COST-EFFECTIVENESS COMPARISON OF CABLE GUARDRAIL vs. W-BEAM GUARDRAIL

by

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MR. PATRICK A. CHASTAIN, E.I.T.

Sponsored by

NEBRASKA DEPARTMENT OF ROADS

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RESEARCH REPORT NO. TRP-03-007-82

UNIVERSITY OF NEBRASKA

Engineering Research Center
College of Engineering and Technology
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Lincoln, Nebraska 68588

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ABSTRACT

The Nebraska Department of Roads, NDR, has been involved 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 takes into consideration the effectiveness and benefits as well as the construction and maintenance costs of guardrail improvements and alternatives to guardrail installation such as flattening the embankment front slope. The "effectiveness" of an improvement is defined as the annual reduction in the number of injury accidents, whereas, the "benefit" of an improvement is defined as the annual reduction in the accident societal costs. Because of certain advantages of cable guardrail in comparison to W-beam safety guardrail, the NDR has been investigating the possibilities of using a much larger percentage of the cable guardrail. The research documented in this report was conducted in support of this policy revision effort.

The computer program in this HP&R study was developed to expedite the lengthy and tedious cost-effectiveness and benefit-cost computations for (a) inst lling cable guardrail on roadside embankments, (b) installing W-beam safety guardrail on roadside embankments, or (c) making embankment modifications.

The findings in this study showed that the installation of cable guardrail was, in all situations investigated, more attractive than the installation of W-beam safety guardrail. In fact, in some situations, it was found that cable guardrail was attractive, whereas, W-beam guardrail was not attractive. The findings in this study also showed that the configuration of the roadside embankment was a very significant factor in justifying the installation of guardrail.

It is to be emphasized that the findings in this study were based on the assumption that there were no "point" hazards on or near the embankment such as culverts and trees. Just as the configuration of the embankment was found to be important in determining the need for the installation of guardrail, it is the opinion of the researchers that it is of equal or greater importance that point hazards also be taken into consideration in future developments of the program.

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 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.

Because of the ease and rapidity in using the computer program to conduct a detailed analysis of each roadside emba kment situation, it is the opinion of the researchers that there is no real need to attempt to develop generalized guardrail guidelines and policies. It is therefore recommended that NDR incorporate the computer program into their Road Design System currently being used.

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NOMEMCLATURE

RD . . . Research and Development

ADT . . . Average Daily Traffic

DOT . . . Department of Transportation

HRR . . . Highway Research Record

NDR . . . Nebraska State Department of Roads

NSC . . . National Safety Council

PDO . . . Property-damage-only type of accidents

TRB . . . Transportation Research Board

TRP . . . Transportation Research Program

TRR . . . Transportation Research Record

TTI . . . Texas Transportation Institute

UNL . . . University of Nebraska-Lincoln

FHWA . . . Federal Highway Administration

SwRI . . . Southwest Research Institute

AASHTO . . American Association of State Highway and Transportation Officials

HVOSM . . . Highway-Vehicle-Object-Simulation-Model

NCHRP . . . National Cooperative Research Board

NHSTA . . . National Highway Traffic Safety Administration

1.

INTRODUCTION

The Nebraska Department of Roads, NDR, has been involoved 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 takes into consideration the effectiveness and benefits as well as the construction and maintenance costs of guardrail improvements and alternatives to guardrail installation such as flattening the embankment front slope. The "effectiveness" of an improvement is defined as the annual reduction in the number of injury accidents, whereas, the "benefit" of an improvement is defined as the annual reduction in the accident societal costs. Because of certain advantages of cable guardrail in comparison to W-beam safety guardrail, the NDR has been investigating the possibilities of using a much larger percentage of the cable guardrail. The research documented in this report was conducted in support of this policy revision effort. The certain advantages of cable guardrail in comparison to W-beam guardrail are:

1. it is less costly to install and maintain
2. it does not cause snow drifting problems
3. it simplifies snow removal problems, and hence, the effectiveness of the system is not reduced to any appreciable extent
4. it is more effective because of the larger defections, and hence, lower vehicle decelerations and injury severity levels
5. it is more effective on slopes because of the low probability of vehicle ramping and vaulting
6. it provides an economic advantage because the useable shoulder can be 2 ft. narrower in width, an hence, the volume of fill needed is greatly reduced.

At the present time, there is no reliable program for making a cost-effectiveness comparison of cable guardrail versus W-beam guardrail. Both the Texas Transportation Institute (19), TTI, and the Southwest Research Institute (10), SwRI, have developed computer programs that can be used to make this type of comparison, however, the results from these programs are questionable because of the oversimplified assumptions made in the development of these programs. Evaluations of the TTI and SwRI programs and the reasons for electing not to use these two programs are presented in Appendix F.

Subsequent to the work of the TTI and the SwRI, the University of Nebraska-Lincoln, UNL, and the NDR (21) undertook a guardrail utilization study to determine the cost-effectiveness of using W-beam guardrail on roadside embankments. The cost-effectiveness program developed by the UNL and the NDR was a refinement of the program developed earlier by the TTI.

The objectives of this HP&R study were to expand the existing UNL and NDR cost-effectiveness and benefit-cost computer program to include:

1. the use of cable guardrail
2. the effects of environmental conditions in regard to the supporting strength of guardrail posts under dry(normal), wet, and frozen soil conditions
3. the effects of vehicle size and their distribution in the traffic stream
4. the severity of guardrail "end" type impacts for different safety end treatments
5. the reduced severity due to flared guardrail sections
6. the effects of lower W-beam guardrail heights of 24-in.
7. the reduced severity due to the installation of a rub-rail on 27-in. guardrail heights

This report describes the computer-aided procedure developed for the economic evaluation of guardrail installations and embankment modifications. Included are a description of the computer program, instructions for its use, validation studies, and case studies which illustrate some applications of the program to analyze a given situation. Also, the cost-effectiveness and index and accident societal costs of a given roadway hazard and its improvement alternatives, are explained. In addition, recommendations for future additions to the existing computer program are presented.

2.

COMPUTER MODELS OF AUTOMOBILE ENCOUNTERS WITH VARIOUS ROADSIDE FEATURES

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.

2.1. 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 (1,2) of the Cornell Aeronautical Laboratories and modified for specific field applications by the Texas Transportation Institute (3).

The idealized-free-body-diagram of HVOSM is shown in Figure 1. The model has 11 deg of freedom and consists of four isolated masses. The masses of the automobile include: (a) the sprung mass of the body, engine and transmission

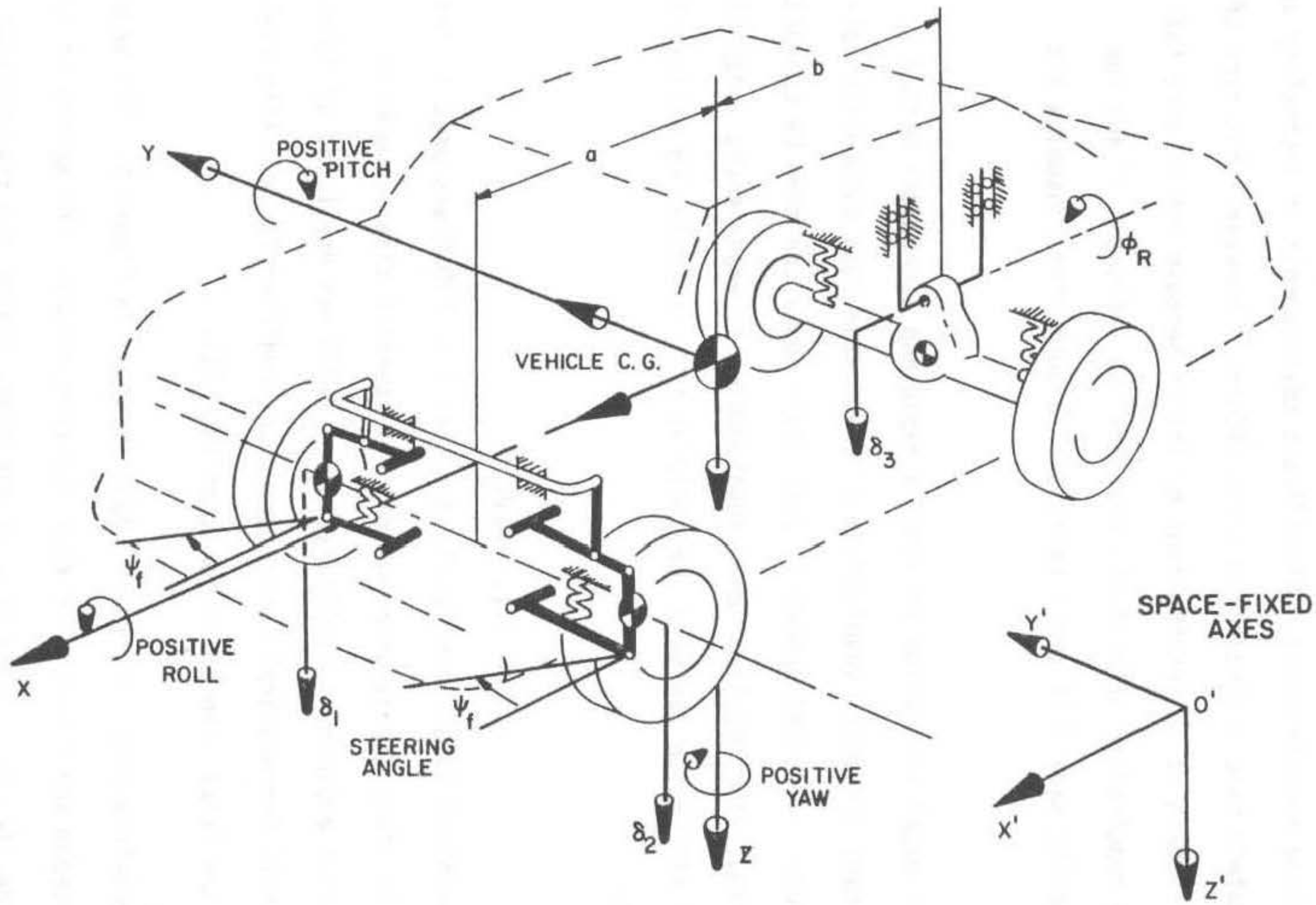


FIGURE 1 : IDEALIZATION OF HVOSM

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.

Standard and compact size automobiles weighing approximately 3,800 and 2,250 lbs, respectively, were used in this study. The properties of the selected automobiles were defined in previous research work conducted by Ross and Post (4,5) and Weaver (6) on sloping grates in medians and roadside embankment slopes. The properties of the standard size vehicle are listed on the computer printout sheets in Appendix A.

The terrain data of a typical embankment configuration, expressed in terms of x-y-z coordinates, are presented in Appendix B. The roadway, shoulder, and soil were assigned friction coefficient values of 0.8, 0.6 and 0.2, respectively; and, the soil in an assumed dry or normal condition was assigned a stiffness value of 4,000 lbs per inch. Terrain contact was only monitored at the corners of the vehicle 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 (3) 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 under gone many rigorous comparisions to full-scale testing with excellent correlation. An example of such a comparison is shown in Figure 2 in which Ross and Post (4) compared the decelerations computed by HVOSM with the decelerations measured by accelerometers during a full scale test on an embankment simulation run in this study.

2.2. BARRIER VII

The BARRIER VII program was utilized in this study to determine the dynamic effect of an automobile interacting with several types of traffic barrier systems. BARRIER VII was developed by Powell (7,8).

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

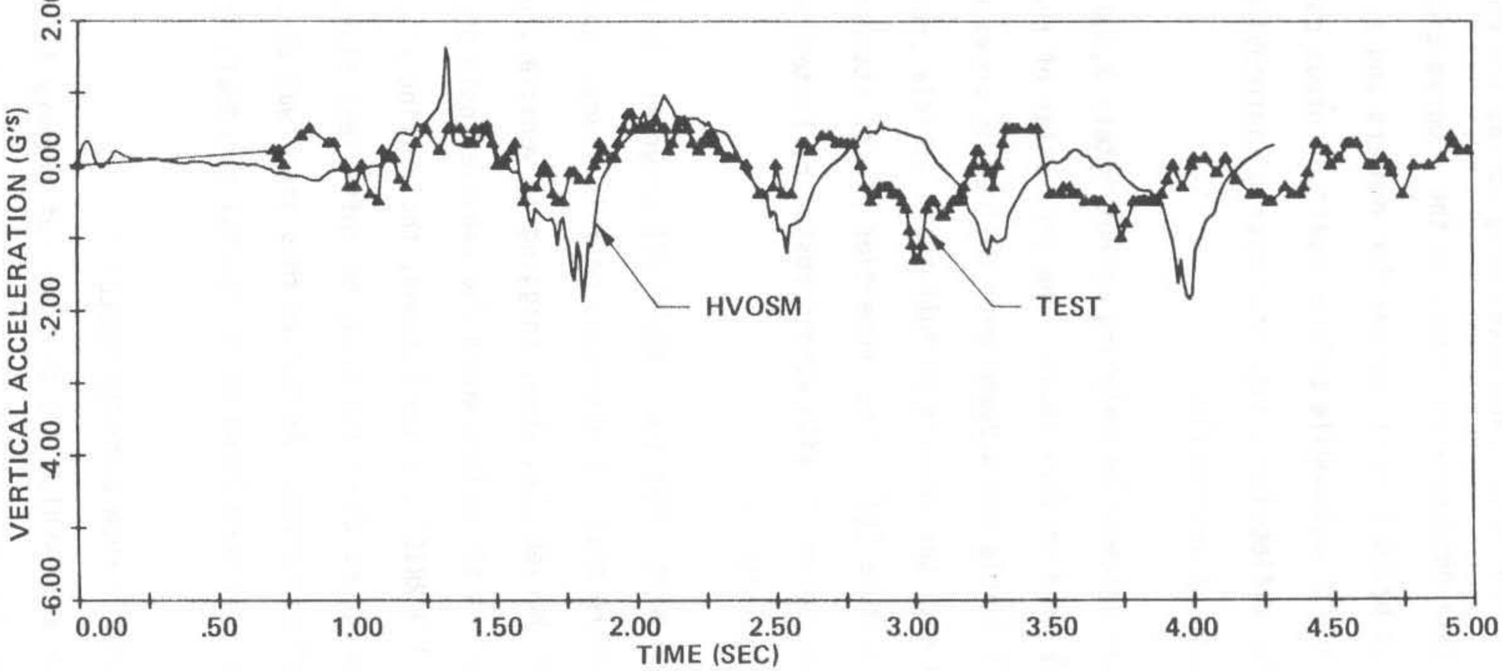


FIGURE 2. COMPARISON OF HVOSM AND FULL SCALE TEST ON EMBANKMENT WITH 3:1 FRONT SLOPE

barrier, are not considered. The automobile slides along the barrier, and the effects of normal forces, friction forces, and wheel drag forces are considered 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 position, and velocities and acceleration of automobile.

Standard and compact size automobiles weighing approximately 3,800 and 2,250 lbs, respectively, were used in this study. The properties of the selected automobiles and the guardrail (cable and W-Beam) were defined in previous research work conducted and validated with the results of full-scale vehicle crash tests by the Southwest Research Institute (10). The properties of the standard size vehicle and blocked-out W-Beam guardrail with wooden posts are listed on the computer printout sheets in Appendix F.

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 there 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.

2.3. OUTPUT FROM COMPUTER MODELS

Output results from HVOSM and BARRIER VII that were of primary interest in this study were the vehicle accelerations. These values were used to determine the severity-index (SI) of the embankment traversals and the guardrail impacts. An indepth discussion of severity-index is presented in Section 3 of this report. The output from an HVOSM simulation of an embankment run is presented in Appendix C. And, the output from a BARRIER VII simulation of a guardrail run is presented in Appendix F.

3.

SEVERITY OF AUTOMOBILE ENCOUNTERS WITH VARIOUS ROADSIDE FEATURES

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 (9) and Weaver (6).

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

where:

SI = Severity-Index

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

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

G_{long} = Auto Acceleration along longitudinal x-axis (see Figure 1)

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 accelerations in Eq. 1 were obtained from computer model simulations using HVOSM and BARRIER VII.

The severity-index computations in the subsequent work were based on accelerations tolerable to an unrestrained occupant, and the automobile accelerations were 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 (6) for use in the severity-index equation are shown in Table 1.

TABLE 1

TOLERABLE AUTOMOBILE ACCELERATIONS

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

3.1. EMBANKMENT SEVERITY-INDICIES

A typical graph of a plot of the computed severity-indicies versus encroachment speed and angle is shown in Figure 3 for a standard size 3,800 lb automobile traversing 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 3 for these two conditions were fitted by visual means. Likewise, all of the linear lines were extropolated to cover the lower and upper speed ranges of 40 and 80 mph which were not simulated in this study.

