=	50.00
ELOCITY IN S DIRECTION (M.P.H)	=	0.0
NGULAR VELOCITY (RAD/SEC)	=	0.0
INIMUM RESULTANT VELOCITY (M.P.H)	=	5.00
RANSLATIONAL KINETIC ENERGY (K.IN)	=	3831.87
OTATIONAL KINETIC ENERGY (K.IN)	=	0.0
OTAL INITIAL KINETIC ENERGY (K.IN)	=	3831.87

UTO TRAJECTORY RESULTS

T	X-ORD	Y-ORD	ANGLE	X-VEL	Y-VEL	R-VEL	S-VEL	T-VEL	ANGLE	X-ACC	Y-ACC	R-ACC	S-ACC	T-ACC	ANGLE
TIME = 0.0 SECS															
1	729.0	-59.4	15.0	48.30	12.94	50.00	0.00	50.00	15.0	0.0	0.0	0.0	0.0	0.0	0.0

ARRIER DEFLECTIONS, TIME = 0.0 SECS

NODE	X-DEFL	Y-DEFL	X-ORD	Y-ORD
1	0.0	0.0	0.0	0.0
2	0.0	0.0	37.5	0.0
3	0.0	0.0	75.0	0.0
4	0.0	0.0	112.5	0.0
5	0.0	0.0	150.0	0.0
6	0.0	0.0	187.5	0.0
7	0.0	0.0	225.0	0.0
8	0.0	0.0	262.5	0.0
9	0.0	0.0	300.0	0.0
10	0.0	0.0	337.5	0.0
11	0.0	0.0	375.0	0.0
12	0.0	0.0	412.5	0.0
13	0.0	0.0	450.0	0.0
14	0.0	0.0	487.5	0.0
15	0.0	0.0	525.0	0.0
16	0.0	0.0	562.5	0.0
17	0.0	0.0	600.0	0.0
18	0.0	0.0	637.5	0.0
19	0.0	0.0	675.0	0.0
20	0.0	0.0	693.8	0.0
21	0.0	0.0	712.5	0.0
22	0.0	0.0	731.3	0.0
23	0.0	0.0	750.0	0.0

DATA ON AUTO-BARRIER CONTACT, TIME = 0.1300 SECS

AUTO POINT	CONTACT INTERFACE	CONTACT BETWEEN NODE	AND NODE	X COORDINATE	Y COORDINATE	NORMAL FORCE	X FORCE	Y FORCE
12	1	32	31	900.45	9.03	0.67	-0.32	-0.64
13	1	32	31	909.35	8.47	5.61	-2.68	-5.41

AUTO TRAJECTORY RESULTS

PT	X-ORD	Y-ORD	ANGLE	X-VEL	Y-VEL	R-VEL	S-VEL	T-VEL	ANGLE	X-ACC	Y-ACC	R-ACC	S-ACC	T-ACC	ANGLE
TIME = 0.1400 SECS															
1	842.5	-39.1	7.1	43.46	3.22	43.53	-2.15	43.58	4.2	-0.72	-1.34	-0.87	-1.24	1.52	-118.1

BARRIER DEFLECTIONS, TIME = 0.1400 SECS

NODE	X-DEFL	Y-DEFL	X-ORD	Y-ORD
1	0.37	0.01	0.4	0.0
2	0.37	-0.00	37.9	-0.0
3	0.37	-0.01	75.4	-0.0
4	0.38	-0.01	112.9	-0.0
5	0.38	-0.01	150.4	-0.0
6	0.39	0.01	187.9	0.0
7	0.39	0.02	225.4	0.0
8	0.39	0.03	262.9	0.0
9	0.40	0.01	300.4	0.0
10	0.40	-0.02	337.9	-0.0
11	0.41	-0.05	375.4	-0.0
12	0.42	-0.06	412.9	-0.1
13	0.42	-0.03	450.4	-0.0
14	0.43	0.03	487.9	0.0
15	0.44	0.09	525.4	0.1
16	0.44	0.12	562.9	0.1
17	0.45	0.10	600.5	0.1
18	0.46	0.04	638.0	0.0
19	0.47	-0.02	675.5	-0.0
20	0.47	-0.02	694.2	-0.0
21	0.48	0.01	713.0	0.0
22	0.48	0.13	731.7	0.1
23	0.49	0.35	750.5	0.4
24	0.49	0.88	769.2	0.9
25	0.48	1.60	788.0	1.6
26	0.47	2.56	806.7	2.6

BEAMS (100 Series)

Axial force is tension positvie. Bending moments are positive clockwise on member ends.

MEMBER FORCES, TIME = 0.1400 SECS

BEAMS, 100 SERIES

MEMBER	NODE I	NODE J	TYPE	FORCE	I-MOMENT	J-MOMENT	F-CODE	M-CODE
1	1	2	101	5.72	-0.00	-0.04	1	1
2	2	3	101	5.78	0.04	-0.21	1	1
3	3	4	101	5.83	0.21	-0.42	1	1
4	4	5	101	5.89	0.42	-0.52	1	1
5	5	6	101	6.98	0.52	-0.06	1	1
6	6	7	101	7.04	0.06	0.54	1	1
7	7	8	101	7.09	-0.54	1.00	1	1
8	8	9	101	7.15	-1.00	1.06	1	1
9	9	10	101	8.28	-1.06	-0.01	1	1
10	10	11	101	8.33	0.01	-1.23	1	1
11	11	12	101	9.48	1.23	-1.90	1	1
12	12	13	101	9.54	1.90	-1.72	1	1
13	13	14	101	10.70	1.72	-0.18	1	1
14	14	15	101	10.76	0.18	1.52	1	1
15	15	16	101	11.95	-1.52	2.70	1	1
16	16	17	101	12.01	-2.70	2.38	1	1
17	17	18	101	13.23	-2.38	0.31	1	1
18	18	19	101	13.28	-0.31	-3.48	1	1
19	19	20	102	14.52	3.48	-8.50	1	1
20	20	21	102	14.55	8.50	-14.47	1	1
21	21	22	102	14.57	14.47	-21.89	1	1
22	22	23	102	14.60	21.89	-31.24	1	1
23	23	24	102	15.86	31.24	-37.56	1	1
24	24	25	102	15.88	37.56	-47.03	1	1
25	25	26	102	15.90	47.03	-60.24	1	1
26	26	27	102	15.93	60.24	-69.57	1	1
27	27	28	102	17.36	69.57	-83.23	1	1
28	28	29	102	17.40	83.23	-80.09	1	3
29	29	30	102	17.20	80.09	-29.51	1	2
30	30	31	102	16.86	29.51	51.22	1	1
31	31	32	102	16.75	-51.22	80.17	1	3
32	32	33	102	14.96	-80.17	33.57	1	2
33	33	34	102	15.01	-33.57	-12.78	1	1
34	34	35	102	15.03	12.78	-62.92	1	1
35	35	36	102	14.02	62.92	-45.51	1	1
36	36	37	102	14.05	45.51	-34.03	1	1
37	37	38	102	14.08	34.03	-27.13	1	1
38	38	39	102	14.10	27.13	-23.63	1	1
39	39	40	102	13.31	23.63	-18.02	1	1
40	40	41	102	13.33	18.02	-13.84	1	1
41	41	42	102	13.35	13.84	-10.41	1	1
42	42	43	102	13.36	10.41	-7.21	1	1
43	43	44	102	12.60	7.21	-5.42	1	1
44	44	45	102	12.62	5.42	-3.50	1	1
45	45	46	102	12.64	3.50	-1.54	1	1

M-Code = flexural state indicator:

1 = elastic;
2 = yielded at i only;
3 = yielded at j only;
4 = yielded at i and j.

F-Code = extensional state indicator:

1 = elastic;
2 = yielded.

POSTS, 300 SERIES

MEMBER	NODE I	NODE J	TYPE	A-SHEAR	B-SHEAR	B-MOMENT	A-MOMENT	CODE
97	1	0	301	5.51	0.01	115.64	0.19	1
98	5	0	302	0.84	-0.01	17.63	-0.22	1
99	9	0	302	0.88	0.02	18.45	0.49	1
100	11	0	302	0.90	-0.08	18.94	-1.71	1
101	13	0	302	0.93	-0.05	19.49	-1.03	1
102	15	0	302	0.96	0.15	20.11	3.12	1
103	17	0	302	0.99	0.17	20.82	3.62	1
104	19	0	302	1.03	-0.03	21.64	-0.59	1
105	23	0	302	1.08	0.59	22.59	12.30	1
106	27	0	302	1.03	2.83	21.53	59.43	1
107	31	0	302	0.0	0.0	0.0	0.0	0
108	35	0	302	-0.85	5.12	-17.83	107.47	1
109	39	0	302	-0.91	0.83	-19.16	17.38	1
110	43	0	302	-0.88	-0.22	-18.52	-4.55	1
111	47	0	302	-0.85	-0.15	-17.79	-3.12	1
112	51	0	302	-0.81	0.01	-17.10	0.19	1
113	55	0	302	-0.78	0.02	-16.45	0.41	1
114	59	0	302	-0.75	-0.00	-15.83	-0.06	1
115	63	0	302	-0.73	-0.00	-15.25	-0.08	1
116	67	0	302	-0.70	0.00	-14.70	0.03	1
117	71	0	302	-0.68	0.00	-14.19	0.01	1
118	75	0	302	-0.65	-0.00	-13.72	-0.01	1
119	79	0	302	-0.63	0.00	-13.28	0.00	1
120	83	0	302	-0.61	0.00	-12.87	0.00	1
121	85	0	302	-0.59	-0.00	-12.49	-0.00	1
122	87	0	302	-0.58	0.00	-12.14	0.00	1
123	89	0	302	-0.56	0.00	-11.82	0.00	1
124	91	0	302	-0.55	-0.00	-11.53	-0.00	1
125	93	0	302	-0.54	0.00	-11.27	0.00	1
126	95	0	302	-0.53	0.00	-11.04	0.00	1
127	97	0	301	-3.52	-0.00	-73.92	-0.00	1

Posts (300 Series)

Shear forces and bending moments are positive for forces on the post in the positive A and B directions.

Code = state indicator

1 = elastic;
2 = plastic hinge about A axis only;
3 = plastic hinge about B axis only;
Δ = plastic hinges about both axes;
negative = in process of failing (e.g. -7 indicates third of ten failure steps);
0 = failed completely

A P P E N D I X

H. W-BEAM GUARDRAIL SEVERITY-INDEX EQUATIONS

Impact Angle	Severity Index Equations	SI Adjustment Factors
5°	SI = 0.01475(Vel) - 0.2660	0.89
10°	SI = 0.01228(Vel) - 0.0470	0.91
15°	SI = 0.01222(Vel) + 0.2470	0.93
20°	SI = 0.01448(Vel) + 0.1678	1.06
25°	SI = 0.01727(Vel) + 0.1827	1.06

A P P E N D I X

I. CASE STUDY NO. 1 (INPUT DATA AND OUTPUT)

FIGURE 1.

ROADSIDE HAZARD INVENTORY FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Inventory Conducted by Richard Ruby Date 06 Sept '79

HIGHWAY

BOX 1

Highway Design Number	Highway Number	Design Speed (mph)	ADT	Lane Width (ft)	Usable Shoulder Width (ft)	Width Shoulder Surfacing (ft)	Median Width (ft)	Deg of Curve	Grade (%) UP	Grade (%) DN	Shoulder Drop-off (in)	Condition Non Paved Shoulder
1-07	1-210	60	01000	12	04	00	00	0	0	2	0	1
1 2 3	4 5 6 7	8 9	10 11 12 13 14	15 16	17 18	19 20	21 22	23	24	25	26	27

1. DR
2. DM
3. ROA
4. RC
5. RL

1. US
2. N
3. I
4. SEC

1 Smooth
2 Rough

HAZARD CLASSIFICATION

Description _____

BOX 2

Hazard Number	Identification Code	Descriptor Code	Offset Code	Grouping Number
0001	07	02	1	10
28 29 30 31	32 33	34 36	36	37 38

1. Right Side
2. Left Side or Median

MILE POINT AT HAZARD

BOX 2

Beginning	Ending
100000	100100
39 40 41 42 43 44	45 46 47 48 49 50

POINT HAZARDS

BOX 3

	Offset (ft)	Width (ft)	Length (ft)	Drop Inlets Only: Height (in)	Drop Inlets Only: Depth (in)
1					
51	52 53	54 55	56 57 58 59	60 61	62 63

LONGITUDINAL HAZARDS (Guardrails, Bridgerails, Barrier Walls, and Curbs)

BOX 4

	Offset (ft) Begin	Offset (ft) End	Top Height (in)	Post Spacing (ft)	Guardrail: Post Spacing at Bridge End	Guardrail: Blockout	Guardrail: Rub Rail	Guardrail End Treatment: Beginning	Guardrail End Treatment: Ending
2									
51	52 53	54 55	56 57	58 59	60	61	62	63	64

60: 1. Reduced 2. Not Reduced
61: 1 No. 2 Yes
62: 1. No 2. Yes
63, 64: 1. Not Anchored (to ground or Bridge) 2. Anchored (to ground or Bridge) 3. Anchored Turndown (not breakaway) 4. Breakaway Terminal Design

SLOPE HAZARDS (Median Ditches, Roadside Ditches, Fill Ditches, and Cut Slopes)

BOX 5

	Hinge Point Offset (ft)	Front Slope (average)	Front Slope Height (ft)	Ditch Width (ft)	Back Slope (average)	Back Slope Height (ft)	Condition of Slopes	Depth of Water
3	04	2:1	20	02	2:1	05	1	1
51	52 53	54	55 56	57 58	59	60 61	62	63

62: 1 Smooth 2 Rough
63: 1 None 2 Less than 2 ft 3 Greater than 2 ft

BOX 6

DATE: Mo 08 Day 30 Yr 79 (70 71, 72 73, 74 75)

Recommendations: CASE STUDY 1

IBM Card Type: 1 (80)

FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard Ruby Date 06 Sept '79

HIGHWAY — BOX 1

⊗

Highway Design Number: 1-05 (1 2 3)
1 DR SRL
2 DM
3 ROA
4 RC
5 RL

Highway Number: 1-210 (4 5 6 7)
1 US
2 N
3 I
4 SEC

Design Speed (mph): 60 (8 9)

ADT: 01000 (10 11 12 13 14)

Hazard Number: 1
Hazard Group Number: 1
Improvement Alternates Number: 1

COSTS — BOX 2

⊗

Capital Costs ($1,000): 0061 (15 16 17 18 19)

Collision Maintenance ($100/accid.): Hazard 001 (20 21 22); Improvement 001 (23 24 25)

Normal Maintenance ($100/yr.): Hazard 02 (26 27); Improvement 02 (28 29)

POINT HAZARD IMPROVEMENTS — BOX 3

○ 1 (30) 1 (31) Alleviate Hazard — (32) 1. Remove; 2. Make Breakaway and/or Relocate; 3. Reconstruct Inlet to Safe Design; 4. Reconstruct Cross Drainage System

○ 1 (30) 2 (31) Install Traffic Barrier (complete Box A) — Descriptor Code (32 33) — Length (ft) (34 35 36 37)

○ 1 (30) 3 (31) Install Energy Attenuator — Descriptor Code (32 33)

LONGITUDINAL HAZARD IMPROVEMENTS — BOX 4

○ 2 (30) 1 (31) Curb — (32) 1 Remove and Regrade; 2 Install Wedge Modification

○ 2 (30) 2 (31) Traffic Barrier — (32) 1 Remove; 2 Modify (complete Boxes A, B & C); 3 Replace with New Design (complete Boxes A, B & C) — Descriptor Code (New Design Only) (33 34)

○ 2 (30) 3 (31) Bridgerail — (32) 1. Modify; 2. Replace with New Design — Descriptor Code (33 34)

SLOPE IMPROVEMENTS — BOX 5

○ 3 (30) 1 (31) Install Traffic Barrier (complete Boxes A and C) — (32) 1 At Bridge; 2 Not at Bridge — Descriptor Code (33 34)

⊗ 3 (30) 2 (31) Modify (complete Box C)

Hinge Point Offset (ft) (32 33)	Front Slope (average) (34)	Front Slope Height (ft) (35 36)	Ditch Width (ft) (37 38)	Back Slope (average) (39)	Back Slope Height (ft) (40 41)	Condition of Slopes (42)	Depth of Water (ft) (43)
08	3:1	20	10	2:1	06	1	1

Condition of Slopes: 1 Smooth; 2 Rough
Depth of Water: 1 None; 2 Less than 2 ft; 3 Greater than 2 ft

NO IMPROVEMENT — BOX 6

○ 4 (30)

BOX A (TRAFFIC BARRIER MODIFICATIONS) — BOX A

○

Offset (ft): Begin (48 49); End (50 51)
Top Height (in) (52 53)
Post Spacing (ft) (54 55)
Post Spacing at Bridge End (56): 1 Reduced; 2 Not Reduced
Guardrail Block Out (57): 1 No; 7 Yes
Rub Rail (58): 1 No; 2 Yes
Guardrail End Treatment — Beginning (59); Ending (60)
1 Not Anchored (to ground or bridge)
2 Anchored (to ground or bridge)
3 Anchored Turndown (not breakaway)
4 Breakaway Terminal Design

BOX B (CHANGES TO EXISTING GUARDRAIL) — BOX B

⊗

Beginning (61): 1 Lengthen; 2 Shorten
Ending (62): 1 Lengthen; 2 Shorten
Change in Length (ft) (63 64)

BOX C (MILE POINT OF CHANGE) — BOX C

Beginning: 1 00 0 00 (65 66 67 68 69 70)
Ending: 1 00 1 00 (71 72 73 74 75 76)

BOX 7

(?)