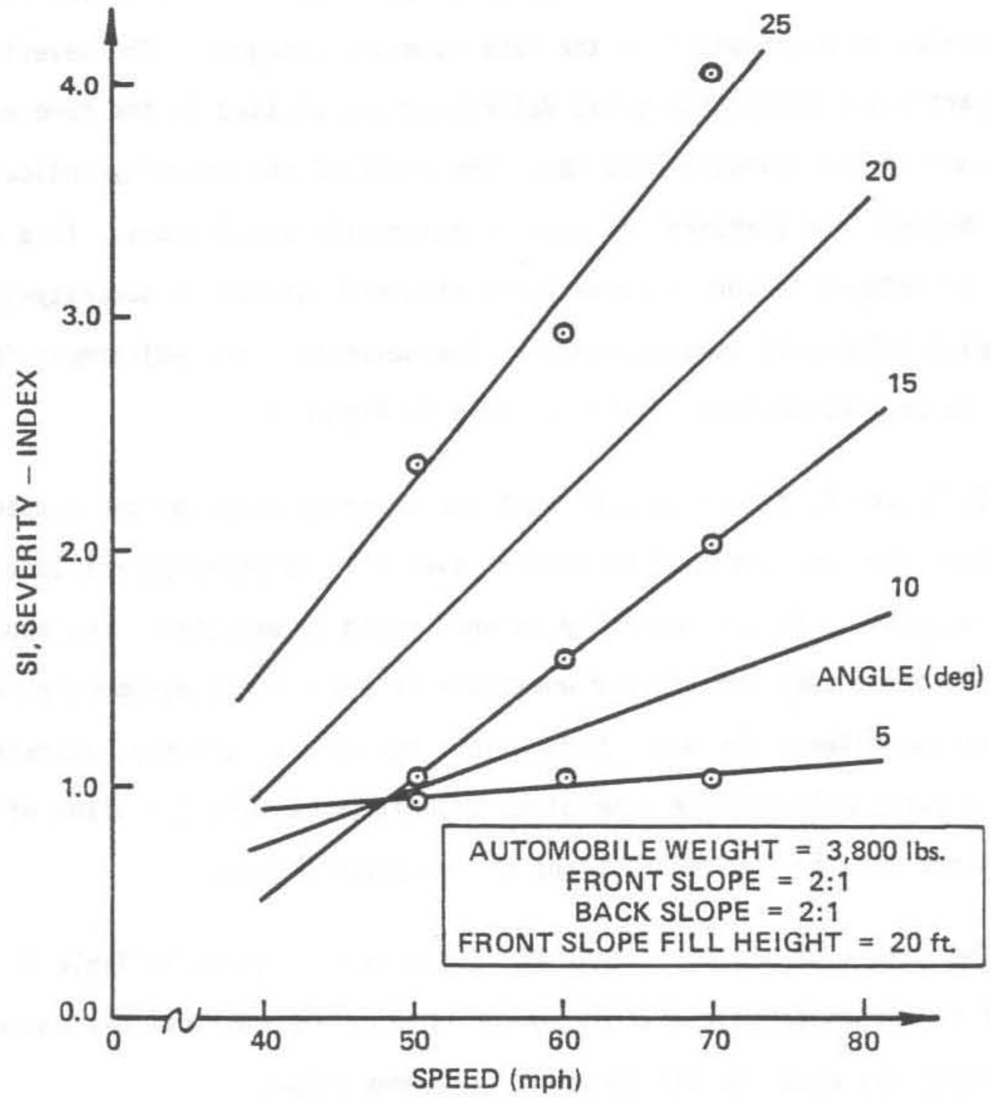


FIGURE 3.

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

In addition, HVOSM simulations were conducted for several ditch configurations using a compact 2,250 lb automobile. Since no dynamic vehicular properties are available for simulating a mini-compact 1,700 lb, the compact and mini-compact automobiles were grouped into the same severity category. The severity-index of a particular encroachment was determined and plotted in the same manner as was done for the standard size car. The ratio of the severity-indices was then taken between the standard and compact automobile simulations. This resulted in an adjustment factor to convert the standard automobile severity-index to a compact automobile severity-index. The severity-index adjustment factors for a 15 deg encroachment angle is shown in Figure 4.

In Figure 4, it can be seen that the severity-index of the compact automobile was lower than the standard automobile over a large encroachment speed range. At first glance, this is contrary to what would be expected. One apparent explanation is that the shorter wheelbase of the compact automobile reduces the interaction between the ditch bottom and the vehicle, thereby, allowing the compact automobile to make a smoother transition between the plane of the front fill slope and the horizontal plane of the ditch bottom.

The matrix of vehicle embankment traversals is shown in Table 2. Including all of the parameters, the total number of possible combinations covered in this study was equal to 145,800 severity-index values.

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 computer program then examined the front slope

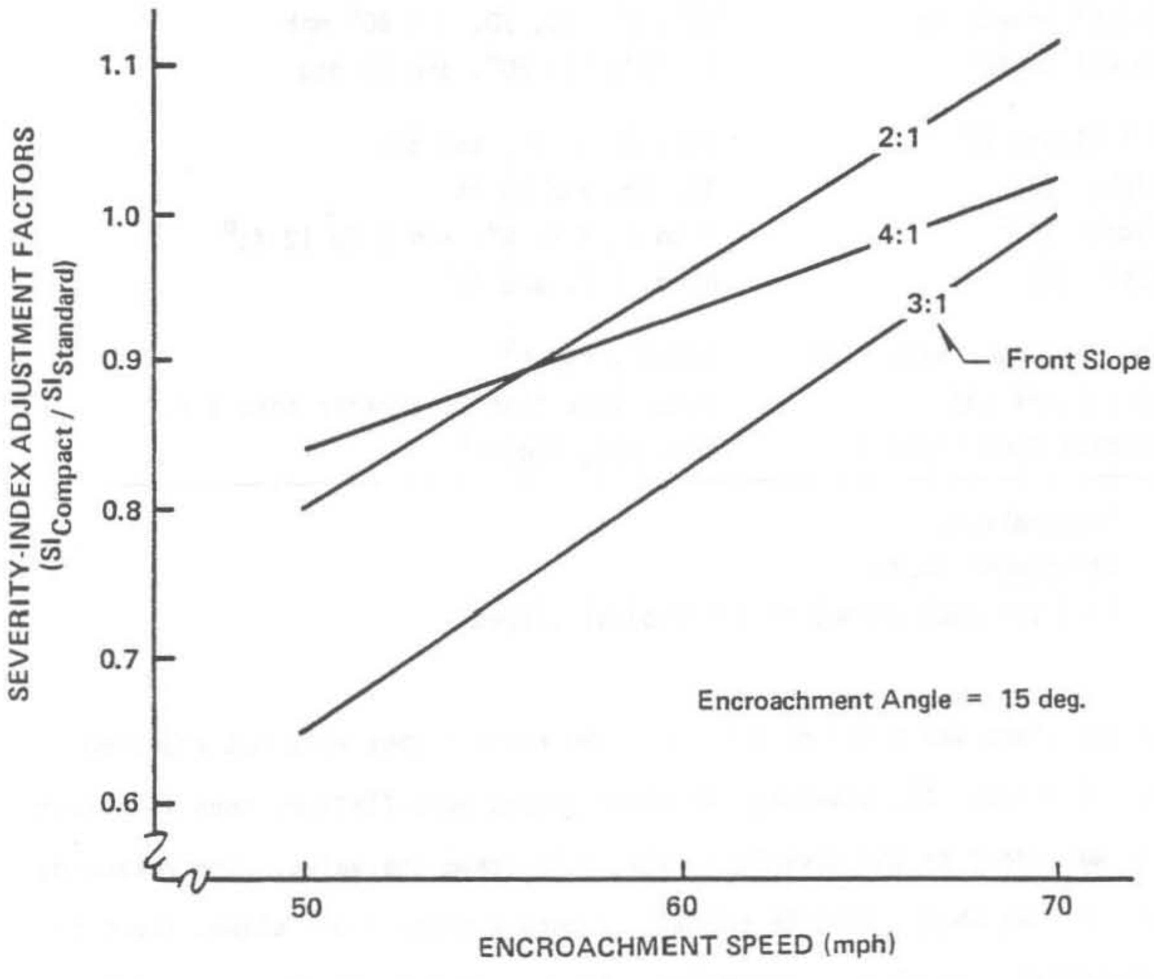


FIGURE 4.

EMBANKMENT SEVERITY-INDEX ADJUSTMENT FACTORS FOR COMPACT AUTOMOBILE IN COMPARISON TO STANDARD AUTOMOBILE

TABLE 2

MATRIX OF VEHICLE EMBANKMENT TRAVERSALS

Variable	Combinations
Automobile Sizes (3)	1700, 2250, 3800 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
From 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, 4 to 8[b], and 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, greater than 2 ft[b]
Environmental Conditions (3)	dry, wet, frozen[b]

a. Interpolated

b. Adjustment Factor

c. Flat (no back slope) or trapezoidal shaped

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 severity-index to increase the value. The reasoning behind this is that when a vehicle encroaches onto 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.

In addition, adjustments were made to account for different environmental conditions. In the case of wet conditions, the severity-index was lowered to account for a lower soil stiffness value which allowed larger vehicle penetration into the soil and thus lower decelerations during a ditch traversal. However, when frozen conditions prevailed, the severities were adjusted upwards since the soil stiffness would be greatly increased. The magnitudes of the adjustment factors were determined by engineering judgment since no HVOSM simulations were conducted for these conditions, and no test data exists for encroachments under frozen or wet conditions.

The results of the HVOSM embankment simulations are presented in Appendix C. whereas, the embankment severity-index equations and adjustment factors are presented in Appendix D.

3.2. GUARDRAIL SEVERITY-INDICIES

The matrix of vehicle guardrail impacts and the resulting severities investigated in this study is shown in Table 3. The possible number of combinations, which is broken out under footnote "b", totals 10,950.

3.2.1. W-Beam Guardrail Side Impacts

The vehicle accelerations obtained from the BARRIER VII (7,8) computer model were used to compute the severity-indices of side guardrail impacts in which the vehicle was restrained and redirected. The two types of guardrail investigated by use of BARRIER VII were the AASHTO (11) G1 Cable Guardrail and the G4 (1W and 2W) W-Beam Guardrail designs.

The severity-index relationships developed for the AASHTO Cable and W-Beam guardrail designs are shown graphically in Figures 5 and 6, respectively, for

TABLE 3

MATRIX OF VEHICLE GUARDRAIL IMPACTS

Variable	Combinations[b]
Automobile Sizes (3)	1700[a], 2250, 4500 lbs
Encroachment Speeds (5)	40, 50, 60, 70, and 80 mph
Encroachment Angles (5)	5, 10, 15, 20, and 25 deg
Guardrail Types (4)	Cable (3 strands) W- Beam (weak steel posts) W-Beam (strong wood posts) W-Beam (strong steel posts)
Post Spacings (2)	6 ft-3 in. and 12 ft-6 in.[a]
Guardrail Heights (2)	24[a] in. and 27 in.
Block-Out W-Beam (2)	Yes and No[a]
Rub-Rail (3)	Yes and No on 27 in. Guardrail[a] No on 24 in. Guardrail[a]
Environmental Conditions (3)	Dry, Wet[a], and Frozen[a]

[a] Adjustment Factors Used

[b] Combinations

Cable Guardrail = 3(5)(5)(1)(1)(1)(1)(1)(1) = 75

W-Beam

Weak Steel Posts = 3(5)(5)(1)(1)(1)(1)(1)(1) = 75

Strong Wood Posts= 3(5)(5)(1)(2)(2)(2)(3)(3) = 5,400

Strong Steel Posts = 3(5)(5)(1)(2)(2)(2)(3)(3) = 5,400

total = 10,950

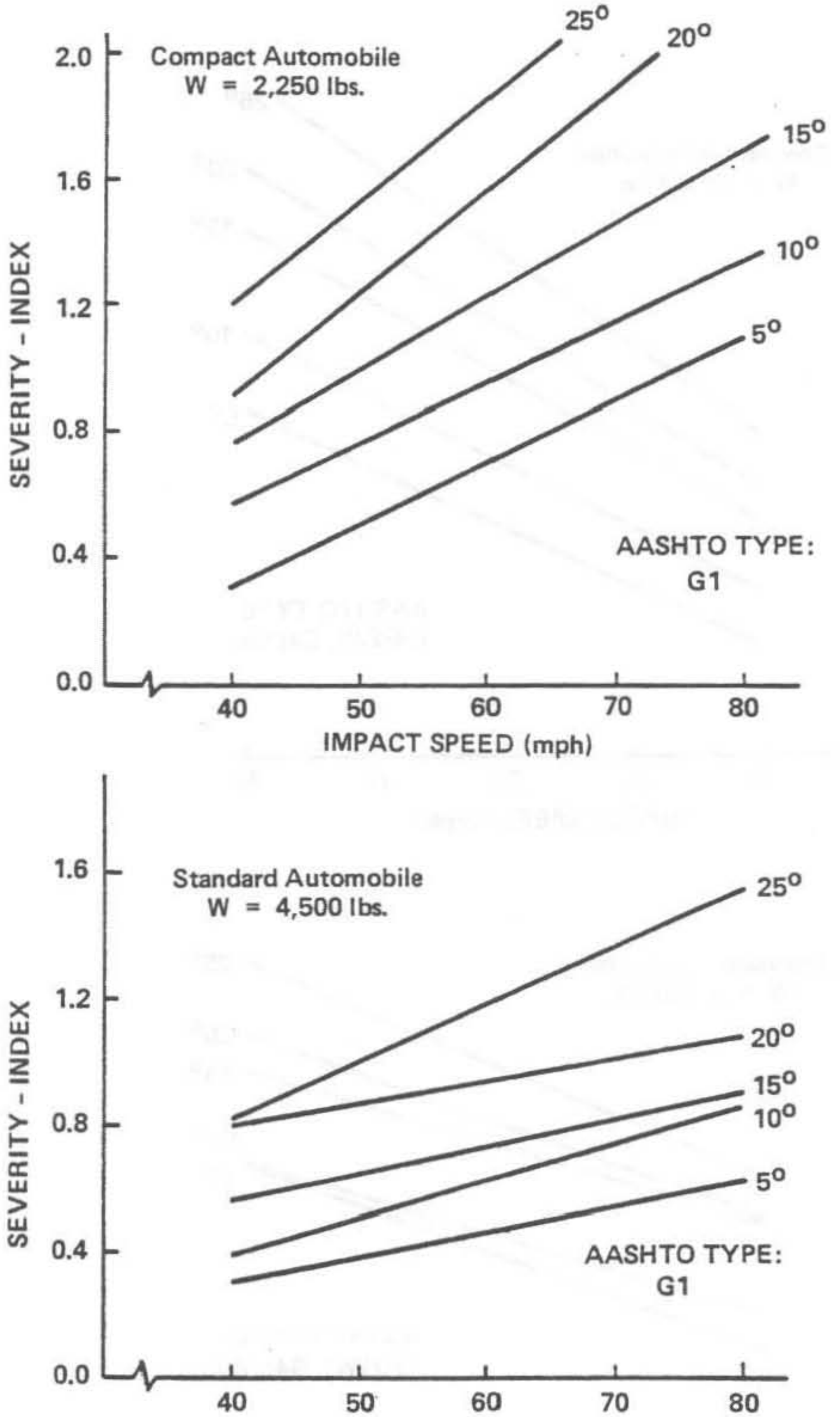
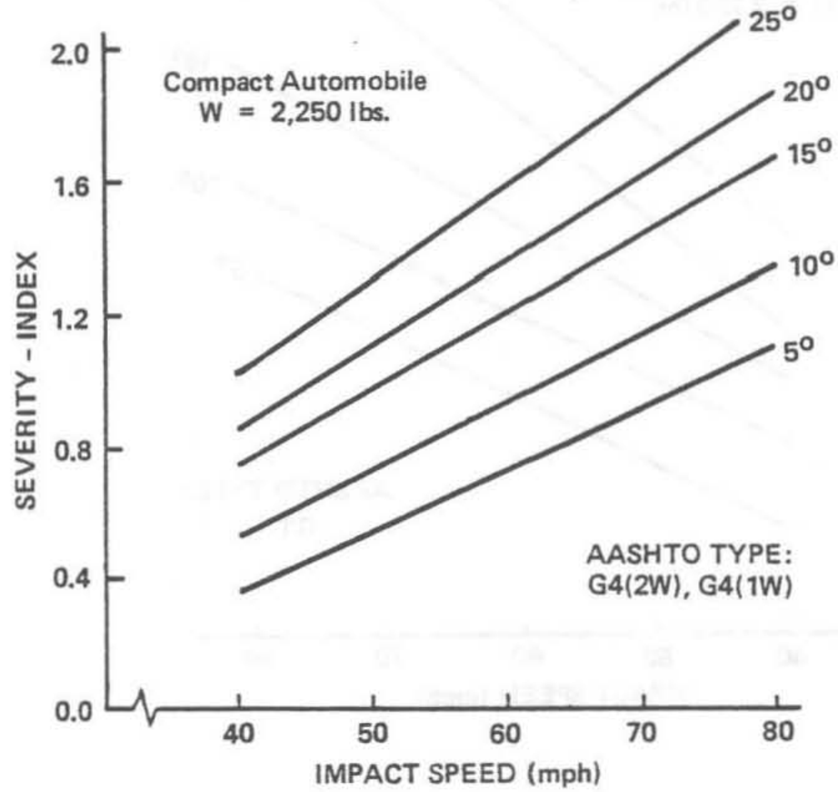


FIGURE 5. SIDE IMPACT SEVERITY – INDEX RELATIONSHIPS FOR AASHTO G1 CABLE GUARDRAIL DESIGN



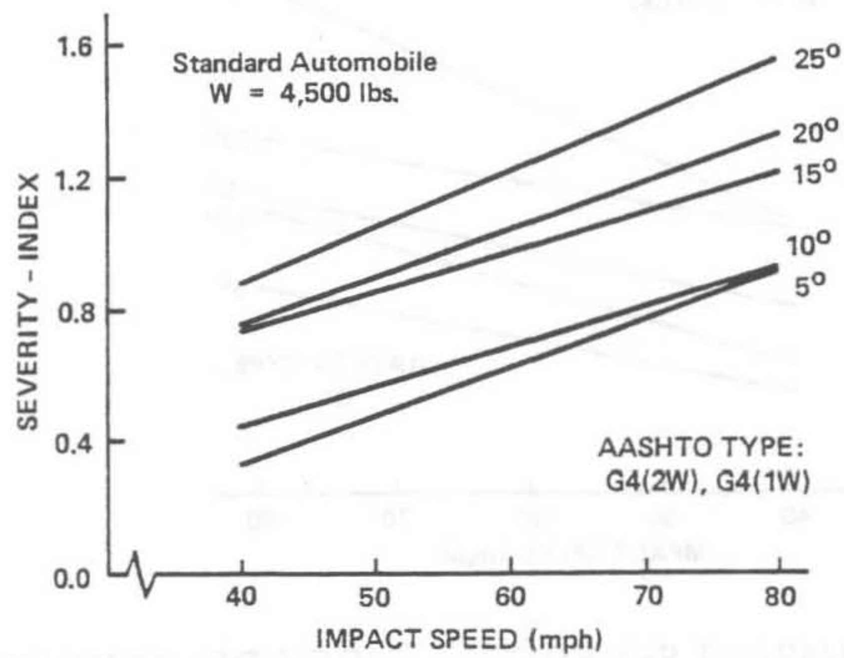


FIGURE 6. SIDE IMPACT SEVERITY – INDEX RELATIONSHIPS FOR AASHTO G4 W-BEAM GUARDRAIL DESIGNS

the standard and compact size automobiles. These relationships were based on dry or normal soil conditions.