1 End of Group (79)
2 End of Group and Program

2 IRM Card Type (80)

FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard Ruby Date 06 Sept '79

HIGHWAY — BOX 1

Highway Design Number: 1-05 (1 DR SRL, 2 DM, 3 ROA, 4 RC, 5 RL)
Highway Number: 1-210 (1 US, 2 N, 3 I, 4 SEC)
Design Speed (mph): 60
ADT: 01000
Hazard Number: 1
Hazard Group Number: 1
Improvement Alternative Number: 2

COSTS — BOX 2

Capital Costs ($1,000): 00125
Collision Maintenance ($100/accid.): Hazard 001; Improvement 003
Normal Maintenance ($100/yr.): Hazard 02; Improvement 03

POINT HAZARD IMPROVEMENTS — BOX 3

- ○ 1 (30) 1 (31) Alleviate Hazard — (32) 1 Remove; 2 Make Breakaway and/or Relocate; 3 Reconstruct Inlet to Safe Design; 4 Reconstruct Cross Drainage System
- ○ 1 (30) 2 (31) Install Traffic Barrier (complete Box A) — Descriptor Code (32 33); Length (ft) (34 35 36 37)
- ○ 1 (30) 3 (31) Install Energy Attenuator — Descriptor Code (32 33)

LONGITUDINAL HAZARD IMPROVEMENTS — BOX 4

- ○ 2 (30) 1 (31) Curb — (32) 1 Remove and Regrade; 2 Install Wedge Modification
- ○ 2 (30) 2 (31) Traffic Barrier — (32) 1 Remove; 2 Modify (complete Boxes A, B & C); 3 Replace with New Design (complete Boxes A, B & C) — Descriptor Code (New Design Only) (33 34)
- ○ 2 (30) 3 (31) Bridgerail — (32) 1 Modify; 2 Replace with New Design — Descriptor Code (33 34)

SLOPE IMPROVEMENTS — BOX 5

- X 3 (30) 1 (31) Install Traffic Barrier (complete Boxes A and C) — (32) 2 1 At Bridge; 2 Not at Bridge — Descriptor Code 06 (33 34)
- ○ 3 (30) 2 (31) Modify (complete Box C) — Hinge Point Offset (ft) (32 33); Front Slope (average) :1 (34); Front Slope Height (ft) (35 36); Ditch Width (ft) (37 38); Back Slope (average) :1 (39); Back Slope Height (ft) (40 41); Transition of Slopes (42): 1 Smooth, 2 Rough; Depth of Water (ft) (43): 1 None, 2 Less than 2 ft, 3 Greater than 2 ft

NO IMPROVEMENT — BOX 6

- ○ 4 (30)

BOX A (TRAFFIC BARRIER MODIFICATIONS) — BOX A

- ⊗ Offset (ft) Begin 10 (48 49); End 10 (50 51)
- Top Height (in) 27 (52 53)
- Post Spacing (ft) 06 (54 55)
- Post Spacing at Bridge End 0 (56): 1 Reduced, 2 Not Reduced
- Guardrail Block Out 1 (57): 1 No, 2 Yes
- Rub Rail 1 (58): 1 No, 2 Yes
- Guardrail End Treatment — Beginning 3 (59); Ending 2 (60): 1 Not Anchored (to ground or bridge); 2 Anchored (to ground or bridge); 3 Anchored Turndown (not breakaway); 4 Breakaway Terminal Design

BOX B (CHANGES TO EXISTING GUARDRAIL) — BOX B

- X Beginning (61): 1 Lengthen, 2 Shorten
- Ending (62): 1 Lengthen, 2 Shorten
- Change in Length (ft) (63 64)

BOX C (MILE POINT OF CHANGE) — BOX C

- Beginning 10000 (65 66 67 68 69 70)
- Ending 10000 (71 72 73 74 75 76)

BOX 7

- (1) (79): 1 End of Group, 2 End of Group and Program
- 2 (80): IRM Card Type

FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard Ruby Date 06 Sept '79

HIGHWAY — BOX 1

⊗

Highway Design Number: 1-05 (1 2 3)
1 DR SRL
2 DM
3 ROA
4 RC
5 RL

Highway Number: 1-270 (4 5 6 7)
1 US
2 N
3 I
4 SEC

Design Speed (mph): 60 (8 9)

ADT: 02000 (10 11 12 13 14)

Hazard Number: 1
Hazard Group Number: 1
Improvement Alternative Number: 3

COSTS — BOX 2

⊗

Capital Costs ($1,000): 00090 (15 16 17 18 19)

Collision Maintenance ($100/accident)
Hazard: 001 (20 21 22)
Improvement: 003 (23 24 25)

Normal Maintenance ($100/yr.)
Hazard: 02 (26 27)
Improvement: 03 (28 29)

POINT HAZARD IMPROVEMENTS — BOX 3

○

1 (30) 1 (31) Alleviate Hazard — (32) 1 Remove; 2 Make Breakaway and/or Relocate; 3 Reconstruct Inlet to Safe Design; 4 Reconstruct Cross Drainage System

○

1 (30) 2 (31) Install Traffic Barrier (complete Box A) - (32 33) Descriptor Code — (34 35 36 37) Length (ft)

○

1 (30) 3 (31) Install Energy Attenuator — (32 33) Descriptor Code

LONGITUDINAL HAZARD IMPROVEMENTS — BOX 4

○

2 (30) 1 (31) Curb — (32) 1. Remove and Regrade; 2. Install Wedge Modification

○

2 (30) 2 (31) Traffic Barrier — (32) 1 Remove; 2 Modify (complete Boxes A, B & C); 3 Replace with New Design (complete Boxes A, B & C) — (33 34) Descriptor Code (New Design Only)

○

2 (30) 3 (31) Bridgerail — (32) 1. Modify; 2. Replace with New Design — (33 34) Descriptor Code

SLOPE IMPROVEMENTS — BOX 5

⊗

3 (30) 1 (31) Install Traffic Barrier (complete Boxes A and C) — (32) 2 1 At Bridge; 2 Not at Bridge — (33 34) 06 Descriptor Code

○

3 (30) 2 (31) Modify (complete Box C)

Hinge Point Offset (ft) (32 33)	Front Slope (average) (34)	Front Slope Height (ft) (35 36)	Ditch Width (ft) (37 38)	Back Slope (average) (39)	Back Slope Height (ft) (40 41)	Condition of Slopes (42)	Depth of Water (ft) (43)
	:1			:1		1 Smooth; 2 Rough	1 None; 2 Less than 2 ft; 3 Greater than 2 ft

NO IMPROVEMENT — BOX 6

○

4 (30)

BOX A (TRAFFIC BARRIER MODIFICATIONS) — BOX A

⊗

Offset (ft) Begin (48 49)	Offset (ft) End (50 51)	Top Height (in) (52 53)	Post Spacing (ft) (54 55)	Post Spacing at Bridge End (56)	Guardrail Block Out (57)	Guardrail Rub Rail (58)	Guardrail End Treatment Beginning (59)	Guardrail End Treatment Ending (60)
04	04	27	06	2	2	1	4	3

Post Spacing at Bridge End: 1. Reduced; 2. Not Reduced
Block Out: 1 No; 2 Yes
Rub Rail: 1 No; 2 Yes
Guardrail End Treatment: 1 Not Anchored (to ground or bridge); 2 Anchored (to ground or bridge); 3 Anchored Turndown (not breakaway); 4 Breakaway Terminal Design

BOX B (CHANGES TO EXISTING GUARDRAIL) — BOX B

⊗

Beginning: (61) 1 Lengthen; 2 Shorten
Ending: (62) 1 Lengthen; 2 Shorten
Change in Length (ft): (63 64)

BOX C (MILE POINT OF CHANGE) — BOX C

Beginning: V0.000 (65 66 67 68 69 70)
Ending: V0.000 (71 72 73 74 75 76)

BOX 7 — BOX 7

(X)

(79) 1 End of Group; 2 End of Group and Program

(80) 2 IBM Card Type

FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard Ruby Date 06 Sept '79

HIGHWAY — BOX 1

Highway Design Number: 1-05 (1 2 3)
1. DR SRL
2. DM
3. ROA
4. RC
5. RL

Highway Number: 1-210 (4 5 6 7)
1. US
2. N
3. I
4. SEC

Design Speed (mph): 60 (8 9)

ADT: 01000 (10 11 12 13 14)

Hazard Number: 1
Hazard Group Number: 1
Improvement Alternative Number: 4

COSTS — BOX 2

Capital Costs ($1,000): 0063.5 (15 16 17 18 19)

Collision Maintenance ($100/accid.): Hazard 001 (20 21 22); Improvement 001 (23 24 25)

Normal Maintenance ($100/yr.): Hazard 02 (26 27); Improvement 02 (28 29)

POINT HAZARD IMPROVEMENTS — BOX 3

○ 1 (30) 1 (31) Alleviate Hazard — (32) 1. Remove; 2. Make Breakaway and/or Relocate; 3. Reconstruct Inlet to Safe Design; 4. Reconstruct Cross Drainage System

○ 1 (30) 2 (31) Install Traffic Barrier (complete Box A) — (32 33) Descriptor Code — (34 35 36 37) Length (ft)