3.2.1.1. Adjustment Factors For Vehicle Vaulting Due to Post Failures In Frozen Ground

Under frozen soil conditions, it was assumed that vehicle vaulting would not be a problem for cable guardrail and W-Beam guardrail with steel posts, but that it would be a problem for W-Beam guardrail with wood posts because the W-Beam subsequent to the failure of a post would drop and rotate prior to the development of any significant tensile forces. To take this effect into consideration, adjustment factors were determined and applied to the severity-indicies computed for dry soil conditions.

In the development of the adjustment factors in the work to follow, it was assumed that (a) the posts were rigidly supported in the frozen soil, (b) the posts acted as a cantilevered beam, and (c) the elastic flexure equation was adequate to predict post failure.

In order to determine the applied loads on a guardrail post, the lateral vehicle decelerations for any given speed-angle combination and guardrail height must be determined. The average lateral vehicle decelerations were determined by use of the following equation from the AASHTO Guide (11).

$$G_{lat} = \frac{V^2 \sin^2\Theta}{2g[AL\sin\Theta - B(1-\cos\Theta) + D]} \qquad \text{---Eq. 2}$$

where:

G_{lat} = average lateral vehicle deceleration (g)

AL = distance from front of vehicle to C.G. (ft) (0.45 x length)

B = half-width of vehicle (ft)

D = lateral barrier deflection (ft)

V = impact velocity (fps)

Θ = impact angle with barrier (deg)

Assuming that the deflection of the guardrail is negligible (D = 0) under frozen soil conditions, a 5 x 5 matrix of vehicle decelerations versus encroachment speed and angle can be developed for any given set of conditions.

The bending stresses at the base of the assumed rigidly supported guardrail posts were computed by use of the following elastic flexure equation:

$$f_{max} = \frac{M}{S} \qquad \text{---Eq. 3}$$

$$= \left[\frac{W(G_{lat})(h)}{S}\right] \left(\frac{\Pi}{2}\right) \qquad \text{---Eq. 3a}$$

where:

f_{max} = max. bending stress in post (psi)

M = max. bending moment (in-lb)

S = elastic section modulus of post (in^3)

W = vehicle weight (lb)

G_{lat} = average lateral vehicle deceleration (g's)

h = resultant height of redirective force from barrier (assumed to be 21 in. for 27 in. installation height and 18 in. for an installation height of 24 in.)

$\frac{\Pi}{2}$ = ratio of peak lateral vehicle deceleration to average lateral vehicle deceleration

A widely accepted value for the ultimate static bending stress in wood is 8 ksi. Assuming that the ultimately carrying capacity under dynamic conditions is approximately 25% higher than under static conditions, the ultimate failure bending stress in wood would be approximately 10 ksi.

Based upon the preceding work, it is now possible to predict when vehicle vaulting will occur. For example, it can be predicted as shown in Table 4 that vaulting of a 27 in. W-Beam guardrail with wooden posts in frozen ground would occur during a 60 mph/25 deg collision with a 2,250 lb automobile. The cases in which the bending stresses equal or exceed the ultimate failure stress of 10 ksi in Table 4 are marked with an asterisk.

TABLE 4

ULTIMATE DYNAMIC BENDING STRESSES
IN W-BEAM WOODEN GUARDRAIL POSTS
(ksi)

Vehicle Weight . . 2,250 lb
Guardrail Height . 27 in.
Soil Condition . . Frozen

Encroachment Speed (mph)	Encroachment Impact Angle (deg)				
	5	10	15	20	25
40	0.9	1.9	2.9	3.8	4.8
50	1.4	2.9	4.5	6.0	7.6
60	2.1	4.2	6.4	8.7	10.9*
70	2.8	5.8	8.7	11.8*	14.8*
80	3.7	7.5	11.4*	15.4*	19.4*

* Post failure ($f_{ult.} \geq 10$ ksi)

3.2.1.2. Adjustment Factors for Long Post Spacings

Adjustment factors were applied to W-Beam guardrail with long post spacings of 12 ft-6 in. using a limited number of BARRIER VII computer runs. The adjustment factors were determined by taking the ratio of the severity-indicies for

12 ft-6 in. post spacings compared to 6 ft-3 in. post spacings. The adjustment factors used in this study are shown in Table 5.

TABLE 5

SEVERITY-INDEX ADJUSTMENT FACTORS FOR W-BEAM GUARDRAIL WITH 12 ft-6 in. POST SPACING

Vehicle Weight (lbs)	Encroachment Angle (deg)	Adjustment Factor
4500	5	0.89
	10	0.91
	15	0.93
	20	1.01
	25	1.12
2250	5	0.89
	10	0.91
	15	0.93
	20	1.01
	25	1.12
1750	5	1.03
	10	1.06
	15	1.08
	20	1.17
	25	1.30

3.2.1.3. Adjustment Factor for Vehicle Snagging

Vehicle snagging occurs when the front end and the wheel submarine under the W-Beam rail member and snag on the guardrail posts. As a result, the vehicle undergoes high rotational and translational accelerations. In this study, it was assumed that whenever snagging occurred that the severity-index increased by a multiplication factor of 2.5.

Vehicle snagging was not considered to be a problem for a 24-in. W-beam guardrail, nor a problem for a 27-in. W-beam guardrail with a rub-rail.

Vehicle snagging on a 27-in. W-beam guardrail without a rub-rail was considered as a possibility only for automobiles smaller than the 4,500 lb weight category. Based on engineering judgement, it was assumed that snagging would occur under the specific set of impact conditions of (a) 60 mph and 25 deg. for compact size automobiles in the 2,250 lb weight category, and (b) 60 mph and 20 deg for mini-compact size automobiles in the 1,700 lb weight category. In order to predict the other impact conditions under which snagging was a problem, the concept of lateral kinetic energy was used. Lateral kinetic energy was expressed as follows:

$$KE_{lat} = \frac{1}{2} \left(\frac{W}{g}\right) V_I^2 \sin^2\Theta \qquad \text{---Eq. 4}$$

where:

KE_{lat} = lateral kinetic energy (kip-ft)

W = vehicle weight (kips)

g - acceleration due to gravity (32.2 ft/sec^2)

V_I = vehicle impact speed (fps)

Θ = vehicle encroachment angle (deg)

Using the above equation, the computed lateral kinetic energy values for a 60 mph/25 deg compact vehicle impact and for a 60 mph/20 deg mini-compact vehicle impact were 53.8 kip-ft and 23.9 kip-ft, respectively. These magnitudes of energy were considered to be the "minimum" under which snagging would occur. For other impact conditions, it was assumed that snagging would occur if the computed lateral kinetic energy was equal to or greater than the minimum values. An illustration of the impact conditions under which snagging would occur for a compact size vehicle is shown in Table 6. In Table 6, it can be seen that snagging would occur under the other impact conditions of 70 mph/25 deg, 80 mph/20 deg, and 80 mph/25 deg.

TABLE 6

ILLUSTRATION TO PREDICT VEHICLE SNAGGING
BASED ON MAGNITUDE OF LATERAL KINETIC ENERGY

Vehicle Weight . . . . 2,500 lb
W-Beam Guardrail Height . . . 27-in.
Rub-Rail . . . . None

Encroachment Impact Speed (mph)	Encroachment Impact Angle (deg)				
	5	10	15	20	25
40	1.0	4.0	9.0	15.6	23.9
50	1.6	6.3	14.0	24.4	37.3
60	2.3	9.1	20.1	35.2	53.7*
70	3.1	12.3	27.4	47.9	73.1*
80	4.0	16.1	35.8	62.5*	95.5*

* Snagging assumed

3.2.1.4. Adjustment Factors for Saturated Soil Conditions

It was assumed in this study, that under saturated soil conditions, the rotations and displacements of a W-beam guardrail would be larger than under dry soil conditions. As a result, the lateral and longitudinal accelerations will be lower as well as the severity-indicies. To take this effect into account, adjustment factors were used. As was done in Section 3.2.1.3, the concept of lateral kinetic energy was used. The complete set of adjustment factors developed are presented in Appendix I.

3.2.1.5. Adjustment Factors for Non-Yielding W-Beam Guardrail In Frozen Soil Conditions

It was assumed in this study, that under subfreezing temeratures in which the soil was frozen to a sufficient depth to prevent the guardrail posts from rotating and displacing, that the W-beam guardrail was non-yielding. As a result, the lateral and longitudinal accelerations will be higher than under normal (dry) soil conditions, and the resulting severity-indicies will increase. To take this situation into consideration, adjustment factors were used. A discussion on the method used to develop the adjustment factors is presented in the work to follow.

The average lateral vehicle decelerations, G_{lat}, during an impact with a non-yielding barrier were determined by using Eq. 2 in which the barrier displacement term, D, was set equal to zero. Assuming that vehicle snagging did not occur on the posts and other bolted rail member connections, the average longitudinal vehicle decellerations were computed by the following equation:

$$G_{long} = \mu G_{lat} \qquad \text{---Eq. 5}$$

where:

G_{long} = average longitudinal vehicle decelerations (g)

G_{lat} = average lateral vehicle decelerations (g) computed by use of Eq. 2

μ = coefficient of sliding friction between vehicle and barrier. . .assumed as 0.35

The same procedure was also used to compute the average lateral and longitudinal vehicle accelerations for the impact conditions in which the guardrail will rotate and displace under dry soil conditions. In this case, the displacements of the guardrail in Eq. 2 were computed by assuming that the guardrail displacements varied in direct proportion to the lateral kinetic energy as follows:

$$D = (C)\ KE_{lat} \qquad \text{---Eq. 6}$$

where:

D = barrier displacement

KE_{lat} = lateral kinetic energy of vehicle at impact. . .Eq. 4

C = proportionality constant

Assuming that the proportionality constant is the same under actual full-scale crash test conditions conducted in dry soil as under frozen soil conditions, then it is possible to write the following equation:

$$D_{dry} = \left[\frac{(KE_{lat})_{dry}}{(KE_{lat})_{test}}\right] D_{test} \qquad \text{---Eq. 7}$$

Upon the substitution of Eq. 4 into Eq. 7, one obtains the following equation:

$$D_{dry} = \left[\frac{(WV_I^{\,2}\sin^2\Theta)_{dry}}{(WV_I^{\,2}\sin^2\Theta)_{test}}\right] D_{test} \qquad \text{---Eq. 8}$$

where:

D_{dry} = dynamic barrier displacement in dry soil (ft)

D_{test} = dynamic barrier displacement in full scale crash test

W = vehicle weight (lb)

V_I = vehicle impact speed (fps)

Θ = vehicle encroachment angle (deg)

Illustrations of the computed severity-indicies computed by use of Eq. 1 under dry and frozen soil conditions are shown in Tables 7 and 8, respectively. The values for full-scale crash test variables in Eq. 8 were obtained from HRR174 (12). It is important to stress that while the severity-index values in Tables 7 and 8 are comparable with each other, the values should not be directly compared to severity-index values in the program which were generated using BARRIER VII simulation. This is due to the fact that the severity-index values derived from BARRIER VII were based on the highest 50 msec average, whereas, the severity-index values in Tables 7 and 8 were based on a time period from impact to the time when the vehicle was parallel to the barrier which is much longer than 50 msec. This longer time period will result in severity-index values which are much lower.

Based upon the preceding work, the adjustment factors to account for the impact conditions in frozen soil were developed by taking the ratio of frozen soil severity-indicies (such as in Table 8) to the dry soil severity-indicies (such as in Table 7). An illustration of the resulting severity-index adjustment factors for a compact size automobile for various impact speed-angle combinations is shown in Table 9.

TABLE 7

ILLUSTRATION OF W-BEAM GUARDRAIL SEVERITY-INDICIES
UNDER DRY SOIL CONDITIONS

Vehicle Weight . . . . 2,250 lb
Guardrail Height . . . 27-in.

Impact Speed (mph)	Impact Encroachment Angle (deg)				
	5	10	15	20	25
40	0.14	0.26	0.37	0.47	0.56
50	0.21	0.38	0.53	0.65	0.76
60	0.28	0.51	0.68	0.83	0.94
70	0.37	0.63	0.83	0.98	1.10
80	0.46	0.76	0.97	1.12	1.24

TABLE 8

ILLUSTRATION OF W-BEAM GUARDRAIL SEVERITY-INDICIES
UNDER FROZEN SOIL CONDITIONS

Vehicle Weight . . . . 2,250 lb
Guardrail Height . . . 27-in.

Impact Speed (mph)	Impact Encroachment Angle (deg)				
	5	10	15	20	25
40	0.15	0.30	0.45	0.61	0.77
50	0.23	0.47	0.71	0.95	1.20
60	0.33	0.67	1.02	1.37	1.87
70	0.45	0.91	1.39	1.87	2.36
80	0.59	1.19	1.81	2.44	3.08

TABLE 9

ILLUSTRATION OF W-BEAM GUARDRAIL SEVERITY-INDEX ADJUSTMENT FACTORS UNDER FROZEN SOIL CONDITIONS

Vehicle Weight . . . . 2,250 lbs
Guardrail Height . . . 27-in.

Impact Speed (mph)	Impact Encroachment Angle (deg)				
	5	10	15	20	25
40	1.07	1.15	1.22	1.30	1.38
50	1.10	1.24	1.34	1.46	1.58
60	1.18	1.31	1.50	1.65	5.00*
70	1.22	1.44	1.67	5.00*	5.00*
80	1.28	1.57	5.00*	5.00*	5.00*

* Assumed Vehicle Vaulting and/or Penetration

The impact conditions in which vaulting and/or penetration would have occurred as determined from the previous work are indicated by an asterisk in Table 9. In these situations, the severity-indicies were set to a high value of five in order to be assured that the probability of an injury type accident as discussed in a previous section (Section 4.5) of this report would be equal to 100%. The complete set of severity-index adjustment factors for other impact conditions are presented in Appendix I.

3.2.2. End Impacts

In addition to side-impact severities, the end-impact severities had to be determined for various types of guardrail end treatments. In the case of cable guardrail, a simple end anchorage system was the only available type of end treatment in the program. However, W-beam guardrail had five different end treatments available for the user to choose from. Limited test data was available to derive the severity-indicies for end impacts on guardrail end treatments (25,26). Therefore, the full-scale test data was extrapolated where possible, and assumptions were made in other cases to determine the severity-index equations for all five types of W-beam end treatments.

A number of variables had to be accounted for in these severity-index equations. The first variable was environmental conditions. In most cases, no adjustment was made between the dry and wet soil conditions. However, if the end treatment incorporated significant soil-post interaction, an assumed adjustment factor to account for frozen soil conditions was included in the equation.

To account for the three different vehicle size classes, it was assumed that the severity-index was proportional to vehicle weight with the higher severity-index values corresponding to the 1,700 lb vehicle size. These values were then checked with the data from the full-scale tests conducted on end treatments of W-beam guardrail to insure their accuracy.

4.

METHODOLOGY TO COMPUTE COST-EFFECTIVENESS AND BENEFIT-COST

Cost-effectiveness is defined as the cost to reduce one injury (fatal or nonfatal) accident. As shown in the below equation (Eq. 8), cost-effectiveness is computed by dividing the annualized cost of the improvement alternative by the annual reduction in the number of injury accidents. In general, the most attractive improvement alternative from an economic point-of-view is that alternative which has the lowest cost-effectiveness value. For example, an improvement alternative costing \$20 to eliminate one injury accident is more attractive than an improvement alternative costing \$40 to eliminate one injury accident.

$$\frac{\text{Cost}}{\text{Effectiveness}} = \frac{\text{annualized cost of improvement alternative (\$/yr)}}{\text{annual reduction in number of injury accidents (\$/mi.accid/yr)}}$$

$$= \text{cost to reduce one injury, fatal or nonfatal, accident (\$/inj. accid.)} \qquad \text{...Eq. 8}$$

On the other hand, benefit-cost is defined as a dimensionless ratio. As shown in the below equation (Eq. 9), benefit-cost is computed by dividing the annual reduction accident societal costs by the annualized cost of the improvement alternative. A benefit-cost ratio of 1 (unity) and higher indicates that an improvement alternative is attractive from an economic point-of-view. In general, the most attractive improvement alternative is that alternative which has the highest benefit-cost ratio. For example, a benefit-cost ratio of 3 indicates that the benefits of the improvement exceed the costs of the improvement by a factor of 3, whereas, a lower benefit-cost ratio of 2 indicates that the benefits of the improvement exceed the costs of the improvement by a factor of 2.

$$\frac{\text{Benefit}}{\text{Cost}} = \frac{\text{annual reduction in accident societal costs (\$/yr)}}{\text{annualized cost of improvement alternative (\$/yr)}} \qquad \text{...Eq. 9}$$

From the above discussion, it can be seen that the primary difference between the two methods is that the cost-effectiveness method takes into consideration the reduction in the number of injury accidents, whereas, the benefit-cost method takes into consideration the reduction in accident societal costs. However, both methods are usually consistent in selecting the same and most attractive improvement alternative.

4.1 FORMULATION OF COST-EFFECTIVENESS AND BENEFIT-COST COMPUTER MODEL

The cost-effectiveness method used in this study is a modified and expanded version of the cost-effectiveness priority approach formulated by Glennon (15) in NCHRP 148 for freeways and implemented in Texas in the management of roadside safety improvement programs on both freeway and non-controlled access roadways (13).

In the NCHRP 148 study, the impact severity of a vehicle encountering a roadside hazard was based on accident data; whereas, in the Texas study, the severity was based upon the judgement of engineers, patrolmen, and other professions involved in the area of highway safety. The primary difference between these two NCHRP 148 and Texas programs and the program in this HP&R study is that mathematical computer simulation models were used to assist in computing impact severities of various size vehicles (a) traversing a wide range of embankment design configurations, and (b) impacting a wide range of both W-beam and cable guardrail design configurations under all possible speed-angle combinations. The methodology to compute impact severity was presented earlier in Section 3 of the report.

4.1.1. Roadside Hazard Envelope

In order for a vehicle to encounter a roadside obstacle, three conditions must exist. These conditions are:

(a) the vehicle must be within the section of the roadway associated with the roadside obstacle, and

(b) a vehicle encroachment must occur, and

(c) the vehicle must be on a collision course with the roadside obstacle.