○ 1 (30) 3 (31) Install Energy Attenuator — (32 33) Descriptor Code

LONGITUDINAL HAZARD IMPROVEMENTS — BOX 4

○ 2 (30) 1 (31) Curb — (32) 1. Remove and Regrade; 2. Install Wedge Modification

○ 2 (30) 2 (31) Traffic Barrier — (32) 1. Remove; 2. Modify (complete Boxes A, B & C); 3. Replace with New Design (complete Boxes A, B & C) — (33 34) Descriptor Code (New Design Only)

○ 2 (30) 3 (31) Bridgerail — (32) 1. Modify; 2. Replace with New Design — (33 34) Descriptor Code

SLOPE IMPROVEMENTS — BOX 5

○ 3 (30) 1 (31) Install Traffic Barrier (complete Boxes A and C) — (32) 1 At Bridge; 2 Not at Bridge — (33 34) Descriptor Code

⊗ 3 (30) 2 (31) Modify (complete Box C)

Hinge Point Offset (ft) (32 33)	Front Slope (average) (34)	Front Slope Height (ft) (35 36)	Ditch Width (ft) (37 38)	Back Slope (average) (39)	Back Slope Height (ft) (40 41)	Condition of Slopes (42)	Depth of Water (ft) (43)
08	3:1	20	06	2:1	05	1	1

Condition of Slopes: 1 Smooth; 2 Rough
Depth of Water: 1 None; 2 Less than 2 ft; 3 Greater than 2 ft

NO IMPROVEMENT — BOX 6

○ 4 (30)

BOX A (TRAFFIC BARRIER MODIFICATIONS) — BOX A

○ Offset (ft): Begin (48 49), End (50 51); Top Height (in) (52 53); Post Spacing (ft) (54 55); Post Spacing at Bridge End (56): 1 Reduced, 2 Not Reduced; Guardrail Block Out (57): 1 No, 2 Yes; Rub Rail (58): 1 No, 2 Yes; Guardrail End Treatment — Beginning (59), Ending (60): 1 Not Anchored (to ground or bridge); 2 Anchored (to ground or bridge); 3 Anchored Turndown (not breakaway); 4 Breakaway Terminal Design

BOX B (CHANGES TO EXISTING GUARDRAIL) — BOX B

⊗ Beginning (61): 1 Lengthen, 2 Shorten; Ending (62): 1 Lengthen, 2 Shorten; Change in Length (ft) (63 64)

BOX C (MILE POINT OF CHANGE) — BOX C

Beginning (65 66 67 68 69 70): 1 6 6 0 0 0
Ending (71 72 73 74 75 76): 1 6 6 1 0 0

BOX 7

1 (79): 1 End of Group; 2 End of Group and Program

2 (80): IBM Card Type

C O S T E F F E C T I V E N E S S P R O G R A M

UNIVERSITY OF NEBRASKA
AND
NEBRASKA DEPARTMENT OF ROADS

HIGHWAY DESIGN NUMBER = DB- 5
TYPE HIGHWAY = US-210
DESIGN SPEED = 60 MPH
ADT = 1000
PROJECT LIFE = 20.0 YRS
INTEREST RATE = 9.000 %
DATE = 8-30-79

H A Z A R D								I M P R O V E M E N T								
HAZARD NO	GROUP NO	IDENT CODE	DESC CODE	HAZARD INDEX (INJ/YR)	SIDE OF ROAD	MILE-POST BEG	MILE-POST END	IMPR ALT	IMPR CODE	HAZARD INDEX (INJ/YR)	CLEAR RECOVERY ZONE (FT)	FIRST COST ($1000)	TOTAL ANNUAL COST ($/YR)	COST EFFECTIVE VALUE	ZERO ACCIDENT REDUCTION (%)	BENEFIT COST RATIO
1	10	7	2	0.01604	1	100.000	100.100	1	3-2-0	0.00895	8	6.1	0	94	86	865.2
1	10	7	2	0.01604	1	100.000	100.100	2	3-1-2	0.00498	10	12.5	3	339	80	249.3
1	10	7	2	0.01604	1	100.000	100.100	3	3-1-2	0.00577	4	9.0	3	348	81	256.4
1	10	7	2	0.01604	1	100.000	100.100	4	3-2-0	0.00895	8	3.5	0	54	86	1507.9

COMPUTER OUTPUT LISTING OF CASE STUDY NO. 1

A P P E N D I X

J. CASE STUDY NO. 2 (INPUT DATA AND OUTPUT)

FIGURE 1.

ROADSIDE HAZARD INVENTORY FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Inventory Conducted by Richard Ruby Date 06 Sept '79