The hazard envelope in Figure 7 defines that area in which an encroaching vehicle has a chance of encountering the obstacle. The hazard envelope is broken down into three zones. The exposure length of each zone along the roadway is a function of the vehicle encroachment angle from the roadway (Θ), the width of the vehicle (2B), and the length (ℓ) and width (w) of the obstacle. A vehicle in Zone 1 would have a chance of encountering the "side" of the obstacle, whereas, a vehicle in Zones 2 or 3 would have a chance of encountering the "end" of the obstacle.

The obstacle in Figure 7 is defined as any roadside hazard which would be a potential danger to the occupants of a vehicle departing from the roadway. The types of obstacles considered in this study were (a) cable guardrail, (b) W-beam guardrail, and (c) embankments on which there were no point type obstacles such as trees and/or culvert headwalls. Furthermore, the obstacle can be considered as either the existing condition or the proposed improvement alternative. The computer coding forms for recording data on an obstacle are presented in Section 5 of this report.

4.1.2. Equations to Compute Cost-Effectiveness and Benefit-Cost

The variables that were taken into consideration in computing cost-effectiveness and benefit-cost are expressed mathematically in the following equations:

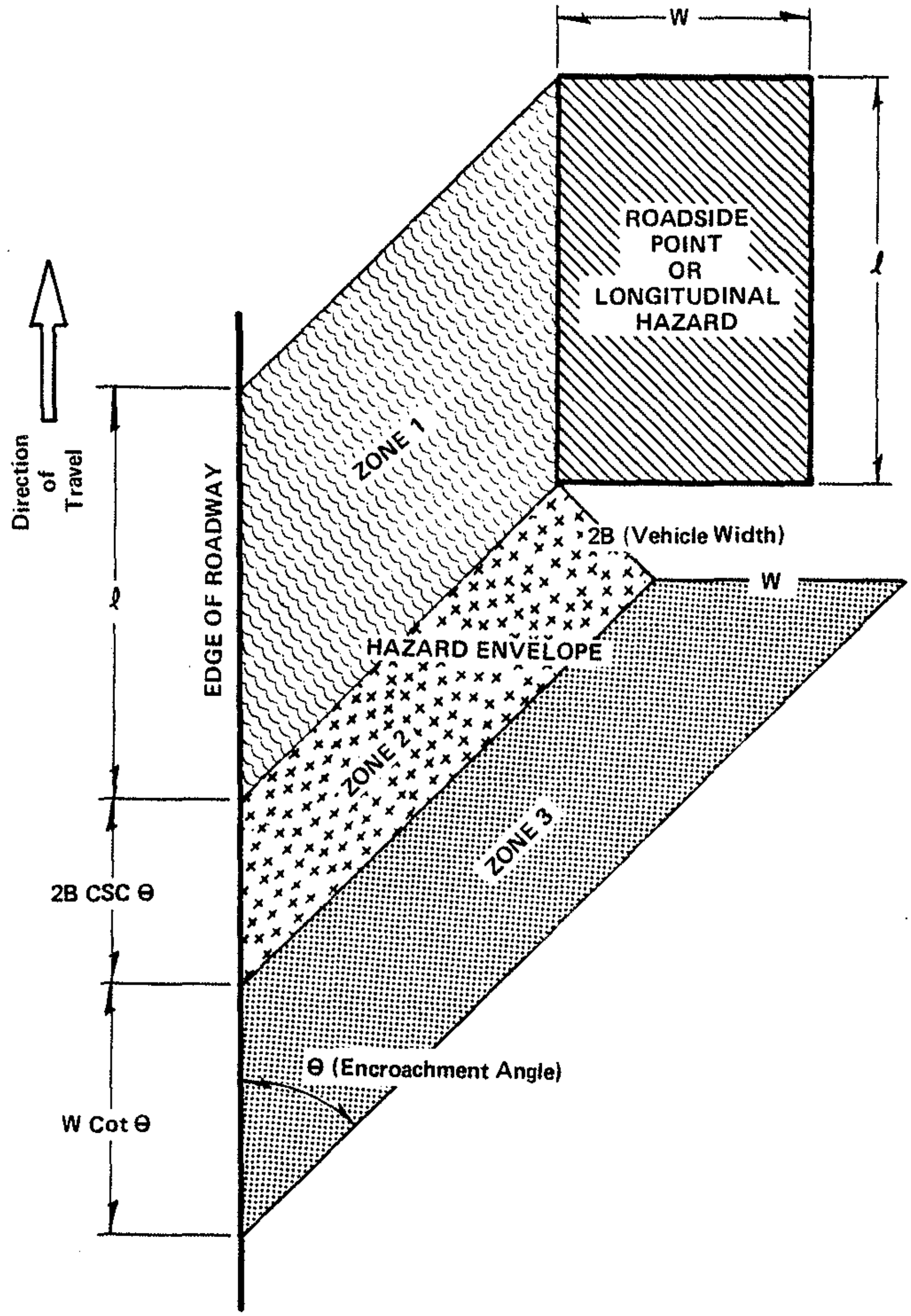


FIGURE 7. ROADSIDE HAZARD ENVELOPE (Typical)

$$\frac{C}{E} = \frac{[CS(crf) + NM + CM]_A - [NM + CM]_B}{[HI]_B - [HI]_A} \quad \text{...Eq. 10}$$

$$\frac{B}{C} = \frac{[AC]_B - [AC]_A}{[CS(crf) + NM + CM]_A - [NM + CM]_B} \quad \text{...Eq. 11}$$

$$\begin{bmatrix} HI \\ AC \\ CM \end{bmatrix}_{\substack{A \\ B}} = \frac{E_f D}{5280} \sum_{i=1}^{3} W_i \sum_{j=1}^{3} EC_j \left\{ \begin{bmatrix} HI \\ AC \\ CM \end{bmatrix}_{Zone\ 1} + \begin{bmatrix} HI \\ AC \\ CM \end{bmatrix}_{Zone\ 2} + \begin{bmatrix} HI \\ AC \\ CM \end{bmatrix}_{Zone\ 3} \right\} \quad \text{... Eq. 12}$$

$$\begin{bmatrix} HI \\ AC \\ CM \end{bmatrix}_{Zone\ 1} = \sum_{r=1}^{2(max)} R_r \sum_{i=j}^{7(max)} L_i \sum_{\Theta=1}^{5} P_I \langle y \geq s \rangle \sum_{V=1}^{5} P_{V,\Theta} \begin{bmatrix} PIS \\ ACS \\ CMS \end{bmatrix}_{V,\Theta} \quad \text{...Eq. 13}$$

$$\begin{bmatrix} HI \\ AC \\ CM \end{bmatrix}_{Zone\ 2} = \sum_{r=1}^{2(max)} R_r \sum_{\Theta=1}^{5} \frac{d}{\sin\Theta} P_I \langle y \geq (s + \frac{d}{2}) \rangle \sum_{V=1}^{5} P_{V,\Theta} \begin{bmatrix} PIE \\ ACE \\ CME \end{bmatrix}_{V,\Theta} \quad \text{...Eq. 14}$$

$$\begin{bmatrix} HI \\ AC \\ CM \end{bmatrix}_{Zone\ 3} = \sum_{r=1}^{2(max)} R_r \sum_{\Theta=1}^{5} \frac{w}{\tan\Theta} P_I \langle y \geq (s + d + \frac{w}{2}) \rangle \sum_{V=1}^{5} P_{V,\Theta} \begin{bmatrix} PIE \\ ACE \\ CME \end{bmatrix}_{V,\Theta} \quad \text{...Eq. 15}$$

where:

$\frac{C}{E}$ = cost-effectiveness ($/inj. accid. reduced)

$\frac{B}{C}$ = benefit-cost ratio

HI_B = hazard-index before improvement (inj. accid./yr)

HI_A = hazard-index after improvement (inj. accid./yr.)

AC_B = accident societal costs before improvement ($/yr)

AC_A = accident societal costs after improvement (\$/yr)

CS_A = improvement capital costs (\$)

crf = capital-recovery-factor = $\frac{i(1+i)^n}{(1ti)^n-1}$

i = compounded annual interest rate

n = life of project

NM_B = normal maintenance costs before improvement (\$/yr)

NM_A = normal maintenance costs after improvement (\$/yr)

CM_B = collision repair costs before improvement (\$/yr)

CM_A = collision repair costs after improvement (\$/yr)

E_f = encroachment rate (number of roadside encroachments per mile per year). (see Table 10)

D = encroachment rate distribution (see Table 11)

W_i = automobile splits in traffic stream

W_1 = proportion of vehicles in 4,500 lb. classification category

W_2 = proportion of vehicles in 2,250 lb. classification category

W_3 = proportion of vehicles in 1,700 lb. classification category

EC_j = environmental conditions

EC_1 = proportion of time dry

EC_2 = proportion of time wet

EC_3 = proportion of time frozen

L_i = length of hazard segment, parallel to roadway (ft.)

Guardrail (see Figure 9)

L_1 = tangent section (upstream and downstream ends not flared)

L_2 to L_4 = tangent and upstream flared end section

L_5 to L_7 = tangent, upstream and downstream flared end sections

R_r = direction of vehicle encroachment

R_1 = adjacent near side traffic

R_2 = opposing far side traffic (applicable to roadside hazards in medians of multilane highways, and to roadside hazards on 2-lane highways)

w = width of roadside hazard, perpendicular to roadway (ft)

2B = width of automobiles (assumed as 6 ft)

V = vehicle encroachment speed (mph)

Θ = vehicle encroachment angle (deg)

$P_{\Theta,V}$ = probability of an encroachment at angle, Θ, and speed, V, given that an encroachment has occurred (see Table 13)

$P_I(y)$ = probability that the existing hazard or improvement will be encountered given that an encroachment at angle, Θ, has occurred (see Figure 8)

$PIS_{\Theta,V}$ = probability of an injury accident given that the existing hazard or improvement has been encountered along its side by a vehicle encroachment at angle, Θ, and speed, V. Probability is a function of the severity-index (see Table 14)

$PIE_{\Theta,V}$ = probability of an injury accident given that the existing hazard or improvement has been encountered on its end by a vehicle encroachment at angle, Θ, and speed, V. Probability is a function of the severity-index (see Table 14)

$ACS_{\Theta,V}$ = accident societal cost given that the existing hazard or improvement has been encountered along its side by a vehicle encroachment at angle, Θ, and speed, V. Cost is a function of severity-index and accident classification (see Table 15)

$ACE_{\Theta,V}$ = accident societal cost given that the existing hazard or improvement has been encountered on its end by a vehicle encroachment at angle, Θ, and speed, V. Cost is a function of severity-index and accident classification (see Table 15)

$CMS_{\Theta,V}$ = accident collision repair costs given that the existing hazard or improvement has been encountered along its side by a vehicle encroachment at angle, Θ, and speed, V.

$CMS_{\Theta,V}$ = accident collision repair costs given that the existing hazard or improvement has been encountered on its end by a vehicle encroachment at angle, Θ, and speed, V.

The method by which the variables in the above equations were computed are described in the work to follow.

4.2 VEHICLE ENCROACHMENT RATES

Field measurement data of the rate at which vehicles encroach on the roadside is very difficult to obtain, and hence, are very limited. The first attempt to determine encroachment rates was made by Hutchinson and Kennedy (16) on freeway medians. More recently, Glennon (17) estimated encroachment rates for different types of roadway classifications as a linear function of average daily traffic (ADT). The encroachment rates estimated by Glennon are shown in Table 10. The Nebraska highway design numbers (14) that corresponds to the different highway classifications are also shown in Table 10. The computer model in this study keys on the Nebraska highway design number.

TABLE 10

VEHICLE ENCROACHMENT RATE AS FUNCTION OF

HIGHWAY CLASSIFICATION AND TRAFFIC VOLUME

Nebraska Highway Design Number	Highway Classification	Encroachment Rate for Both Direction of Travel (encroachments/mile/year)
DR 1	Rural Interstate and Expressway	0.000900 ADT
DR 2	Rural Multilane	0.000590 ADT
DR 3	Divided Highway	0.000590 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
DR 10	Urban Interstate	0.000900 ADT
DM 20		0.000900 ADT
DM 30	Urban Multilane	0.000900 ADT
DM 40	Divided Highway	0.000900 ADT
DM 50	Urban Major Arterial	0.001330 ADT
DM 60	Street	0.001330 ADT

ADT = Average Daily Traffic

The encroachment rates shown in Table 10 pertain to both directions of travel. The assumed encroachment rate distributions used in this study are shown in Table 11. On a divided multilane roadway, it was assumed that 40% of the total ADT will encroach in the median, and that 30% will encroach on the right side of the roadway in each direction; whereas, on an undivided multilane roadway and a 2-lane roadway, it was assumed that 50% of the total ADT will encroach on the right side of the roadway in each direction. No attempt was made to assign traffic lane distributions of ADT on multilane roadways.

TABLE 11

ROADSIDE VEHICLE ENCROACHMENT RATE DISTRIBUTION
(assumed)

Highway Type	Right Side (each direction)	Median (Both Directions)
2-Lane or Multi-Lane (not div.)	0.50	----
Multi-Lane (div.)	0.30	0.40

4.3 VEHICLE 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. As shown in Table 12, it was assumed that vehicle speeds were normally distributed with the mean and standard deviation values computed from the Nebraska spot speed data. The encroachment angle distributions were based on the data reported by Hutchinson and Kennedy (16).

TABLE 12

MEAN SPEEDS AND STANDARD DEVIATIONS

Highway Classification	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 classification 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 shown in Table 13 for different highway classifications.

Using the point mass model presented by Ross (18), 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.

4.4. PROBABILITY OF VEHICLE ENCOUNTER

The probability that a vehicle encroaching from the roadway will encounter a roadside obstacle is largely a function of the lateral offset of the obstacle in relation to the roadway. The greater this distance, the further the vehicle must travel to reach the obstacle, and hence, the less likely that it will encounter the obstacle.

TABLE 13

VEHICLE ENCROACHMENT SPEED-ANGLE PROBABILITIES

Vehicle Speed (mph)	Encroachment Angle (deg)				
	<7.5	7.5-12.5	12.5-17.5	17.5-22.5	>22.5
INTERSTATE-URBAN					
<45	.010	.004	.003	.002	.003
45-55	.210	.088	.053	.035	.053
55-65	.243	.101	.061	.040	.060
65-75	.016	.007	.004	.003	.004
>75	.000	.000	.000	.000	.000
INTERSTATE-RURAL					
<45	.001	.000	.000	.000	.000
45-55	.090	.038	.022	.015	.022
55-65	.335	.139	.084	.056	.084
65-75	.054	.023	.014	.009	.014
>75	.000	.000	.000	.000	.000
MULTILANE-DIVIDED AND UNDIVIDED					
<45	.016	.007	.004	.003	.004
45-55	.271	.113	.068	.045	.068
55-65	.188	.078	.047	.031	.047
65-75	.005	.002	.001	.001	.001
>75	.000	.000	.000	.000	.000
2-LANE RURAL					
<45	.006	.002	.001	.001	.002
45-55	.217	.090	.054	.036	.055
55-65	.249	.104	.062	.041	.062
65-75	.009	.004	.002	.001	.002
>75	.000	.000	.000	.000	.000

The encroachment data of Hutchinson and Kennedy (16) were analyzed to determine the relationship between vehicle encroachment angle (Θ) and the probability distribution of the lateral extent of the vehicle encroachment. The four resulting distributions used in this study are shown in Figure 8. Vehicle encroachment speed was not taken into consideration because this type of data is non-existent.

On a 2-lane roadway and for traffic departing to the right, the lateral offset distance of the roadside obstacle is measured relative to the edge of the travelled roadway; whereas, for opposing traffic departing to the left, the lateral offset distance of the obstacle is measured relative to the centerline of the roadway. On a divided multilane roadway, the effects of opposing traffic are neglected because the probability of a vehicle crossing the median as well as the opposing traffic lanes in order to encounter a roadside obstacle would be negligble.

4.4.1. Guardrail Considerations

The end sections of guardrail are usually flared away from the roadway to reduce the probability of a vehicle impacting the end section of the guardrail. It is well recognized that impacting the end section of a guardrail is much more severe than impacting the side of the guardrail. On a two lane roadway or a multilane undivided roadway, the general accepted practice is to flare both the upstream and downstream end sections of the guardrail; whereas, on a divided multilane roadway, the general accepted practice is to only flare the upstream end which can be impacted.