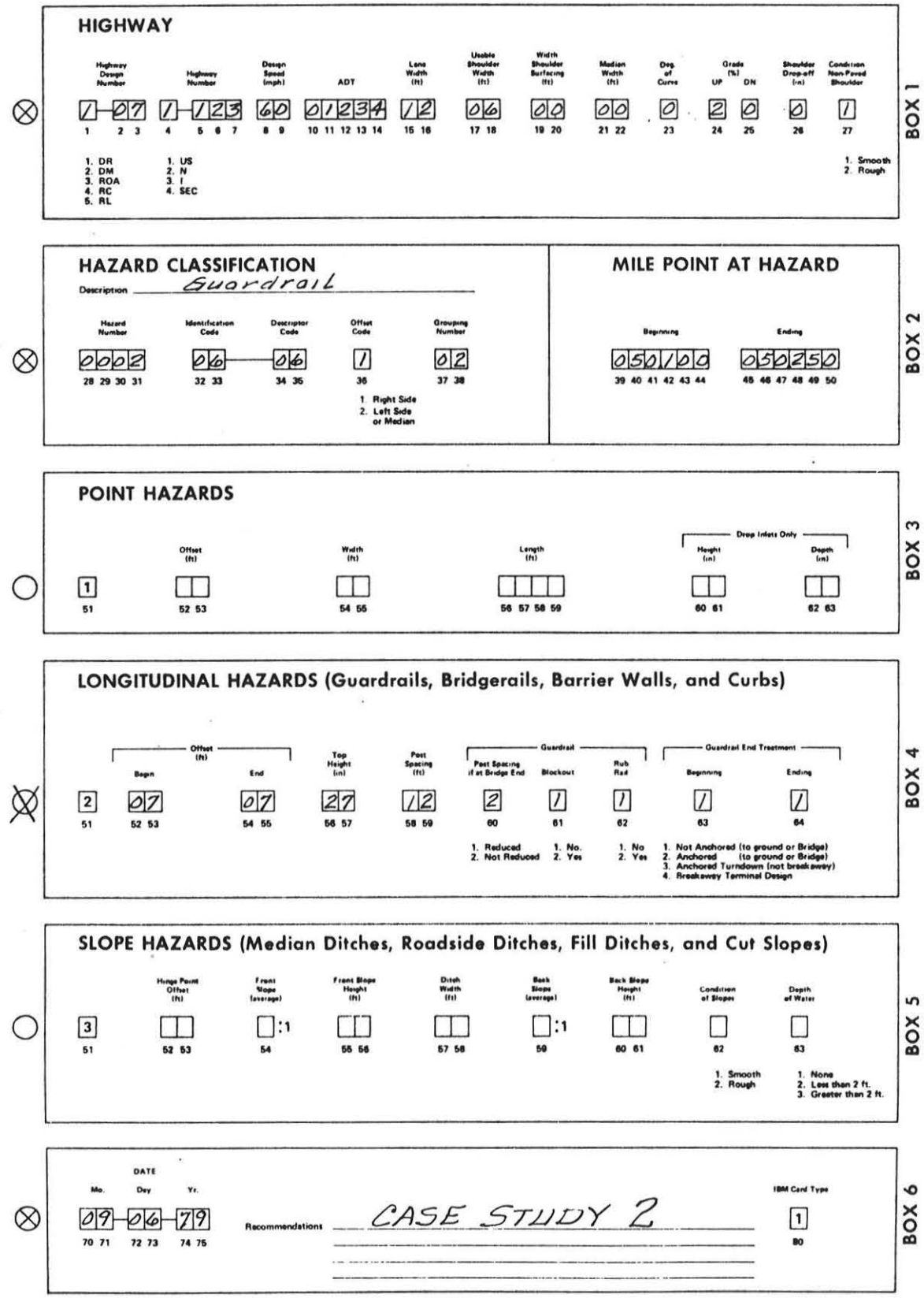


FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard King Date 06 Sept '77

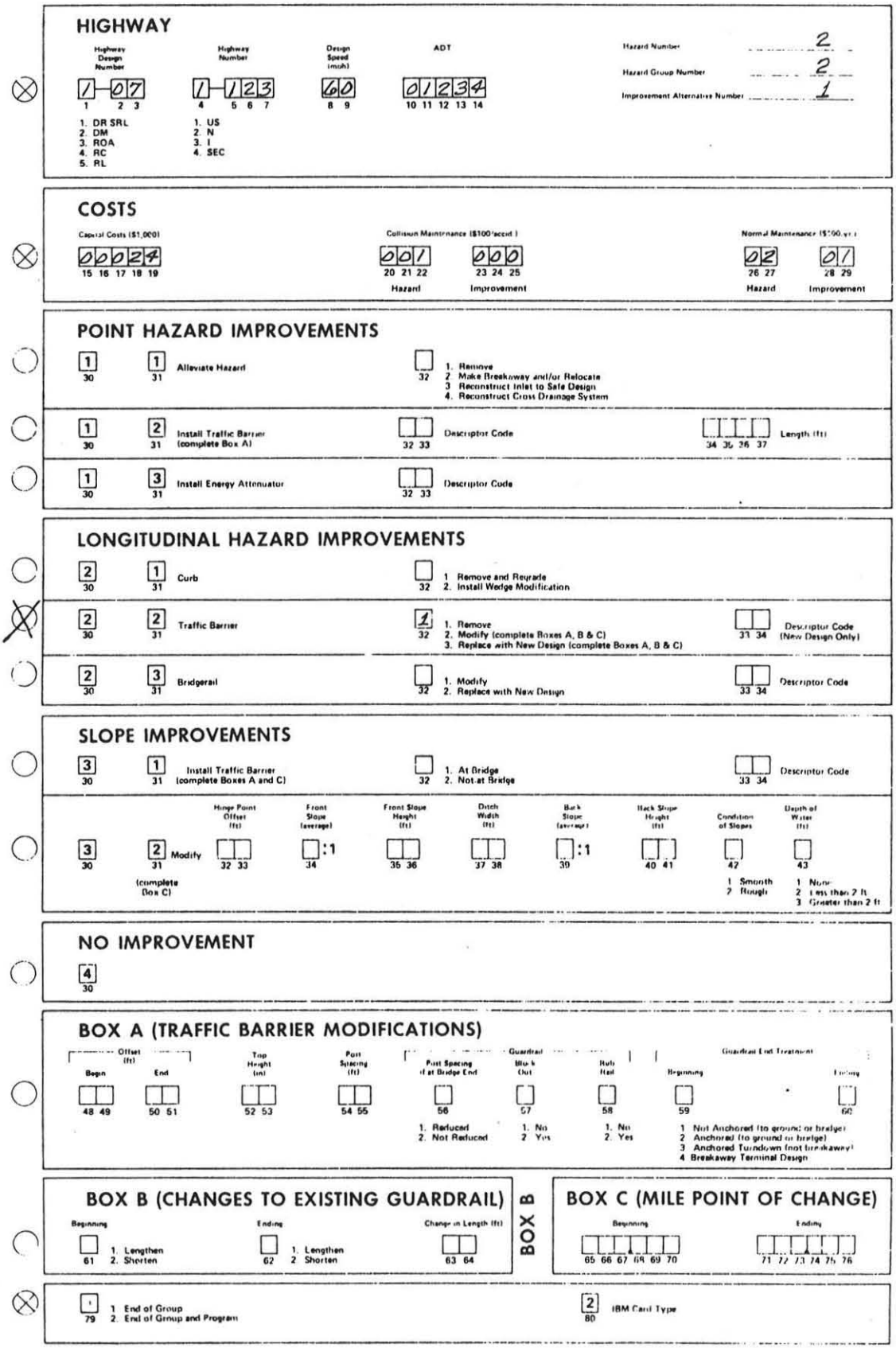


FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard Ruby Date 06 Sept '79

HIGHWAY — BOX 1

⊗

Highway Design Number (1 2 3)	Highway Number (4 5 6 7)	Design Speed (mph) (8 9)	ADT (10 11 12 13 14)
1-07	1-123	60	01234

1. DR SRL, 2. DM, 3. ROA, 4. RC, 5. RL
1. US, 2. N, 3. I, 4. SEC

Hazard Number 2
Hazard Group Number 2
Improvement Alternative Number 2

COSTS — BOX 2

⊗

Capital Costs ($1,000) (15 16 17 18 19)	Collision Maintenance ($100/accid.) Hazard (20 21 22)	Collision Maintenance ($100/accid.) Improvement (23 24 25)	Normal Maintenance ($100/yr.) Hazard (26 27)	Normal Maintenance ($100/yr.) Improvement (28 29)
00005	001	001	02	02

POINT HAZARD IMPROVEMENTS — BOX 3

○ 1 (30) 1 (31) Alleviate Hazard — (32) 1. Remove; 2. Make Breakaway and/or Relocate; 3. Reconstruct Inlet to Safe Design; 4. Reconstruct Cross Drainage System

○ 1 (30) 2 (31) Install Traffic Barrier (complete Box A) — (32 33) Descriptor Code — (34 35 36 37) Length (ft)

○ 1 (30) 3 (31) Install Energy Attenuator — (32 33) Descriptor Code

LONGITUDINAL HAZARD IMPROVEMENTS — BOX 4

○ 2 (30) 1 (31) Curb — (32) 1. Remove and Regrade; 2. Install Wedge Modification

⊗ 2 (30) 2 (31) Traffic Barrier — (32) 2 1. Remove; 2. Modify (complete Boxes A, B & C); 3. Replace with New Design (complete Boxes A, B & C) — (33 34) Descriptor Code (New Design Only)

○ 2 (30) 3 (31) Bridgerail — (32) 1. Modify; 2. Replace with New Design — (33 34) Descriptor Code

SLOPE IMPROVEMENTS — BOX 5

○ 3 (30) 1 (31) Install Traffic Barrier (complete Boxes A and C) — (32) 1. At Bridge; 2. Not at Bridge — (33 34) Descriptor Code

○ 3 (30) 2 (31) Modify (complete Box C)

Hinge Point Offset (ft) (32 33)	Front Slope (average) (34) :1	Front Slope Height (ft) (35 36)	Ditch Width (ft) (37 38)	Back Slope (average) (39) :1	Back Slope Height (ft) (40 41)	Condition of Slopes (42)	Depth of Water (ft) (43)
						1 Smooth, 2 Rough	1 None, 2 Less than 2 ft., 3 Greater than 2 ft.

NO IMPROVEMENT — BOX 6

○ 4 (30)

BOX A (TRAFFIC BARRIER MODIFICATIONS) — BOX A

⊗

Offset (ft) Begin (48 49)	Offset (ft) End (50 51)	Top Height (in) (52 53)	Post Spacing (ft) (54 55)	Guardrail: Post Spacing at Bridge End (56)	Guardrail: Block Out (57)	Guardrail: Rub Rail (58)	Guardrail End Treatment: Beginning (59)	Guardrail End Treatment: Ending (60)
07	07	27	12	2	1	1	1	1

(56) 1. Reduced, 2. Not Reduced
(57) 1. No, 2. Yes
(58) 1. No, 2. Yes
(59, 60) 1. Not Anchored (to ground or bridge); 2. Anchored (to ground or bridge); 3. Anchored Turndown (not breakaway); 4. Breakaway Terminal Design

BOX B (CHANGES TO EXISTING GUARDRAIL) — BOX B

⊗

Beginning (61)	Ending (62)	Change in Length (ft) (63 64)
2 (1. Lengthen, 2. Shorten)	2 (1. Lengthen, 2. Shorten)	90

BOX C (MILE POINT OF CHANGE) — BOX C

Beginning (65 66 67 68 69 70)	Ending (71 72 73 74 75 76)
050708	050741

BOX 7

⊗

(79) 1 End of Group, 2 End of Group and Program

(80) 2 IBM Card Type

FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard Ruby Date 06 Sept '79

HIGHWAY

Highway Design Number: 1-07 (cols 1 2 3)
1 DR SRL
2 DM
3. ROA
4. RC
5. RL

Highway Number: 1-123 (cols 4 5 6 7)
1. US
2. N
3. I
4. SEC

Design Speed (mph): 60 (cols 8 9)

ADT: 01238 (cols 10 11 12 13 14)

Hazard Number: 2
Hazard Group Number: 2
Improvement Alternative Number: 3

BOX 1

COSTS

Capital Costs ($1,000): 00019 (cols 15 16 17 18 19)

Collision Maintenance ($100/accid.)
Hazard: 001 (cols 20 21 22)
Improvement: 001 (cols 23 24 25)

Normal Maintenance ($100/yr.)
Hazard: 02 (cols 26 27)
Improvement: 01 (cols 28 29)

BOX 2

POINT HAZARD IMPROVEMENTS

○	1 (30)	1 (31)	Alleviate Hazard	(32) 1. Remove 2. Make Breakaway and/or Relocate 3. Reconstruct Inlet to Safe Design 4. Reconstruct Cross Drainage System
○	1 (30)	2 (31)	Install Traffic Barrier (complete Box A)	(32 33) Descriptor Code; (34 35 36 37) Length (ft)
○	1 (30)	3 (31)	Install Energy Attenuator	(32 33) Descriptor Code

BOX 3

LONGITUDINAL HAZARD IMPROVEMENTS

○	2 (30)	1 (31)	Curb	(32) 1. Remove and Regrade 2. Install Wedge Modification
⊗	2 (30)	2 (31)	Traffic Barrier	(32) 2 — 1. Remove 2. Modify (complete Boxes A, B & C) 3. Replace with New Design (complete Boxes A, B & C); (31 34) Descriptor Code (New Design Only)
○	2 (30)	3 (31)	Bridge rail	(32) 1. Modify 2. Replace with New Design; (33 34) Descriptor Code

BOX 4

SLOPE IMPROVEMENTS

○	3 (30)	1 (31)	Install Traffic Barrier (complete Boxes A and C)	(32) 1. At Bridge 2. Not at Bridge; (33 34) Descriptor Code

			Hinge Point Offset (ft) (32 33)	Front Slope (average) (34) :1	Front Slope Height (ft) (35 36)	Ditch Width (ft) (37 38)	Back Slope (average) (39) :1	Back Slope Height (ft) (40 41)	Condition of Slopes (42) 1. Smooth 2. Rough	Depth of Water (ft) (43) 1. None 2. Less than 2 ft. 3. Greater than 2 ft.
○	3 (30)	2 (31) Modify (complete Box C)								

BOX 5

NO IMPROVEMENT

○ 4 (30)

BOX 6

BOX A (TRAFFIC BARRIER MODIFICATIONS)

Offset (ft) Begin (48 49)	Offset (ft) End (50 51)	Top Height (in) (52 53)	Post Spacing (ft) (54 55)	Guardrail: Post Spacing at Bridge End (56) 1. Reduced 2. Not Reduced	Guardrail: Block Out (57) 1. No 2. Yes	Guardrail: Rub Rail (58) 1. No 2. Yes	Guardrail End Treatment: Beginning (59) 1. Not Anchored (to ground or bridge) 2. Anchored (to ground or bridge) 3. Anchored Turndown (not breakaway) 4. Breakaway Terminal Design	Guardrail End Treatment: Ending (60)
10	10	27	12	2	1	1	2	2

BOX A

BOX B (CHANGES TO EXISTING GUARDRAIL)

Beginning: 2 (61) 1. Lengthen 2. Shorten
Ending: 2 (62) 1. Lengthen 2. Shorten
Change in Length (ft): 90 (63 64)

BOX B

BOX C (MILE POINT OF CHANGE)

Beginning: 050108 (65 66 67 68 69 70)
Ending: 050241 (71 72 73 74 75 76)

BOX C

⊗ (79) 1. End of Group 2. End of Group and Program

(80) 2 IBM Card Type

BOX 7

FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by *Richard Ruby* Date *06 Sept '79*

BOX 1 — HIGHWAY

Highway Design Number (1 2 3)	Highway Number (4 5 6 7)	Design Speed (mph) (8 9)	ADT (10 11 12 13 14)	Hazard Number	Hazard Group Number	Improvement Alternative Number
1-07	1-123	60	01234	2	2	4

1. DR SRL 2. DM 3. ROA 4. RC 5. RL
1. US 2. N 3. I 4. SEC

BOX 2 — COSTS

Capital Costs ($1,000) (15 16 17 18 19)	Collision Maintenance ($100/accid.) Hazard (20 21 22)	Collision Maintenance ($100/accid.) Improvement (23 24 25)	Normal Maintenance ($100/yr.) Hazard (26 27)	Normal Maintenance ($100/yr.) Improvement (28 29)
00135	001	003	02	02

BOX 3 — POINT HAZARD IMPROVEMENTS

○	1 (30)	1 (31) Alleviate Hazard	(32) 1. Remove 2. Make Breakaway and/or Relocate 3. Reconstruct Inlet to Safe Design 4. Reconstruct Cross Drainage System
○	1 (30)	2 (31) Install Traffic Barrier (complete Box A)	(32 33) Descriptor Code; (34 35 36 37) Length (ft)
○	1 (30)	3 (31) Install Energy Attenuator	(32 33) Descriptor Code

BOX 4 — LONGITUDINAL HAZARD IMPROVEMENTS

○	2 (30)	1 (31) Curb	(32) 1. Remove and Regrade 2. Install Wedge Modification
⊗	2 (30)	2 (31) Traffic Barrier	(32) 3 1. Remove 2. Modify (complete Boxes A, B & C) 3. Replace with New Design (complete Boxes A, B & C); (33 34) 06 Descriptor Code (New Design Only)
○	2 (30)	3 (31) Bridgerail	(32) 1. Modify 2. Replace with New Design; (33 34) Descriptor Code

BOX 5 — SLOPE IMPROVEMENTS

○	3 (30)	1 (31) Install Traffic Barrier (complete Boxes A and C)	(32) 1. At Bridge 2. Not at Bridge; (33 34) Descriptor Code
○	3 (30)	2 (31) Modify (complete Box C)	Hinge Point Offset (ft) (32 33); Front Slope Leverage (34) :1; Front Slope Height (ft) (35 36); Ditch Width (ft) (37 38); Back Slope Leverage (39) :1; Back Slope Height (ft) (40 41); (42) Condition of Slopes 1. Smooth 2. Rough; (43) Depth of Water (ft) 1. None 2. Less than 2 ft 3. Greater than 2 ft

BOX 6 — NO IMPROVEMENT

○ 4 (30)

BOX A — BOX A (TRAFFIC BARRIER MODIFICATIONS)

Offset (ft) Begin (48 49)	Offset (ft) End (50 51)	Top Height (in) (52 53)	Post Spacing (ft) (54 55)	Guardrail: Post Spacing at Bridge End (56)	Guardrail: Block Out (57)	Guardrail: Rub Rail (58)	Guardrail End Treatment: Beginning (59)	Guardrail End Treatment: Ending (60)
⊗ 10	10	27	06	2	2	1	4	3

(56) 1. Reduced 2. Not Reduced; (57) 1. No 2. Yes; (58) 1. No 2. Yes; (59, 60) 1. Not Anchored (to ground or bridge) 2. Anchored (to ground or bridge) 3. Anchored Turndown (not breakaway) 4. Breakaway Terminal Design

BOX B — BOX B (CHANGES TO EXISTING GUARDRAIL)

⊗ Beginning (61) 1 Lengthen 2 Shorten; Ending (62) 1 Lengthen 2 Shorten; Change in Length (ft) (63 64)

BOX C — BOX C (MILE POINT OF CHANGE)

Beginning (65 66 67 68 69 70) 05/00; Ending (71 72 73 74 75 76) 05025

BOX 7

⊗ (79) 1 End of Group 2 End of Group and Program

(80) 2 IBM Card Type

FIGURE 1.

ROADSIDE HAZARD INVENTORY FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Inventory Conducted by Richard Ruby Date 06 Sept '79

BOX 1 — HIGHWAY

Highway Design Number	Highway Number	Design Speed (mph)	ADT	Lane Width (ft)	Usable Shoulder Width (ft)	Width Shoulder Surfacing (ft)	Median Width (ft)	Deg. of Curve	Grade (%) UP	Grade (%) DN	Shoulder Drop-off (in)	Condition Non-Paved Shoulder
1-07	1-123	60	01234	12	06	00	00	0	2	0	1	1
1 2 3	4 5 6 7	8 9	10 11 12 13 14	15 16	17 18	19 20	21 22	23	24	25	26	27

1. DR
2. DM
3. ROA
4. RC
5. RL

1. US
2. N
3. I
4. SEC

1. Smooth
2. Rough

BOX 2 — HAZARD CLASSIFICATION

Description Slope

Hazard Number	Identification Code	Descriptor Code	Offset Code	Grouping Number
0003	07	02	1	02
28 29 30 31	32 33	34 35	36	37 38

1. Right Side
2. Left Side or Median

BOX 2 — MILE POINT AT HAZARD

Beginning	Ending
050100	050250
39 40 41 42 43 44	45 46 47 48 49 50

BOX 3 — POINT HAZARDS

	Offset (ft)	Width (ft)	Length (ft)	Drop Inlets Only: Height (in)	Drop Inlets Only: Depth (in)
1					
51	52 53	54 55	56 57 58 59	60 61	62 63

BOX 4 — LONGITUDINAL HAZARDS (Guardrails, Bridgerails, Barrier Walls, and Curbs)

	Offset (ft): Begin	Offset (ft): End	Top Height (in)	Post Spacing (ft)	Guardrail: Post Spacing if at Bridge End	Guardrail: Blockout	Guardrail: Rub Rail	Guardrail End Treatments: Beginning	Guardrail End Treatments: Ending
2									
51	52 53	54 55	56 57	58 59	60	61	62	63	64

1. Reduced
2. Not Reduced

1. No.
2. Yes

1. No
2. Yes

1. Not Anchored (to ground or Bridge)
2. Anchored (to ground or Bridge)
3. Anchored Turndown (not breakaway)
4. Breakaway Terminal Design

BOX 5 — SLOPE HAZARDS (Median Ditches, Roadside Ditches, Fill Ditches, and Cut Slopes)

	Hinge Point Offset (ft)	Front Slope (average)	Front Slope Height (ft)	Ditch Width (ft)	Back Slope (average)	Back Slope Height (ft)	Condition of Slopes	Depth of Water
3	06	3:1	15	08	3:1	10	2	1
51	52 53	54	55 56	57 58	59	60 61	62	63