The hazard envelope of a guardrail flared on both ends is shown in Figure 9 for near side traffic departing to the right on a 2-lane roadway. The computer

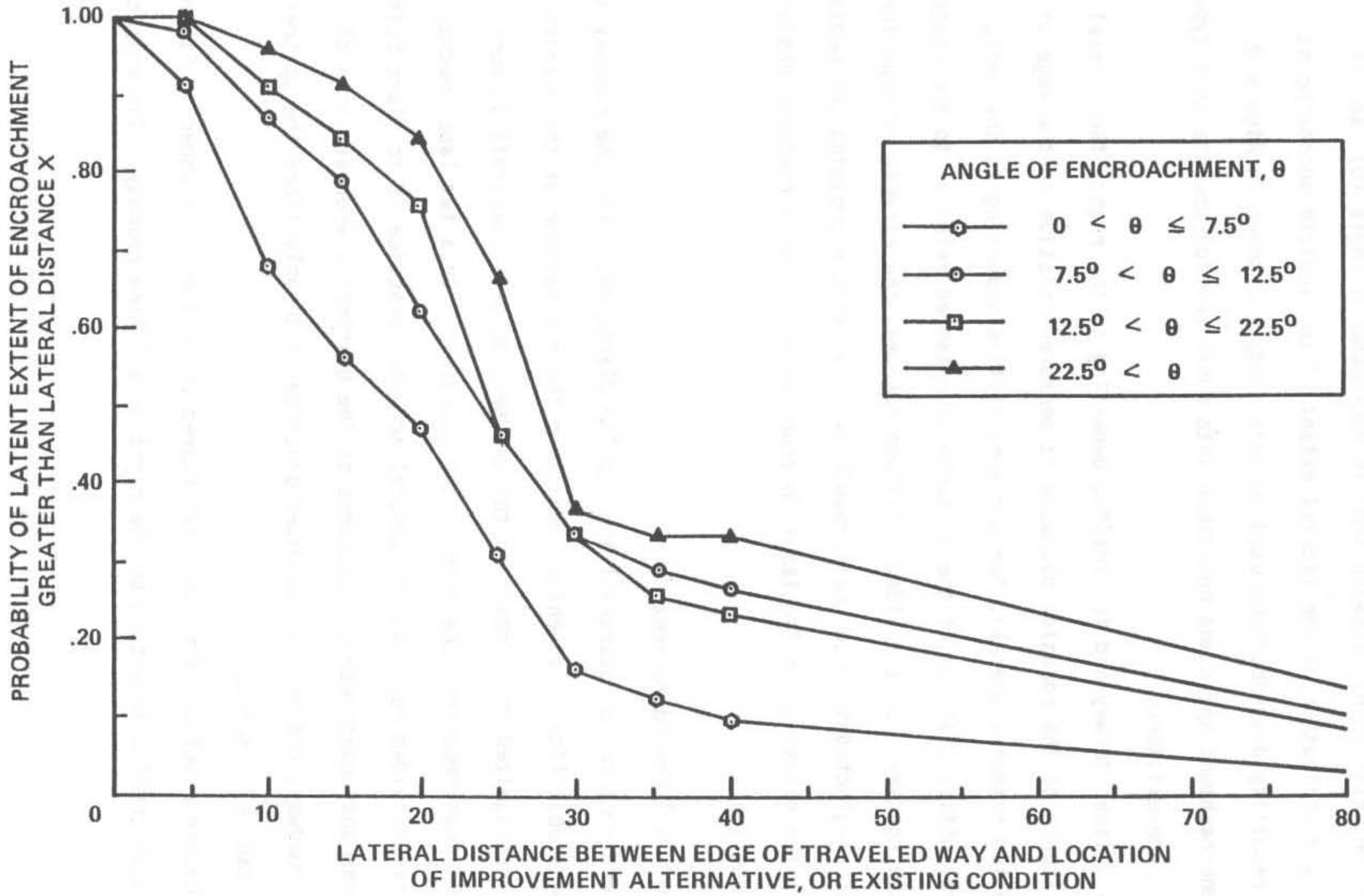


FIGURE 8. DISTRIBUTIONS OF LATERAL EXTENT OF ENCROACHMENTS

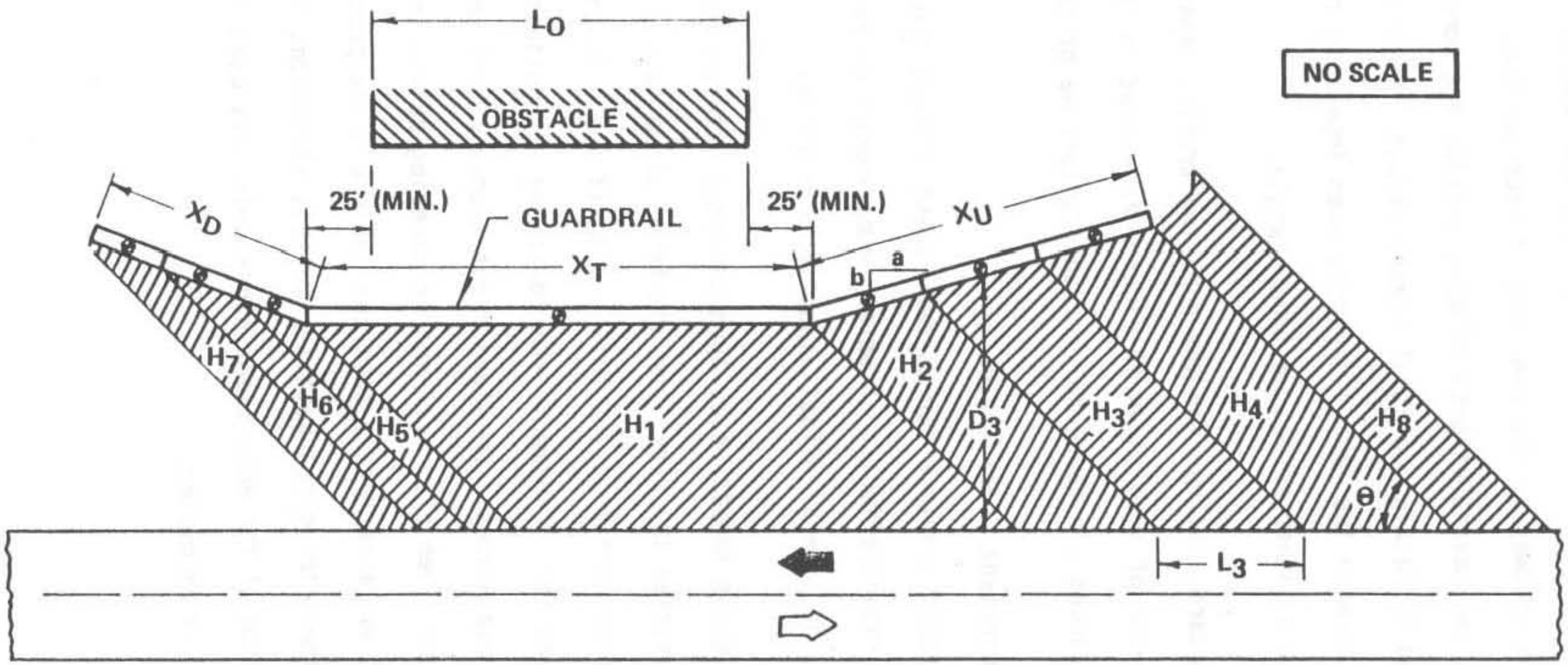


FIGURE 9. GUARDRAIL HAZARD ENVELOPES : ADJACENT TRAFFIC

program internally divides both the upstream and downstream flared ends into three equal length sections and computes the lateral offset distance from the edge of the roadway to the centroid of each section. As can be seen in Eq. 11 (page 41), the hazard effects of each section are computed individually and then summed to obtain the total hazard effect. No attempt was made in this study to increase the impact severity when impacting the sides of the flared sections at a higher effective impact angle.

The hazard envelope for the opposing traffic departing to the left would be the reverse of than shown in Figure 9, except in this case, the lateral offset distances are computed from the centerline of the roadway.

4.4.2. Embankment Considerations

The hazard envelope for an embankment differs from a guardrail in that it has no end hazard effects. However, embankments do require special consideration when computing lateral offset impact probabilities.

The highest impact severity associated with an embankment occurs when the vehicle traverses the area from the front slope to the ditch bottom or the area from the ditch bottom to the back slope, if any. In computing lateral impact probabilities for embankments the following assumptions were made.

(a) Steep Slopes...On steep front slopes of 3:1 and steeper, it was assumed that a vehicle could not be steering backup onto the roadway and that it was a certainty that the vehicle would proceed down the slope and impact the ditch bottom. In this situation, the lateral offset distance of the embankment hinge point was used in computing the probability of an encounter.

(b) Moderate Slopes...On moderate slopes of 4:1 and 5:1, it was assumed that there was a fair probability of safely steering the vehicle back up onto the roadway. In this situation, the average lateral offset distance between the hinge point and ditch bottom was used in computing the probability of an encounter.

(c) Flat Slopes...On flat slopes of 6:1 and flatter, it was assumed that there was a very high probability that the vehicle could be steered safely back up onto the roadway. In this situation, the lateral offset distance to the bottom of the ditch was used in computing the probability of an encounter.

4.5 PROBABILITY OF INJURY ACCIDENT

The probability of an injury accident (fatal or non-fatal) given that an obstacle has been encountered is a fuction of the severity-index of the impact. In turn, the severity-index is a function of vehicle size, speed and angle of the encroachment, and the type and configuration of the obstacle. As described in a previous section of this report, computer simulation models (HVOSM and BARRIER VII) were used to determine the severity-indices of embankment traversals and guardrail impacts over a range of conditions.

The relationship between severity-index and the probability of an injury accident was developed by Post (27) in a recent research study. This relationship is presented in Table 14. To facilitate its use in the computer program, the histogram relationship was approximated by the two linear functions shown in Figure 10.

TABLE 14

RELATIONSHIP BETWEEN SEVERITY-INDEX AND PROBABILITY OF INJURY ACCIDENT

Severity-Index	Probability of Injury Accident
≤ 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

4.6 ACCIDENT CLASSIFICATION AND SOCIETAL COSTS

In this study, accidents were classified into the three broad categories of (a) fatal accidents (b) injury accidents (c) property-damage-only (PDO) accidents. Various agencies such as the NHSTA and the NSC publish these costs, however, the user of the computer program must specify the costs on the coding form presented in Section 5. The accident societal costs of NHSTA that were used in conducting the parametric and case studies in this report are shown in Table 15.

The relationship between severity-index and the probability of an injury accident given in the previous section in Table 14 was expanded to include the accident percentage breakdown by the type of obstacle encountered. This relationship is shown in Table 16. The type of obstacle was classified as (a) a point hazard such as a tree, (b) a longitudinal hazard such as a guardrail, and (c) a slope hazard such as an embankment. As mentioned earlier, only

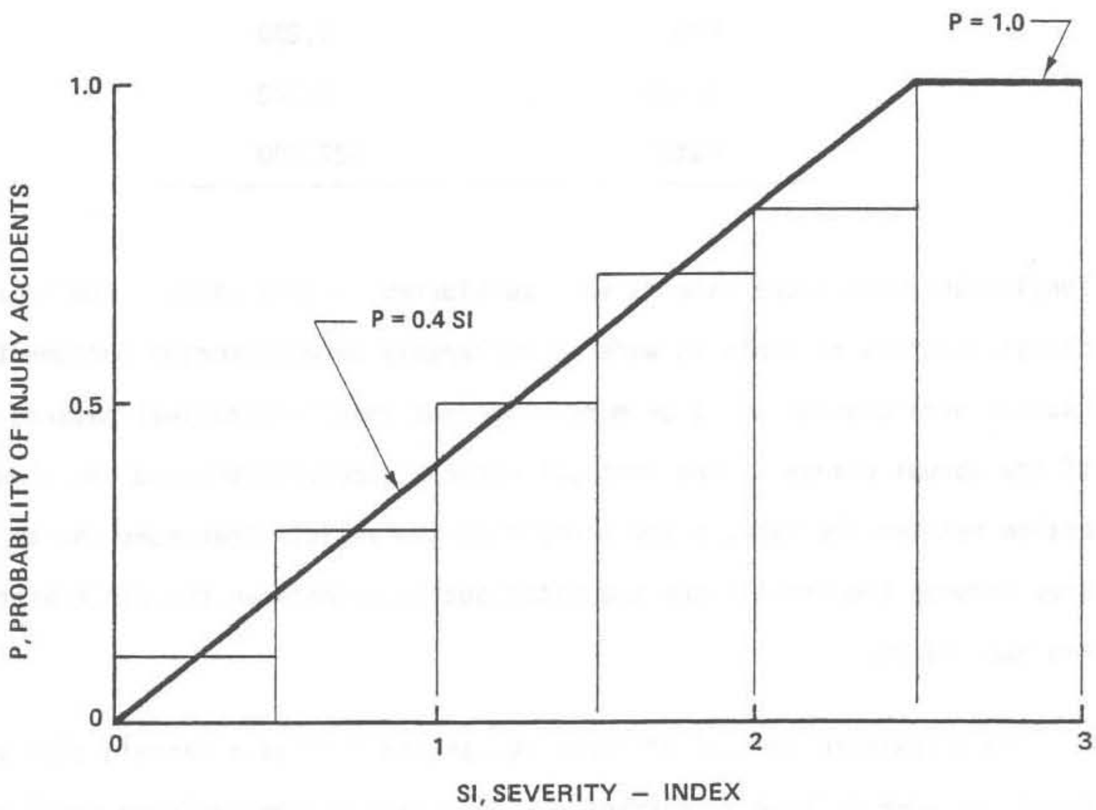


FIGURE 10. RELATIONSHIP BETWEEN SEVERITY – INDEX AND PROBABILITY OF INJURY ACCIDENT

TABLE 15

NHSTA ACCIDENT SOCIETAL COSTS

Type of Accident	Cost ($)
PDO	1,200
Injury	5,900
Fatal	427,600

longitudinal and slope hazards were considered in this study. The accident classifications in Table 16 were based largely on engineering judgement. Slope hazards were considered to be more hazardous than longitudinal hazards because of the abrupt change in the vertical vehicle accelerations and the plowing action between the vehicle and terrain as the vehicle traverses the transition area between the front slope and ditch bottom or between the ditch bottom and the back slope.

To illustrate the use of Table 16, assume that as a certain size vehicle traverses some defined embankment configuration at some defined speed-angle combination that the severity-index is computed to be equal to a value of 1.8. Using the NHSTA societal costs given in Table 15, the total accident cost for the defined conditions would be computed as follows:

$$\text{Total Accident Cost} = 0.30(\$1{,}200) + 0.66(\$5{,}900) + 0.04(\$427{,}600) = 21{,}358$$

TABLE 16

RELATIONSHIP BETWEEN SEVERITY-INDEX AND

INJURY ACCIDENT PROBABILITY AND ACCIDENT CLASSIFICATION

Severity Index	Probability of Injury Accident[a]	ACCIDENT CLASSIFICATION								
		PDO Only Accidents (%)			Injury Accidents (%)			Fatal Accidents (%)		
		Point Haz.	Long. Haz.	Slope Haz.	Point Haz.	Long. Haz.	Slope Haz.	Point Haz.	Long. Haz.	Slope Haz.
$SI \le 0.5$	0.1	90	90	90	10	10	10	0	0	0
$0.5 < SI \le 1.0$	0.3	70	70	70	30	30	30	0	0	0
$1.0 < SI \le 1.5$	0.5	50	50	50	48	50	48	2	0	2
$1.5 < SI \le 2.0$	0.7	30	30	30	66	70	66	4	0	4
$2.0 < SI \le 2.5$	0.8	20	20	20	72	78	74	8	2	6
$2.5 < SI$	1.0	0	0	0	88	96	92	12	4	8

a. Number of fatal and non-fatal injury accidents per total accidents

b. Assumed classification

4.7 GUARDRAIL COLLISION MAINTENANCE COSTS

4.7.1 Guardrail Side Impacts

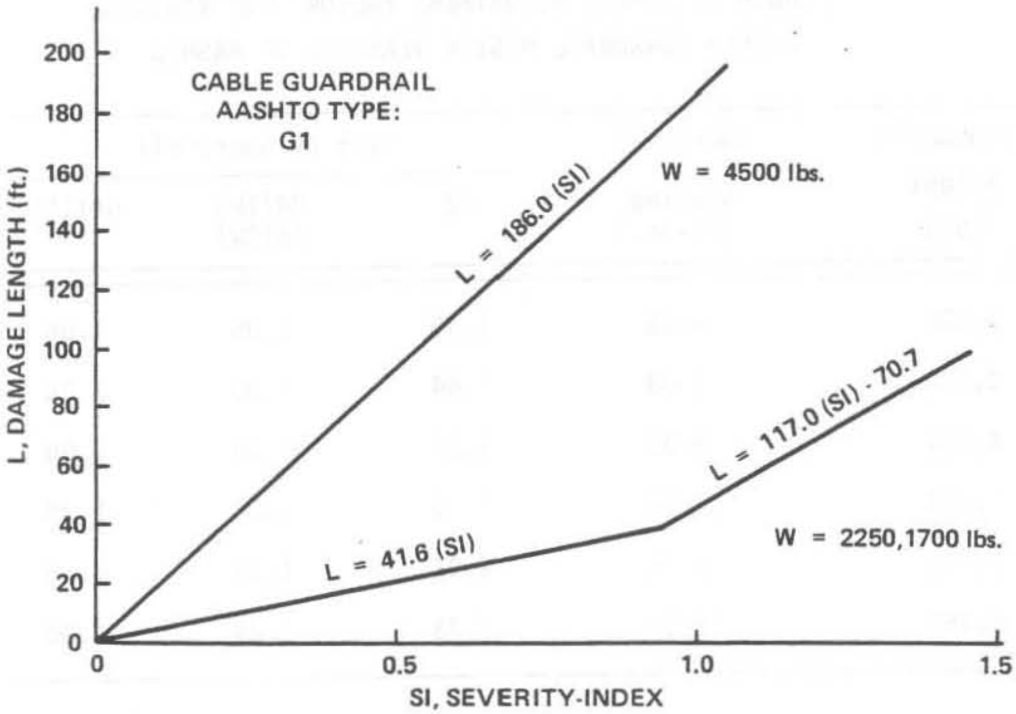
In order to compute the cost-effectiveness and the benefit-cost of a guardrail improvement alternative, it is necessary to take into consideration the guardrail collision maintenance costs. The amount of damage is a function of vehicle size, encroachment speed and angle, and the type of guardrail. As discussed earlier, these variables can be expressed in terms of a severity-index. The BARRIER VII computer model and the research results of SwRI (10) were used to compute severity-indices and to ascertain the magnitude of guardrail damage.

The relationships between severity-index and the length of guardrail damage as a function of vehicle size are shown in Figure 11 for the cable guardrail and W-beam guardrail designated as AASHTO G1 and G4 (1W and 2W), respectively. The computer program internally computes the collision maintenance repair costs by multiplying the length of guardrail damage in Figure 11 by the collision unit repair costs provided by the user on an Input Coding Form described in Section 5 of this report.

In order to account for different post spacings and other design versions of the W-beam guardrail, the length of damage obtained from Figure 11 was multiplied by an adjustment factor shown in Table 17. These adjustment factors were determined by taking the ratio of the severity-indices for a given vehicle size and impact speed-angle combination.