1. Smooth
2. Rough

1. None
2. Less than 2 ft.
3. Greater than 2 ft.

BOX 6

DATE Mo	Day	Yr	Recommendations	IBM Card Type
09	06	79	CASE STUDY 2	1
70 71	72 73	74 75		80

FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard Ruby Date 06 Sept '79

HIGHWAY — BOX 1

⊗

Highway Design Number: 1-07 (1 2 3)
1. DR SRL
2. DM
3. ROA
4. RC
5. RL

Highway Number: 1-123 (4 5 6 7)
1 US
2. N
3. I
4. SEC

Design Speed (mph): 60 (8 9)

ADT: 01234 (10 11 12 13 14)

Hazard Number: 3
Hazard Group Number: 2
Improvement Alternative Number: 1

COSTS — BOX 2

⊗

Capital Costs ($1,000): 00000 (15 16 17 18 19)

Collision Maintenance ($100/accid.): Hazard 000 (20 21 22); Improvement 000 (23 24 25)

Normal Maintenance ($1/yr.): Hazard 01 (26 27); Improvement 01 (28 29)

POINT HAZARD IMPROVEMENTS — BOX 3

○ 1 (30) 1 (31) Alleviate Hazard — (32) 1. Remove; 2. Make Breakaway and/or Relocate; 3. Reconstruct Inlet to Safe Design; 4. Reconstruct Cross Drainage System

○ 1 (30) 2 (31) Install Traffic Barrier (complete Box A) — (32 33) Descriptor Code — (34 35 36 37) Length (ft)

○ 1 (30) 3 (31) Install Energy Attenuator — (32 33) Descriptor Code

LONGITUDINAL HAZARD IMPROVEMENTS — BOX 4

○ 2 (30) 1 (31) Curb — (32) 1. Remove and Regrade; 2. Install Wedge Modification

○ 2 (30) 2 (31) Traffic Barrier — (32) 1. Remove; 2. Modify (complete Boxes A, B & C); 3. Replace with New Design (complete Boxes A, B & C) — (33 34) Descriptor Code (New Design Only)

○ 2 (30) 3 (31) Bridgerail — (32) 1. Modify; 2. Replace with New Design — (33 34) Descriptor Code

SLOPE IMPROVEMENTS — BOX 5

○ 3 (30) 1 (31) Install Traffic Barrier (complete Boxes A and C) — (32) 1. At Bridge; 2. Not at Bridge — (33 34) Descriptor Code

○ 3 (30) 2 (31) Modify (complete Box C)

Hinge Point Offset (ft)	Front Slope (average)	Front Slope Height (ft)	Ditch Width (ft)	Back Slope (average)	Back Slope Height (ft)	Condition of Slopes	Depth of Water (ft)
(32 33)	:1 (34)	(35 36)	(37 38)	:1 (39)	(40 41)	(42)	(43)

Condition of Slopes: 1. Smooth; 2. Rough
Depth of Water: 1. None; 2. Less than 2 ft.; 3. Greater than 2 ft.

NO IMPROVEMENT — BOX 6

⊗ 4 (30)

BOX A (TRAFFIC BARRIER MODIFICATIONS) — BOX A

○

Offset (ft): Begin (48 49); End (50 51)
Top Height (in) (52 53)
Post Spacing (ft) (54 55)
Guardrail: Post Spacing at Bridge End (56): 1. Reduced; 2. Not Reduced
Guardrail: Block Out (57): 1. No; 2. Yes
Guardrail: Rub Rail (58): 1. No; 2. Yes
Guardrail End Treatment: Beginning (59); Ending (60)
1. Not Anchored (to ground or bridge)
2. Anchored (to ground or bridge)
3. Anchored Turndown (not breakaway)
4. Breakaway Terminal Design

BOX B (CHANGES TO EXISTING GUARDRAIL) — BOX B

○

Beginning (61): 1. Lengthen; 2. Shorten
Ending (62): 1. Lengthen; 2. Shorten
Change in Length (ft) (63 64)

BOX C (MILE POINT OF CHANGE) — BOX C

Beginning (65 66 67 68 69 70)
Ending (71 72 73 74 75 76)

BOX 7

⊗

(79) 1. End of Group; 2. End of Group and Program

2 (80) IBM Card Type

FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard Ruby Date 06 Sept '79

HIGHWAY (BOX 1)

Highway Design Number: 1-07 (1 2 3) — 1. DR SRL 2. DM 3. ROA 4. RC 5. RL
Highway Number: 1-123 (4 5 6 7) — 1. US 2. N 3. I 4. SEC
Design Speed (mph): 60 (8 9)
ADT: 01234 (10 11 12 13 14)
Hazard Number: 3
Hazard Group Number: 2
Improvement Alternative Number: 2

COSTS (BOX 2)

Capital Costs ($1,000): 00025 (15 16 17 18 19)
Collision Maintenance ($100/accident): Hazard 001 (20 21 22); Improvement 001 (23 24 25)
Normal Maintenance ($100/yr): Hazard 01 (26 27); Improvement 01 (28 29)

POINT HAZARD IMPROVEMENTS (BOX 3)

- 1 (30) 1 (31) Alleviate Hazard — 32: 1. Remove 2. Make Breakaway and/or Relocate 3. Reconstruct Inlet to Safe Design 4. Reconstruct Cross Drainage System
- 1 (30) 2 (31) Install Traffic Barrier (complete Box A) — Descriptor Code (32 33); Length (ft) (34 35 36 37)
- 1 (30) 3 (31) Install Energy Attenuator — Descriptor Code (32 33)

LONGITUDINAL HAZARD IMPROVEMENTS (BOX 4)

- 2 (30) 1 (31) Curb — 32: 1. Remove and Regrade 2. Install Wedge Modification
- 2 (30) 2 (31) Traffic Barrier — 32: 1 Remove 2 Modify (complete Boxes A, B & C) 3 Replace with New Design (complete Boxes A, B & C); Descriptor Code (New Design Only) (33 34)
- 2 (30) 3 (31) Bridge rail — 32: 1. Modify 2. Replace with New Design; Descriptor Code (33 34)

SLOPE IMPROVEMENTS (BOX 5)

- 3 (30) 1 (31) Install Traffic Barrier (complete Boxes A and C) — 32: 1. At Bridge 2. Not at Bridge; Descriptor Code (33 34)
- 3 (30) 2 (31) Modify (complete Box C)

Hinge Point Offset (ft) (32 33)	Front Slope (average) (34)	Front Slope Height (ft) (35 36)	Ditch Width (ft) (37 38)	Back Slope (average) (39)	Back Slope Height (ft) (40 41)	Condition of Slopes (42)	Depth of Water (ft) (43)
08	3:1	15	06	3:1	10	1	1

Condition of Slopes: 1. Smooth 2. Rough
Depth of Water: 1. None 2. Less than 2 ft. 3. Greater than 2 ft.

NO IMPROVEMENT (BOX 6)

4 (30)

BOX A (TRAFFIC BARRIER MODIFICATIONS)

Offset (ft) Begin (48 49)	Offset (ft) End (50 51)	Top Height (in) (52 53)	Post Spacing (ft) (54 55)	Guardrail: Post Spacing at Bridge End (56)	Guardrail: Block Out (57)	Guardrail: Rub Rail (58)	Guardrail End Treatment: Beginning (59)	Guardrail End Treatment: Ending (60)

Post Spacing at Bridge End: 1 Reduced 2 Not Reduced
Block Out: 1 No 2 Yes
Rub Rail: 1 No 2 Yes
Guardrail End Treatment: 1 Not Anchored (to ground or bridge) 2 Anchored (to ground or bridge) 3 Anchored Turndown (not breakaway) 4 Breakaway Terminal Design

BOX B (CHANGES TO EXISTING GUARDRAIL)

Beginning: 1 Lengthen 2 Shorten (61)
Ending: 1 Lengthen 2 Shorten (62)
Change in Length (ft) (63 64)

BOX C (MILE POINT OF CHANGE)

Beginning: 050760 (65 66 67 68 69 70)
Ending: 052450 (71 72 73 74 75 76)

BOX 7

1 End of Group 2 End of Group and Program (79)
2 (80) IBM Card Type

FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard Ruby Date 06 Sept '79

HIGHWAY — BOX 1

Highway Design Number: 1-07 (cols 1-3) — 1. DR SRL 2. DM 3. ROA 4. RC 5. RL
Highway Number: 1-123 (cols 4-7) — 1. US 2. N 3. I 4. SEC
Design Speed (mph): 60 (cols 8-9)
ADT: 01234 (cols 10-14)
Hazard Number: 3
Hazard Group Number: 2
Improvement Alternative Number: 3

COSTS — BOX 2

Capital Costs ($1,000): 00030 (cols 15-19)
Collision Maintenance ($100/accid.): Hazard 001 (cols 20-22); Improvement 001 (cols 23-25)
Normal Maintenance ($100/yr.): Hazard 01 (cols 26-27); Improvement 01 (cols 28-29)