4.7.2 Guardrail End Impacts

In the case of end type impacts on guardrail, a linear proportionality was assumed between the percent damaged of the end section and the severity-index of the collision. This proportionality factor ranged linearly from 0.50



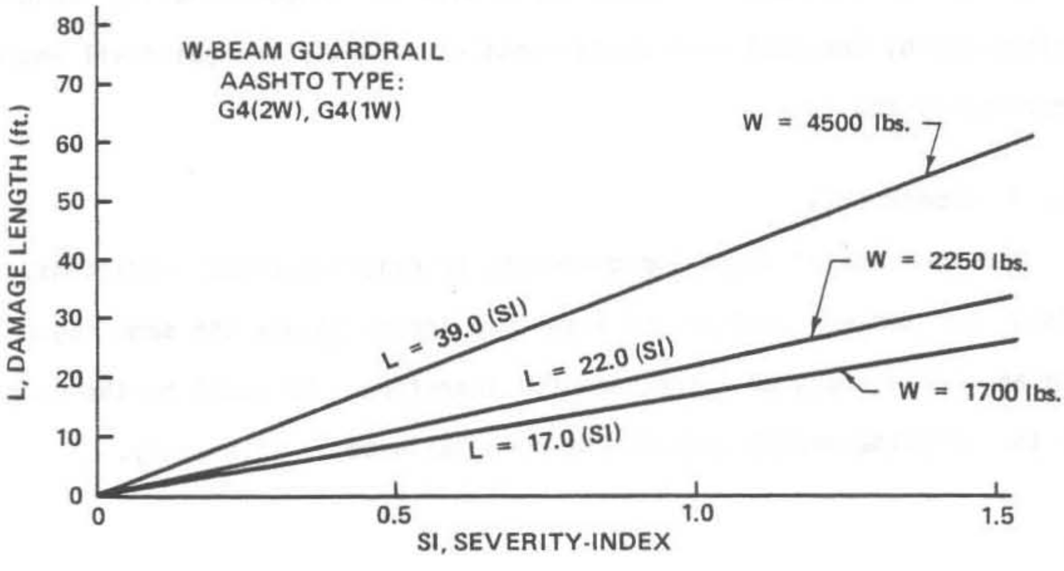


FIGURE 11.
RELATIONSHIP BETWEEN SEVERITY-INDEX AND GUARDRAIL DAMAGE

TABLE 17

LENGTH OF DAMAGE ADJUSTMENT FACTORS FOR VARIOUS W-BEAM GUARDRAIL DESIGN VERSIONS OF AASHTO

Automobile Weight (lbs)	Guardrail Post Spacing (ft-in.)	Type of Guardrail		
		G2	G4(1W) G4(2W)	G4(1S)
1,700	6-03	1.59	1.06	1.06
2,250	6-03	1.64	1.00	1.09
4,450	6-03	1.87	1.00	1.08
1,700	12-06	2.00	1.24	1.35
2,250	12-06	2.05	1.27	1.36
4,450	12-06	2.33	1.26	1.36

for a severity-index of 0.25 up to 1.00 for a severity-index of 2.50. Then to determine the replacement cost after a hit, the proportionality factor was multiplied by the collision repair cost of a particular guardrail end section provided by the user.

4.7.3 Embankments

In the case of slope improvements, or existing slope conditions, the collision maintenance cost during a vehicle traversal was the same regardless of the angle and speed of encroachment. Therefore, the costs by the user input on the Roadside Hazard Improvement Form was used in this study.

5.

USER COMPUTER PROGRAM

The computer program in this study was developed to expedite the lengthy and tedious cost-effectiveness and benefit-cost calculations for making specific type of guardrail improvements on roadside embankments. The basic format of the program was developed in an earlier study presented by Weaver (13). Implementation of the computer program requires that the user complete four types of computer coding forms. The forms, shown in Figures 12 through 15, are titled:

FIGURE 12. ROADSIDE COST-EFFECTIVENESS FORM: GENERAL INFORMATION

FIGURE 13. ROADSIDE COST-EFFECTIVENESS FORM: GUARDRAIL COLLISION REPAIR COSTS

FIGURE 14. ROADSIDE HAZARD INVENTORY FORM

FIGURE 15. ROADSIDE HAZARD IMPROVEMENT FORM

The numbers in the boxes above the "blank" boxes to be filled in by the user represent the column positions on the IBM data card; whereas, the combination letters and numbers (i.e. G18) below the blank boxes are the computer program names for the information contained within the boxes.

Since there were no default provisions made in this study, the computer program assigns a value of zero to any box left blank by the user.

A discussion on the use of the coding forms and the program strategy is presented in the work to follow. The flow-charts of the computer program are presented in Appendix K, and the source listing of the computer program is presented in Appendix L.

5.1. USE OF CODING FORMS

5.1.1. Roadside Cost-Effectiveness Form: General Information

The General Information Form in Figure 12 is the first IBM card to be provided by the user at the start of a computer run. This form contains

FIGURE 12

ROADSIDE COST-EFFECTIVENESS FORM

GENERAL INFORMATION

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

HP & R 79-4

HIGHWAY DESIGN NO. .... HIGHWAY NO. .... DATE ....

IBM CARD NO. 1

ENVIRONMENTAL CONDITIONS (Mo./Yr.)

WET — 1 — G10

SUB-FREEZING — 3 — G12

AUTOMOBILE SPLIT CATEGORIES (%)

1,700 lb. — 5 6 — G13

2,250 lb. — 8 9 — G14

4,500 lb. — 11 12 — G15

ECONOMIC FACTORS

PROJECT LIFE (Yr.) — 14 15 — G16

INTEREST RATE (%) — 17 18 19 20 21 — G17

SOCIETAL ACCIDENT COSTS

FATAL ($) — 23 24 25 26 27 28 29 — 0427600 — G18

INJURY ($) — 31 32 33 34 35 — G19

PDO ($) — 37 38 39 40 — G20

Rev. Date 08-08-81

FIGURE 13

ROADSIDE COST-EFFECTIVENESS FORM

GUARDRAIL COLLISION REPAIR COSTS

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

HP & R 79-4

IBM CARD NO. 2

LENGTH OF NEED SECTION ($/L.F.) — DATE ....

Item	Columns	Value	Item	Columns	Value	Item	Columns	Value	Item	Columns	Value
G1	1 2 3 4	04.75	G4(1W)	21 22 23 24		MB1	41 42 43 44		MB4W	61 62 63 64	
G2	6 7 8 9		G4(2W)	26 27 28 29		MB2	46 47 48 49		MB4S	66 67 68 69	
G3	11 12 13 14		G4(1S)	31 32 33 34		MB3	51 52 53 54			71 72 73 74	
G9	16 17 18 19		G4(2S)	36 37 38 39		MB9	56 57 58 59			76 77 78 79	

IBM CARD NO. 3

END TERMINAL ($/EA.)

Item	Designation	Columns	Value
NOT ANCHORED	*GRE1	1 2 3 4 5	
ANCHORED (W-BEAM)	*GRE2	7 8 9 10 11	
ANCHORED (CABLE)	*GRE3	13 14 15 16 17	
TURN DOWN	*GRE4	19 20 21 22 23	
TURN DOWN (BREAKAWAY)	*GRE5	25 26 27 28 29	

CRASHWORTHY ENDS

Item	Columns	Value
GET 1	31 32 33 34 35 36	0785.00
GET 2	38 39 40 41 42 43	
MBET 1	45 46 47 48 49 50	
MBET 2	52 53 54 55 56 57	

*NON-AASHTO DESIGNATION

Rev. Date 08-08-81

FIGURE 14

ROADSIDE HAZARD INVENTORY FORM

DATE ____________

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

INVENTORY CONDUCTED BY ____________

BOX 1 — HIGHWAY

SHOULDER

H50		H51													
HIGHWAY DESIGN NO.		HIGHWAY NO.		POSTED SPEED LIMIT (mph)	ADT (Both Directions)	LANE WIDTH (Ft.)	MEDIAN WIDTH (Ft.)	DEGREE OF CURVE	GRADE (%) Up	GRADE (%) Dn	PAVED WIDTH (Ft.)	USABLE WIDTH (Ft.)	SURFACE TYPE	DROP-OFF (In.)	CONDITION RUT
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	28
H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16

H1: 1. DR 2. DH 3. RDA 4. RC 5. RL

H3: 1. N 2. US 3. I 4. SEC

H14: 1. SOD 2. GRAVEL 3. SOIL

H16: 0. NONE 1. SHALLOW 2. DEEP

BOX 2 — HAZARD CLASSIFICATION

DESCRIPTION ____________

HAZARD NO.	IDENT. NO.	DESCR. CODE	OFFSET CODE	GROUP NO.
29 30	31 32	33 34	35	36 37
H17	H18	H19	H20	H21

H20: 1. RIGHT SIDE 2. LEFT SIDE

MILE - POINT OF HAZARD

BEGINNING	ENDING
38 39 40 41 42 43	44 45 46 47 48 49
H22	H23

BOX 3 — POINT HAZARD (Utility Pole, Tree, Sign, Support, Culvert Headwall, Drainage Inlet)

	LATERAL OFFSET (Ft.)	WIDTH (Ft.)	LENGTH (Ft.)	DRAINAGE HEIGHT (Ft.)	INLETS (Only) DEPTH (Ft.)	NUMBER POINT HAZARDS IN GROUP
50	51 52	53 54	55 56 57	58	59	60 61 62
1						
H30	H31	H32	H33	H34	H35	H36

BOX 4 — LONGITUDINAL HAZARD (Guardrail, Bridgerail, CMB, Wall, Curb)

	LATERAL OFFSET (Ft.)
50	51 52
2	
H30	H31

NOTE: If Guardrail, Complete Box 6

BOX 5 — SLOPE HAZARD (Fill Slope, Cut Slope, Channel Slope, Ditch)

SIDE SLOPES / CROSS CHANNEL

	HINGE POINT OFFSET (Ft.)	AVG. FRONT SLOPE	AVG. FRONT SLOPE HEIGHT (Ft.)	DITCH WIDTH (Ft.)	DEPTH OF WATER IN DITCH	AVG. BACK SLOPE	AVG. BACK SLOPE HEIGHT (Ft.)	CONDITION OF SLOPES	AVG. TRANSVERSE CHANNEL SLOPE	AVG. CHANNEL HEIGHT (Ft.)
50	51 52	53	54 55	56 57	58	59 60	61 62	63	64 65	66 67
3	18	2:1	20	10	1	02:1	05	1		
H30	H31	H32	H33	H34	H35	H36	H37	H38	H39	H40

H35: 1. NONE 2. LESS THAN 2 FT. 3. GREATER THAN 2 FT.

H38: 1. SMOOTH 2. ROUGH

BOX 6 — GUARDRAIL

GUARDRAIL LOCATION	LATERAL OFFSETS (Ft.) Begin	Tangent	End	FLARE RATE (a:b) Begin	End	AVG. SHOULDER SLOPES Tangent	Flared	TOP HEIGHT (In.)	POST SPACING (Ft.)	BLOCK OUT	RUB RAIL
53	54 55	56 57	58 59	60 61	62 63	64	65	66 67	68 69	70	71
						8:1	8:1			1	
H49	H33	H34	H35	H36	H37	H38	H39	H40	H41	H42	H43

H49: 1. EMBANKMENT 2. BRIDGE ENDS 3. POINT HAZARDS

H42: 1. YES 2. NO

H43: 1. YES 2. NO

BRIDGE APPROACH: REDUCED POST SPACING	BRIDGE APPROACH: DOUBLE W-BEAM	END TREATMENTS: Begin	END TREATMENTS: End	POST BACKFILL MATERIAL
72	73	74	75	76
				2
H44	H45	H46	H47	H48

H44: 1. YES 2. NO

H45: 1. YES 2. NO

End treatments: 1. ANCHORED 2. NOT ANCHORED 3. TURN DOWN (B/A) 4. TURN DOWN (Not B/A) CRASHWORTHY TERMINALS 5. GET1 6. GET2 7. MEET1 8. MEET 2

H48: 1. NON-COHESIVE 2. COHESIVE

BOX 7 — PROGRAM CONTROL DATA

80

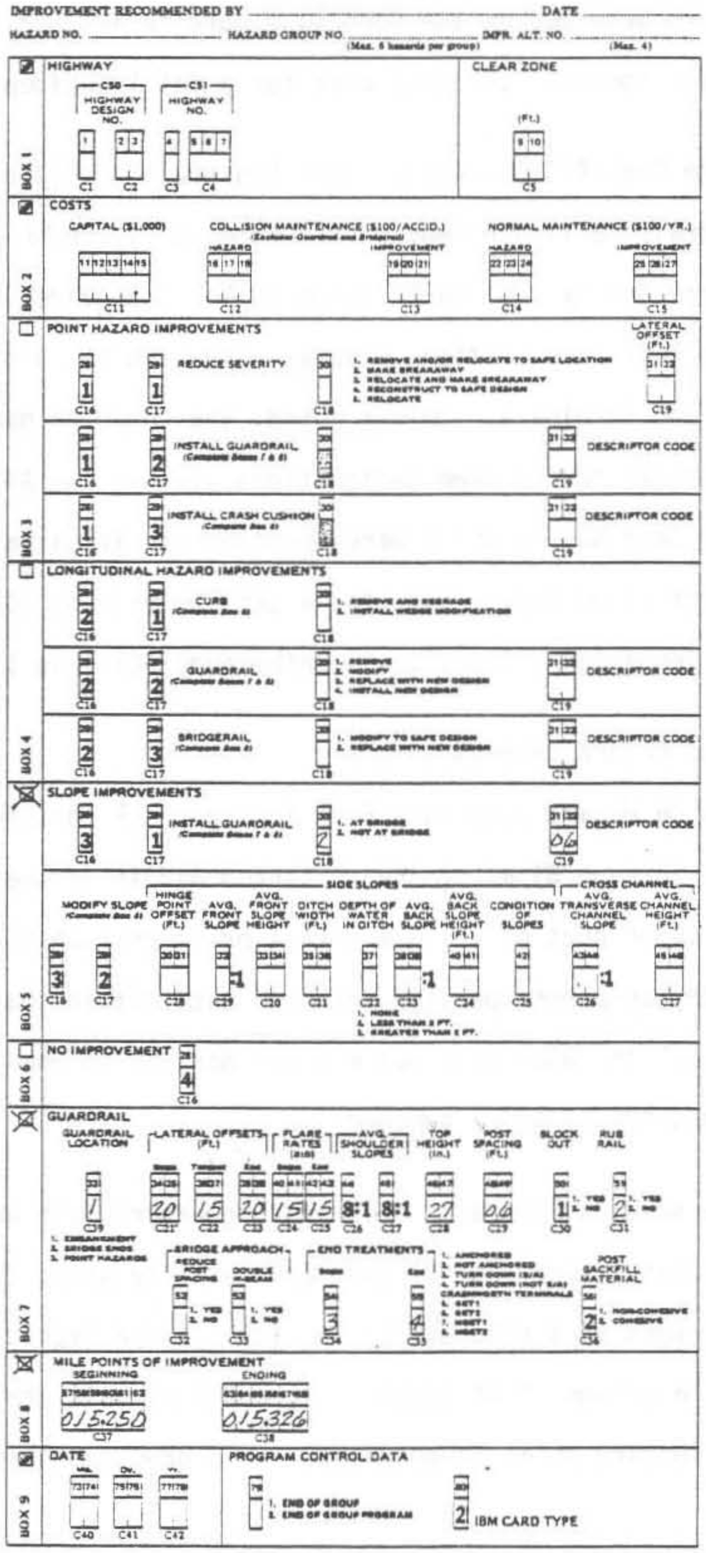
1 IBM CARD TYPE

RECOMMENDATIONS ____________

FIGURE 15

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN



IMPROVEMENT RECOMMENDED BY ______ DATE ______
HAZARD NO. ______ HAZARD GROUP NO. ______ (Max. 6 hazards per group) IMPR. ALT. NO. ______ (Max. 4)

BOX 1 — HIGHWAY: C50 HIGHWAY DESIGN NO.; C51 HIGHWAY NO.; C1, C2, C3, C4. CLEAR ZONE (Ft.) C5

BOX 2 — COSTS: CAPITAL ($1,000) C11; COLLISION MAINTENANCE ($100/ACCID.) HAZARD C12, IMPROVEMENT C13; NORMAL MAINTENANCE ($100/YR.) HAZARD C14, IMPROVEMENT C15

BOX 3 — POINT HAZARD IMPROVEMENTS
- 1 1 REDUCE SEVERITY: 1. REMOVE AND/OR RELOCATE TO SAFE LOCATION 2. MAKE BREAKAWAY 3. RELOCATE AND MAKE BREAKAWAY 4. RECONSTRUCT TO SAFE DESIGN 5. RELOCATE — LATERAL OFFSET (Ft.) C19
- 1 2 INSTALL GUARDRAIL (Complete Boxes 7 & 8) — DESCRIPTOR CODE C19
- 1 3 INSTALL CRASH CUSHION (Complete Box 8) — DESCRIPTOR CODE C19

BOX 4 — LONGITUDINAL HAZARD IMPROVEMENTS
- 2 1 CURB (Complete Box 8): 1. REMOVE AND REGRADE 2. INSTALL WEDGE MODIFICATION
- 2 2 GUARDRAIL (Complete Boxes 7 & 8): 1. REMOVE 2. MODIFY 3. REPLACE WITH NEW DESIGN 4. INSTALL NEW DESIGN — DESCRIPTOR CODE
- 2 3 BRIDGERAIL (Complete Box 8): 1. MODIFY TO SAFE DESIGN 2. REPLACE WITH NEW DESIGN — DESCRIPTOR CODE

BOX 5 — SLOPE IMPROVEMENTS (X)
- 3 1 INSTALL GUARDRAIL (Complete Boxes 7 & 8): 1. AT BRIDGE 2. NOT AT BRIDGE — 2 — DESCRIPTOR CODE 06
- 3 2 MODIFY SLOPE (Complete Box 8): SIDE SLOPES — HINGE POINT OFFSET (Ft.) C28; AVG. FRONT SLOPE C29 :1; AVG. FRONT SLOPE HEIGHT C30; DITCH WIDTH (Ft.) C31; DEPTH OF WATER IN DITCH C32 (1. NONE 2. LESS THAN 2 FT. 3. GREATER THAN 2 FT.); AVG. BACK SLOPE C33 :1; AVG. BACK SLOPE HEIGHT (Ft.) C34; CONDITION OF SLOPES C35; CROSS CHANNEL — AVG. TRANSVERSE CHANNEL SLOPE C36 :1; AVG. CHANNEL HEIGHT (Ft.) C37

BOX 6 — NO IMPROVEMENT 4 C16

BOX 7 — GUARDRAIL (X): GUARDRAIL LOCATION C39 = 1 (1. EMBANKMENT 2. BRIDGE ENDS 3. POINT HAZARDS); LATERAL OFFSETS (Ft.) 20, 15, 20; FLARE RATES (a:b) 15, 15; AVG. SHOULDER SLOPES 8:1, 8:1; TOP HEIGHT (In.) 27; POST SPACING (Ft.) 06; BLOCK OUT 1 (1. YES 2. NO); RUB RAIL 2 (1. YES 2. NO); BRIDGE APPROACH — REDUCE POST SPACING (1. YES 2. NO), DOUBLE W-BEAM (1. YES 2. NO); END TREATMENTS — Begin, End (1. ANCHORED 2. NOT ANCHORED 3. TURN DOWN (B/A) 4. TURN DOWN (NOT B/A) CRASHWORTHY TERMINALS 5. SET1 6. SET2 7. MELT1 8. MELT2); POST BACKFILL MATERIAL 2 (1. NON-COHESIVE 2. COHESIVE)

BOX 8 — MILE POINTS OF IMPROVEMENT (X): BEGINNING 015250 C37; ENDING 015326 C38

BOX 9 — DATE: Mo. C40, Dy. C41, Yr. C42; PROGRAM CONTROL DATA: 1. END OF GROUP 2. END OF GROUP PROGRAM; 2 IBM CARD TYPE information on the environmental conditions, automobile split categories, economic factors, and societal accident costs.

The numbers provided on the form in Figure 12 are for illustrative purposes. For example, the societal accident cost for a fatal accident is $427,600.

5.1.2. Roadside Cost-Effectiveness Form: Guardrail Collision Repair Costs

The Guardrail Collision Repair Cost Form in Figure 13 contains two IBM cards to be provided by the user. IBM Card No. 2 provides cost data on the guardrail length-of-need section, whereas, IBM Card No. 3 provides cost data on the guardrail end terminals. Unless noted, the computer names adjacent to the boxes are identical to the name designations used in the AASHTO Guide (11). The numbers on IBM Card Nos. 2 and 3 were provided for illustrative purposes. For example, the collision repair cost for a cable guardrail (G1) is $4.75 plf, whereas, the collision repair cost for a crashworthy end (GET1) is $785.

5.1.3. Roadside Hazard Inventory Form

The Roadside Hazard Inventory Form in Figure 14 contains seven designated Boxes (Boxes 1 through 7) along the left-hand margin of the form. The small square in the upper part of the Box with a pre-marked check (Boxes 1, 2, and 7) informs the IBM key-punch operator that the data within that Box must always be punched; whereas, the user must put a check mark in an unmarked square if the data within that Box is to be punched.

As can be seen in Figure 14, an existing hazard must be inventoried as either (a) a point hazard (Box 3) such as a utility pole, (b) a longitudinal hazard (Box 4) such as a bridgerail, or (c) a slope hazard (Box 5). The pre-marked number in column 50 of Boxes 3, 4, and 5 signals the computer program as to the type of hazard being inventoried. This procedure was used so that all of the inventory data could be punched on a single IBM Card, and thereby, minimize the number of forms to be handled by field personnel conducting the inventory.

At the present time, the computer program in this study is limited in scope, in that, it was only programmed to handle a fill slope type of existing hazard. However, the program has the capability to be expanded to handle point and longitudinal type hazards or any combination of the three types of hazards.

Data on the highway design number and geometrics in Box 1 can be obtained from the Nebraska Department of Roads (NDR) Minimum Design Standards (14).

Data on a description of the hazard in Box 2 is provided in Table 18. For example, a guardrail is identified by an Identification Code No. 06, whereas, a Description No. 02 identifies the guardrail as a cable type.

The numbers in Box 5 were provided for illustrative purposes. For example, the existing embankment inventoried has a 2:1 front slope, a front fill slope 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 hinge point of the embankment is located 18 ft from the edge of the travelled roadway, there is no water in ditch, and the condition of the slopes is smooth.

5.1.4. Roadside Hazard Improvement Form

The Roadside Hazard Improvement Form in Figure 16 contains nine designated Boxes (Boxes 1 through 9) along the left-hand margin of the form. The small square in the upper part of each Box with a pre-marked check (Boxes 1, 2, and 9) informs the IBM key-punch operator that data within that Box must always be punched; whereas, the user must put a check mark in an unmarked square of the data within that Box must be punched.

TABLE 18 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 18 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 18 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)

As can be seen in Figure 15, the recommended improvement alternative must consist of either (a) a point hazard improvement in Box 3, (b) a longitudinal hazard improvement in Box 4, or (c) a slope improvement in Box 5. The type of improvement alternative recommended in Figure 15 must match the same type of hazard inventoried in Figure 14. It is important to reemphasize that the point hazard improvement and the longitudinal hazard improvement categories were not programmed in this study.

The slope improvement in Box 5 consists of either (a) installing guardrail, or (b) modifying the configuration of the slope. If the recommendation is to install guardrail, then the details and milepoint data of the guardrail in Boxes 7 and 8 must also be provided by the user; whereas, if the recommendation is to modify the slope, then the milepost data in Box 8 must also be provided. The boxes filled in by hand in Figure 15 illustrates the installation of a W-beam guardrail on an embankment. For example, the details of W-beam guardrail are as follows:

- 27-in. in height
- posts spaced 6 ft-3in on centers (note that the 3 in. is assumed in program and therefore it was omitted in form)
- no rub-rail
- offset distance from edge of road of 15 ft.
- both ends fared on ratio of 15:1 and offset 20 ft.
- breakaway turn-down upstream end
- non-breakaway turn-down downstream end

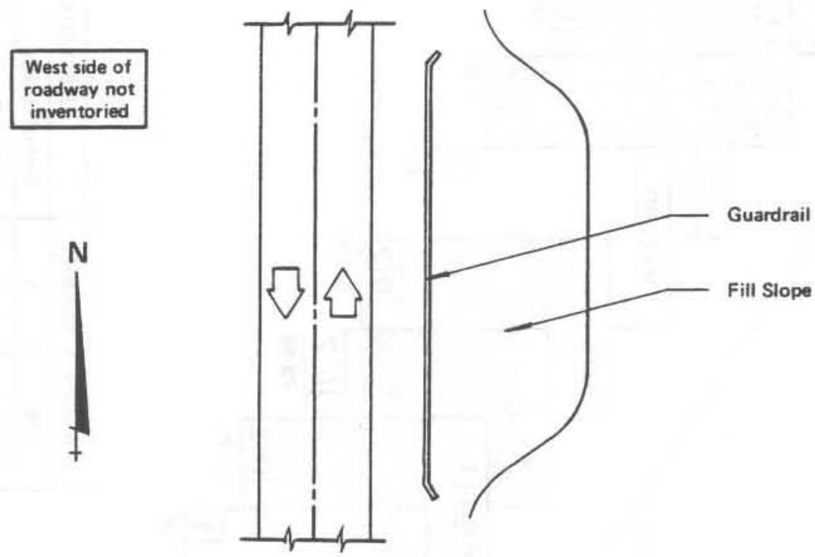
In Box 2 on the cost data, it is to be noted that if the recommended improvement is a guardrail, then the collision maintenance cost data is not provided because these costs are provided on Input Coding Form in Figure 13.

5.2. INPUT DATA FORMAT

Referring back to Box 2 of the Hazard Inventory Form (Figure 14), it is necessary for the user to define the 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 existing hazards in a group is shown in Figure 16. In this case, a guardrail (Hazard No. 1) is protecting a fill slope (Hazard No. 2). The only real existing hazard before making any improvement is the guardrail if one assumes that the existing guardrail is structurally adequate and of adequate length to restrain and redirect an out-of-control vehicle. Improvement Alternative Nos. 1 and 2 specify the removal of the guardrail so that the hazard after each improvement becomes the existing fill slope and the modified fill slope, respectively. On the other hand, Improvement Alternative No. 3 specifies shortening and moving the existing guardrail laterally so that the hazard after the improvement becomes the guardrail. In all three improvements, the reduction in the hazard-index and the accident societal costs are measures of the improvement effectiveness and benefit.

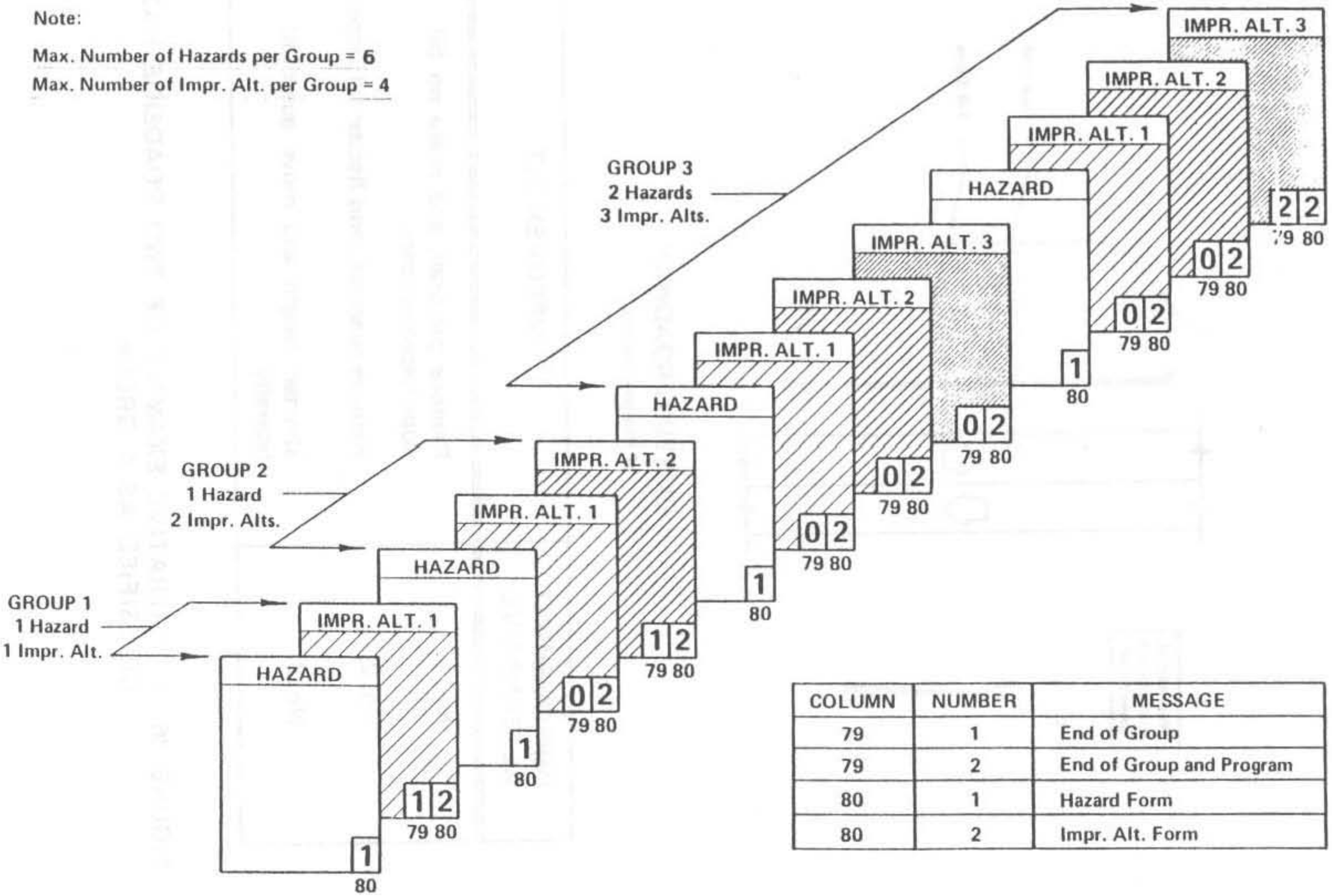
The input data arrangement of the hazard inventory and improvement coding forms for three different size groups is illustrated in Figure 17. Group No. 1 consists of one hazard and one improvement alternative; Group No. 2 consists of one hazard and two improvement alternatives; and, Group No. 3 consists 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



EXISTING ROADWAY
(2 Roadside Hazards)

IMPROVEMENT ALTERNATIVE	IMPROVEMENT
No. 1	Remove guardrail, and make no fill slope improvements.
No. 2	Remove guardrail, and flatten fill slope.
No. 3	Shorten length and move guardrail laterally

FIGURE 16. ILLUSTRATIVE EXAMPLE OF TWO ROADSIDE HAZARDS CLASSIFIED AS A GROUP



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

alternative forms as shown in Group 3. The maximum number of hazards per group is six, and the maximum number of improvement alternatives per group is four.

5.3 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 17, the computer reads the first 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 17.

The computer program developed in this study was limited to cable and 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 types of roadside hazards not covered in this study would require the development of additional subroutines. The program as it now stands contains a main program and 31 subroutines. A flow-chart of the Main Program is shown in Figure 18 and a brief description of each subroutine is presented in Table 19.

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 by-passes 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 20.

FIGURE 18

MAIN PROGRAM

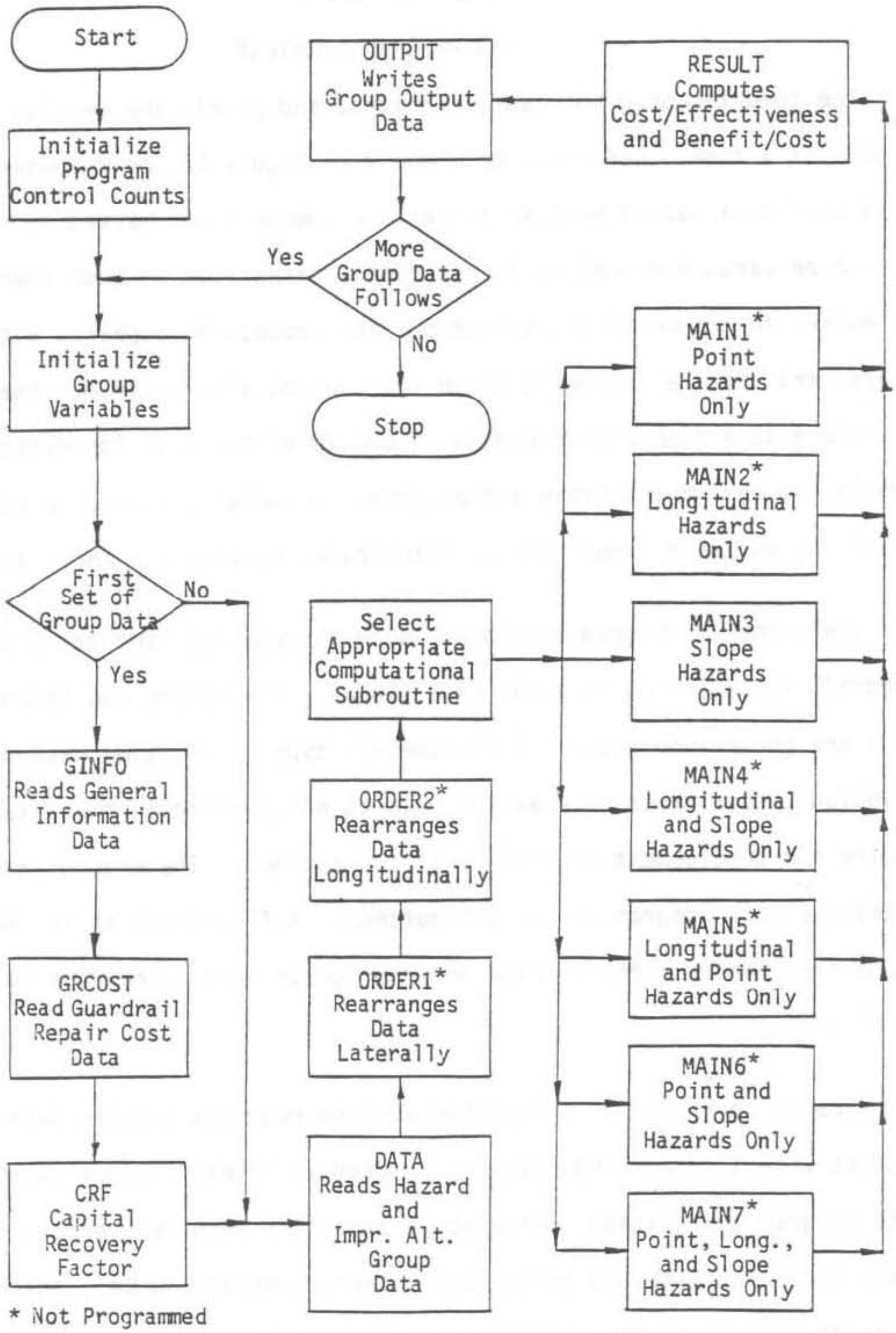


TABLE 19 DESCRIPTION OF SUBROUTINES

NAME	DESCRIPTION
MAIN	Main program control
MAIN1 [a]	Submain program control for point hazards only in group
MAIN2 [a]	Submain program control for longitudinal hazards only in group
MAIN3	Submain program control for slope hazards only in group
MAIN4 [a]	Submain program control for longitudinal and slope hazards in group
MAIN5 [a]	Submain program control for longitudinal and point hazards in group
MAIN6 [a]	Submain program control for point and slope hazards in group
MAIN7 [a]	Submain program control for point, longitudinal, and slope hazards in group
GINFO	Input data. . .subroutine stores general information on accident societal costs, economic factors, automobile splits in traffic stream and environmental conditions.
GRCOST	Input data. . .subroutine stores guardrail collision repair cost data
DATA	Input data. . .subroutine stores data from the roadside hazard inventory and improvement alternative forms
FREQ	Subroutine computes encroachment frequency for a specified type of highway and ADT
PROB1	Subroutine computes probability of vehicle reaching hazard
PROB2	Subroutine assigns vehicle speed-angle impact probabilities for a specified type of highway
PROB3	Subroutine computes probability of injury accident based on severity-index

[a] Not Programmed.