POINT HAZARD IMPROVEMENTS — BOX 3

- ◯ 1 (30) / 1 (31) Alleviate Hazard — (32) 1. Remove 2. Make Breakaway and/or Relocate 3. Reconstruct Inlet to Safe Design 4. Reconstruct Cross Drainage System
- ◯ 1 (30) / 2 (31) Install Traffic Barrier (complete Box A) — Descriptor Code (32 33) — Length (ft) (34 35 36 37)
- ◯ 1 (30) / 3 (31) Install Energy Attenuator — Descriptor Code (32 33)

LONGITUDINAL HAZARD IMPROVEMENTS — BOX 4

- ◯ 2 (30) / 1 (31) Curb — (32) 1. Remove and Regrade 2. Install Wedge Modification
- ◯ 2 (30) / 2 (31) Traffic Barrier — (32) 1. Remove 2. Modify (complete Boxes A, B & C) 3. Replace with New Design (complete Boxes A, B & C) — Descriptor Code (New Design Only) (33 34)
- ◯ 2 (30) / 3 (31) Bridgerail — (32) 1. Modify 2. Replace with New Design — Descriptor Code (33 34)

SLOPE IMPROVEMENTS — BOX 5

- ◯ 3 (30) / 1 (31) Install Traffic Barrier (complete Boxes A and C) — (32) 1. At Bridge 2. Not at Bridge — Descriptor Code (33 34)
- ⊗ 3 (30) / 2 (31) Modify (complete Box C) — Hinge Point Offset (ft) 08 (32 33); Front Slope (average) 4:1 (34); Front Slope Height (ft) 15 (35 36); Ditch Width (ft) 10 (37 38); Back Slope (average) 4:1 (39); Back Slope Height (ft) 10 (40 41); Condition of Slopes 1 (42) 1 Smooth 2 Rough; Depth of Water (ft) 1 (43) 1 None 2 Less than 2 ft. 3 Greater than 2 ft.

NO IMPROVEMENT — BOX 6

◯ 4 (30)

BOX A (TRAFFIC BARRIER MODIFICATIONS) — BOX A

◯ Offset (ft) Begin (48 49) End (50 51); Top Height (in) (52 53); Post Spacing (ft) (54 55); Post Spacing at Bridge End (56) 1. Reduced 2. Not Reduced; Guardrail Block Out (57) 1. No 2. Yes; Rub Rail (58) 1. No 2. Yes; Guardrail End Treatment Beginning (59) 1. Not Anchored (to ground or bridge) 2. Anchored (to ground or bridge) 3. Anchored Turndown (not breakaway) 4. Breakaway Terminal Design; Ending (60)

BOX B (CHANGES TO EXISTING GUARDRAIL) — BOX B

⊗ Beginning (61) 1 Lengthen 2 Shorten; Ending (62) 1 Lengthen 2 Shorten; Change in Length (ft) (63 64)

BOX C (MILE POINT OF CHANGE) — BOX C

Beginning 050100 (65 66 67 68 69 70)
Ending 050250 (71 72 73 74 75 76)

BOX 7

◯ (79) 1. End of Group 2. End of Group and Program
2 (80) IBM Card Type

FIGURE 2.

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
LINCOLN, NEBRASKA

Improvement Recommended by Richard Ruby Date 06 Sept '79

BOX 1 — HIGHWAY

Highway Design Number: 1-07 (1 2 3)
1. DR SRL 2. DM 3. ROA 4. RC 5. RL

Highway Number: 1-123 (4 5 6 7)
1. US 2. N 3. I 4. SEC

Design Speed (mph): 40 (8 9)

ADT: 01234 (10 11 12 13 14)

Hazard Number: 3
Hazard Group Number: 2
Improvement Alternative Number: 4

BOX 2 — COSTS

Capital Costs ($1 000): 00015 (15 16 17 18 19)

Collision Maintenance ($100/accid.): Hazard 001 (20 21 22); Improvement 001 (23 24 25)

Normal Maintenance ($100/yr.): Hazard 01 (26 27); Improvement 01 (28 29)

BOX 3 — POINT HAZARD IMPROVEMENTS

1 (30) 1 (31) Alleviate Hazard — (32) 1. Remove 2. Make Breakaway and/or Relocate 3. Reconstruct Inlet to Safe Design 4. Reconstruct Cross Drainage System

1 (30) 2 (31) Install Traffic Barrier (complete Box A) — (32 33) Descriptor Code — (34 35 36 37) Length (ft)

1 (30) 3 (31) Install Energy Attenuator — (32 33) Descriptor Code

BOX 4 — LONGITUDINAL HAZARD IMPROVEMENTS

2 (30) 1 (31) Curb — (32) 1. Remove and Regrade 2. Install Wedge Modification

2 (30) 2 (31) Traffic Barrier — (32) 1. Remove 2. Modify (complete Boxes A, B & C) 3. Replace with New Design (complete Boxes A, B & C) — (33 34) Descriptor Code (New Design Only)

2 (30) 3 (31) Bridgerail — (32) 1. Modify 2. Replace with New Design — (33 34) Descriptor Code

BOX 5 — SLOPE IMPROVEMENTS

3 (30) 1 (31) Install Traffic Barrier (complete Boxes A and C) — (32) 1. At Bridge 2. Not at Bridge — (33 34) Descriptor Code

3 (30) 2 (31) Modify (complete Box C)

Hinge Point Offset (ft) (32 33)	Front Slope (average) (34)	Front Slope Height (ft) (35 36)	Ditch Width (ft) (37 38)	Back Slope (average) (39)	Back Slope Height (ft) (40 41)	Condition of Slopes (42)	Depth of Water (ft) (43)
10	3:1	15	04	3:1	10	1	1

1 Smooth 2 Rough
1 None 2 Less than 2 ft 3 Greater than 2 ft

BOX 6 — NO IMPROVEMENT

4 (30)

BOX A — BOX A (TRAFFIC BARRIER MODIFICATIONS)

Offset (ft) Begin (48 49) End (50 51); Top Height (in) (52 53); Post Spacing (ft) (54 55); Post Spacing at Bridge End (56): 1 Reduced 2 Not Reduced; Guardrail Block Out (57): 1 No 2 Yes; Rub Rail (58): 1 No 2 Yes; Guardrail End Treatment Beginning (59); Ending (60): 1 Not Anchored (to ground or bridge) 2 Anchored (to ground or bridge) 3 Anchored Turndown (not breakaway) 4 Breakaway Terminal Design

BOX B — BOX B (CHANGES TO EXISTING GUARDRAIL)

Beginning: (61) 1. Lengthen 2. Shorten
Ending: (62) 1. Lengthen 2. Shorten
Change in Length (ft): (63 64)

BOX C — BOX C (MILE POINT OF CHANGE)

Beginning: 05010 (65 66 67 68 69 70)
Ending: 05025 (71 72 73 74 75 76)

BOX 7

2 (79) 1. End of Group 2. End of Group and Program

2 (80) IBM Card Type

C O S T E F F E C T I V E N E S S P R O G R A M

UNIVERSITY OF NEBRASKA
AND
NEBRASKA DEPARTMENT OF ROADS

HIGHWAY DESIGN NUMBER = DR- 7
TYPE HIGHWAY = US-123
DESIGN SPEED = 60 MPH
ADT = 1234
PROJECT LIFE = 20.0 YRS
INTEREST RATE = 9.000 %
DATE = 9- 6-79

H A Z A R D								I M P R O V E M E N T							
HAZARD NO	GROUP NO	IDENT CODE	DESC CODE	HAZARD INDEX (INJ/YR)	SIDE OF ROAD	MILE-POST BEG	MILE-POST END	IMPR ALT	IMPR CODE	HAZARD INDEX (INJ/YR)	CLEAR RECOVERY ZONE (FT)	FIRST COST ($1000)	TOTAL ANNUAL COST ($/YR)	COST EFFECTIVE VALUE	ZERO ACCIDENT REDUCTION (%)	BENEFIT COST RATIO
2	2	6	6	0.01494	1	50.100	50.250	1	2-2-1	0.00000	6	2.4	**********	GROUP	**********	
3	2	7	2	0.00000	1	50.100	50.250	1	4-0-0	0.01784	6	0.0	----------	NOT COST-EFFECTIVE	--------	
2	2	6	6	0.01494	1	50.100	50.250	2	2-2-2	0.01355	7	0.5	**********	GROUP	**********	
3	2	7	2	0.00000	1	50.100	50.250	2	3-2-0	0.01610	8	2.5	----------	NOT COST-EFFECTIVE	--------	
2	2	6	6	0.01494	1	50.100	50.250	3	2-2-2	0.01243	10	1.9	**********	GROUP	**********	
3	2	7	2	0.00000	1	50.100	50.250	3	2-2-0	0.00000	0	3.0	*********	ERROR MESSAGE = 10	*********	
2	2	6	6	0.01494	1	50.100	50.250	4	2-2-3	0.00000	10	13.5	**********	GROUP	**********	
3	2	7	2	0.00000	1	50.100	50.250	4	3-2-0	0.01517	10	1.5	----------	NOT COST-EFFECTIVE	--------	

COMPUTER OUTPUT LISTING OF CASE STUDY NO. 2