TABLE 19 DESCRIPTION OF SUBROUTINES

NAME	DESCRIPTION
COST3	Subroutine computes total accident societal costs based on severity-index
COST4	Subroutine computes guardrail collision maintenance costs based on severity-index
CRF	Subroutine computes economic capital-recovery-factor for a specified compounded interest rate and project life
SLOPE	Subroutine computes severity-index for vehicle traversing roadside embankments
SLADJ	Environmental slope adjustment factors
SLOPE1	Slope hazard subroutine for existing embankment geometry
SLOPE2	Slope hazard subroutine for improved embankment geometry
GRAIL	Subroutine for guardrail placement on embankments
GRAIL2	Subroutine computes severity-index of vehicle impacting side of cable guardrail (G-1)
GREND2	Subroutine computes severity-index of vehicle impacting end of cable guardrail (G-1)
GRAIL6	Subroutine computes severity-index of vehicle impacting side of W-beam guardrail with wood posts [G4(1W) and G4(2W)]
GRADJ6	Subroutine adjustments of severity-index for vehicle impacting side of W-beam guardrail with wood posts under wet and frozen conditions
GREND6	Subroutine computes severity-index of vehicle impacting end of W-beam guardrail with wood posts
NOIMPR	No improvement subroutine

TABLE 19 DESCRIPTION OF SUBROUTINES

NAME	DESCRIPTION
COMPUT	Subroutine computes hazard-index, total accident costs, and collision maintenance costs
RESULT	Subroutine computes cost-effectiveness and benefit-cost ratios
OUTPUT	Subroutine prints output data

TABLE 20

ERROR MESSAGES AND CODES

Code Number	Error Message
10	Illegal improvement type
11	Must be guardrail addition or slope improvement
20	Illegal front slope
21	Illegal back slope
22	Illegal fill height
30	Point hazards not available
31	Point hazards not available

5.4 OUTPUT FORMAT

A sample listing of the computer output format is shown in Figure 19. The listing shown is from Case Study No. 2 presented in Section 7 of the report.

The "heading block" contains user input data on the highway type and traffic characteristics; automobile size and distribution in traffic stream; environmental conditions; societal accident costs; and, economic factors.

The information below the heading block contains both user input data and computer computations on the "Hazard" and "Improvement Alternative". Referring to Table 18, the HAZ CODE 7-2 identifies the Hazard as a fill slope; whereas, referring to both Table 18 and the Hazard Improvement Form in Figure 15, the IMPR CODE 3-1-2-2 for Improvement Alternative No. 4 identifies the Improvement as a cable guardrail. The listing in Figure 19 contains four improvement alternatives which is the maximum permitted for any one group of hazards. The beginning and ending points of the Hazard and Improvement Alternative are defined by the MILEPOST data provided by the user.

The computer computations on HAZARD INDEX and TOTAL ACCIDENT COSTS are shown for both the Hazard and the Improvement Alternative. For example, the annual reduction in accident costs, which is defined as the Benefit, is equal to $829 for the cable guardrail in Improvement Alternative No. 4. The construction costs (FIRST COST) of the cable guardrail is $3,300; whereas, the annualized TOTAL HIGHWAY COST, which includes construction and maintenance costs, is equal to $707.

The COST EFFECT RATIO (C/E) and the BENEFIT COST RATIO (B/C) for the cable guardrail improvement alternatives (No. 4) are calculated as follows:

FIGURE 19

SAMPLE LISTING OF COMPUTER OUTPUT FORMAT

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 = NH-100
DESIGN SPEED = 55 MPH
ADT = 5000

AUTOMOBILE SPLITS
4,450 (LB) = 60 %
2,250 (LB) = 30 %
1,750 (LB) = 10 %

ENVIROMENTAL CONDITIONS
DRY = 8 MO/YR
WET = 2 MO/YR
SUB-FREEZING = 2 MO/YR

SOCIETAL ACCIDENT COSTS
PDO = $ 1200
INJURY = $ 5900
FATAL = $ 427600

ECONOMIC FACTORS
PROJECT LIFE = 20.0 YRS
INTEREST RATE = 15.000 %

DATE = 7- 9-82

***** H A Z A R D *****								******* I M P R O V E M E N T *******										
HAZ NO	GR NO	HAZ CODE	SIDE OF ROAD	MILE-POST BEG	MILE-POST END	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	IMPR ALT	IMPR CODE	MILE-POST BEG	MILE-POST END	CLEAR ZONE (FT)	FIRST COST ($1000)	TOTAL HWY COST ($/YR)	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	COST EFFECT RATIO ($/INJ)	BENEFIT COST RATIO
1	1	7- 2	1	1.000	1.076	0.0615	1330	1	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0793	849	-60742	0.45
1	1	7- 2	1	1.000	1.076	0.0615	1330	2	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0780	800	-65342	0.49
1	1	7- 2	1	1.000	1.076	0.0615	1330	3	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0781	800	-65301	0.49
1	1	7- 2	1	1.000	1.076	0.0615	1330	4	3-1-2-2	0.989	1.083	12.0	3.3	707	0.0564	501	136420	1.17

Cost-Effectiveness Ratio

$$\frac{C}{E} = \frac{\text{TOTAL HWY COST}}{\text{Reduction in HAZARD INDEX}}$$

$$= \frac{707}{0.0615 - 0.0564}$$

$$\frac{C}{E} = \$138{,}627/\text{inj. accident eliminated}$$

The reason that the cost-effectiveness ratio calculated above differs from the ratio given in output listing is because the values shown on the listing have been "rounded-off".

Benefit-Cost Ratio

$$\frac{B}{C} = \frac{\text{Reduction in TOTAL ACCIDENT COST}}{\text{TOTAL HWY COST}}$$

$$= \frac{1330 - 501}{707}$$

$$\frac{B}{C} = 1.17$$

6.

VALIDATION STUDIES

In order to have confidence in the cost-effectiveness and benefit-cost computer program developed in this study, three validation studies were conducted. A discussion of the validation studies is presented in the work to follow.

6.1 W-BEAM GUARDRAIL SEVERITY STUDY

The accident severity data reported by Glennon (15) in NCHRP 148 for W-beam guardrail located on the embankments of rural interstate highways is shown in Table 21. Out of a total of 4,228 accidents, it can be seen that 1,494 accidents resulted in fatal and non-fatal injury accidents. Based on this data, the probability of an injury accident involving guardrail was 35%. It is to be noted that the data in NCHRP 148 includes vehicle impacts with both the side and ends of guardrail.

TABLE 21

ACCIDENT SEVERITY DATA FOR GUARDRAIL[a]

(Ref = NCHRP 148)

Source	Guardrail Location	Fatal and Non-Fatal Injury Accidents	Total Accidents	Probability of Injury Accident
Calif.	Embankments	1,319	3,867	0.34
Ill.	Embankments	14	30	0.47
Ohio	Embankments	161	331	0.49
Total		1,494	4,228	0.35

[a]Type Highway: Rural Interstate

The probabilty of an injury accident predicted by the computer program was compared to the accident data presented in NCHRP 148. Since the data on the guardrail accidents in NCHRP 148 did not include any design details, it had to be assumed in order to conduct the comparative study that typical guardrail installation was (a) 300 ft. in length, (b) its end sections were not safety treated nor flared, (c) the posts were spaced 6 ft-3 in. on center, and (d) the soil, in which the posts were placed, was dry. Also, it was assumed that the automobile population consisted entirely of large size automobiles.

The probability of an injury accident predicted by the computer for "side" type vehicle-guardrail impacts was 30.8%. This value was determined from the following speed-angle summation term in Eq. 11.

$$\sum_{\Theta=1}^{5} \sum_{V=1}^{5} P_{V,\Theta} \; PIS_{V,\Theta} = 0.308$$

The probability of an injury accident predicted by the computer program for "end" type vehicle-guardrail impacts was 94.9%. This value was determined from the following speed-angle summation term in Eqs. 12 or 13:

$$\sum_{\Theta=1}^{5} \sum_{V=1}^{5} P_{V,\Theta} \; PIE_{V,\Theta} = 0.949$$

In order to obtain a weighted probability of an injury accident, the effects of the side and end impacts need to be combined. This was accomplished by taking into consideration the side and end exposure lengths of the guardrail along the roadside as shown earlier in Figure 7. Using a weighted encroachment angle of 11 deg obtained from the speed-angle encroachment relationship data in Table 13 for an interstate rural highway classification, it was determined that the side and end exposure lengths constituted 87.7 and 12.3% of the total guardrail length, respectively.

Based upon the above results, the computer program predicted a weighted probability of an injury accident of 39%. This value was obtained as follows:

$$\begin{array}{c} \text{Weighted} \\ \text{Probability} \\ \text{of Injury Accident} \end{array} = \begin{array}{c} \text{Effects} \\ \text{of} \\ \text{Side Impacts} \end{array} + \begin{array}{c} \text{Effects} \\ \text{of} \\ \text{End Impacts} \end{array}$$

$$= (0.308)(0.877) + (0.949)(0.123)$$

$$= 0.39$$

It can be seen that the probability of an injury accident predicted by the computer program of 39% compares well with the probability of an injury accident of 35% presented in NCHRP 148.

6.2 GUARDRAIL SENSITIVITY STUDY

In order to be assured that the guardrail and related subroutines in the computer program were programmed and operating correctly, a guardrail sensitivity study was conducted, whereby, the computer hazard-index (Eq.s 11-13 in Section 4.1.2) due to a change in a variable was compared to the hazard-index of a "base" guardrail condition. If no change in hazard-index occurred or if a change occurred in the wrong direction, then this was a signal to the researchers that there was an error in the program. The base condition was defined as follows:

(1) Automobile Split

(a) 4,500 lb. auto....30%

(b) 2,500 lb. auto....40%

(c) 1,700 lb. auto....30%

(2) Traffic Volume

(a) ADT = 3650 veh/day

(3) Highway Classification

(a) Nebraska DR-3

(4) Environmental Soil Conditions

(a) Dry.......7 mo.

(b) Wet.......3 mo.

(c) Frozen....2 mo.

(5) Guardrail Design

(a) Type......................AASHTO G4(2W)

(b) Length....................300 ft.

(c) Tangent Offset............10 ft.

(d) End Offsets...............15 ft.

(e) End Section Flare..........15:1

(f) Upstream End Terminal......BCT

(g) Downstream End Terminal....Anchored-Not B/A

The computed hazard-index of the base guardrail condition defined above was 0.0375 inj/yr. The sensitivity study consisted of 18 runs. The variable changes investigated and resulting hazard-indices are shown in Table 22. In comparison to the base condition, all of the hazard-indices due to the variable changes appear to be in correct direction. For example, by changing the upstream end terminal from a BCT to a non-breakaway and non-anchored end (Run No. 8), the hazard-index increased from a value of 0.0375 inj./yr to a value of 0.0391 inj./yr.

6.3 EMBANKMENT SEVERITY STUDY

In order to validate the severity of an automobile traversing an embankment predicted by the computer program, a comparative study was made with the findings presented in NCHRP 148.

TABLE 22

RESULTS OF W-BEAM GUARDRAIL SENSITIVITY STUDY

Run No.	Variable Change	Hazard-Index (inj/yr)
Base Condition		0.0375
1	Flare Rate = 10:1	0.0380
2	Flare Rate = 20:1	0.0369
3	Guardrail Height = 24 in.	0.0364
4	Post Spacing = 12 ft-6 in.	0.0362
5	Installation of Rub-Rail	0.0364
6	Downstream End Not Anchored and Not B/A*	0.0386
7	Downstream End Turndown and B/A	0.0370
8	Upstream End Not Anchored, Not B/A	0.0391
9	Upstream End Turndown and B/A	0.0349
10	Upstream End Turndown and Not B/A	0.0361
11	Double Length of Guardrail	0.0704
12	Increase Offsets by 5 ft.	0.0298
13	12 Mo. Dry	0.0351
14	1 Mo. Wet, 2 Mo. Frozen	0.0368
15	Use all 4500 lb. Autos	0.0297
16	Use all 2500 lb. Autos	0.0371
17	Use all 1700 lb. Autos	0.0458
18	Use all 4500 lb. Autos and 12'-06" Post Spacings	0.0325

*Breakaway

The embankment severities in NCHRP 148, which were based on accident data, were expressed only in terms of the steepness of the front slope. The data in NCHRP 148 contained no information on the height of fill, ditch width, nor the steepness of the back slope. Because the computer program in this study requires that the computer geometric configuration be defined, it was necessary in order to conduct a comparative study to assume a typical embankment configuration. A typical embankment configuration was assumed to have (a) a height of 20 ft, (b) a ditch width of 7 ft, and (c) a back slope of 4:1.

A comparison between the embankment severities (hazard-index) of the computer program and NCHRP 148 as a function of lateral offset of the embankment hinge point and front slope steepness is shown in Figure 20. The length of the embankment was assumed to be 0.1 mi and the ADT was assumed to be 100,000. As can be seen in Figure 20, a good comparison was obtained with the largest difference existing in the 2:1 front slope category. This difference amounted to an average of 17%. Again, it should be emphasized that the fill slope hazards in NCHRP 148 were grouped independently of fill height, ditch width, and back slope. Some of the discrepencies in the slope comparisons can be attributed to different ditch configurations between the accident data and the typical ditch section used for the validation study.

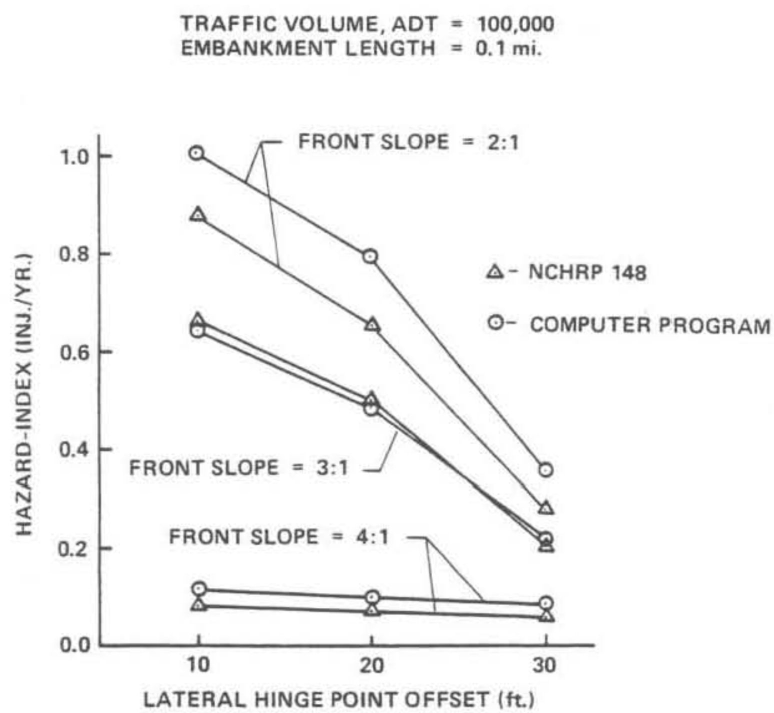


FIGURE 20.

EMBANKMENT SEVERITY COMPARISON BETWEEN NCHRP 148 AND COMPUTER PROGRAM

7.

CASE STUDIES

7.1 CASE STUDY NO. 1...RURAL INTERSTATE HIGHWAY

The purpose of this study was to conduct a cost-effectiveness and benefit-cost comparative study on the installation of cable guardrail and W-beam safety guardrail on various roadside embankment configurations of a rural interstate highway.

The rural interstate highway being considered conformed to the Nebraska DR-1 Minumum Design Standards (14) presented in Table 23. The roadway was assumed to be carrying an ADT of 60,000. Data on the environmental conditions, automobile splits, economic factors, and accident societal costs are shown in the Computer Input Coding Form in Figure 21. The cable guardrail conforms to the AASHTO G1 design designation, and the W-beam safety guardrail conforms to the AASHTO G4(2W) design designation. Data on the two types of guardrail and for a specific embankment configuration with 2:1 front slopes, a fill height of 10 ft, a ditch width of 2 ft., and a back slope of 2:1 are shown on the four Computer Input Coding Forms in Figures 22 thru 25. This embankment configuration constitutes 1 out of a possible 81 configurations that were investigated.

A sample output listing of the computer program is presented in Figure 26. The hazard in this case was the embankment and the improvement alternatives were the guardrail. The benefit-cost ratios of 11.21 and 8.23 refer to the cable guardrail and the W-beam safety guardrail, respectfully.

The relationship between benefit-cost of cable guardrail installations on various front slopes as a function fill height, ditch width and back slope are shown in Figures 27 thru 29 whereas, the relationships for W-beam guardrail are shown in Figures 30 thru 32. The two data points from the sample output listing in Figure 26 are shown as solid black circles in Figures 27 and 30.

To illustrate of the use of the results shown in Figures 27 thru 32. assume that the roadside embankment configuration consisted of a 2:1 front

TABLE 23

STATE OF NEBRASKA
MINIMUM DESIGN STANDARDS OF THE BOARD OF PUBLIC ROADS CLASSIFICATIONS & STANDARDS
RURAL STATE HIGHWAYS

(1) Design Year Traffic ADT DHV	Design Number	Design Speed (MPH)	(2) Max. Curve (Deg.)	Max. Grade (%)	Number of Lanes	Lane Width (Feet)	Median Width (Feet)	Shoulder Width (Feet)	Width of Shoulder Surfacing (Feet)	(3) Lateral Obstacle Clearance (Feet) Desirable	(3) Lateral Obstacle Clearance (Feet) Minimum	(4) Normal Design ROW Width (Feet)	Access Control
Interstate	DR1	70	3.0	3	4 Div. Min.	12	36	6.5 Lt., 12.5 Rt.	4 Lt., 10 Rt.	30	12	300	Full
Expressway*	DR1	70	3.0	3	4 Div.	12	36	6.5 Lt., 12.5 Rt.	4 Lt., 10 Rt.	30	12	300	Full with some at-grade intersections
Major Arterial													
Over 750	DR2	70	3.5	4****	4 Div.	12	36	6.5 Lt., 12.5 Rt.	4 Lt., 10 Rt.	30	12	200	In Accordance With Access Control Policy
750-400	DR3	65	3.5	4****	(Special Study) 2 Min.	12	36 Ult. if Required	6 Lt., 10 Rt. 10 on 2 lanes	4 Lt., 8 Rt. 8 on 2 lanes	30	12	200 (4 Lane) 120 (2 Lane)	
400-200	DR4	65	3.5	4****	2	12	None	10	††	30	12	120	"
1700-850	DR5**	60***	3.5	4****	2	12	None	8	††	20	10	120	"
850-400	DR6**	55***	4.5	4.5****	2	12	None	6	None†††	12	8	100	"
Under 400	DR7**	50	7.0	7****	2	11†	None	4	None	12	6	80	"

Note: The 1965 edition of AASHO "A Policy on Geometric Design of Rural Highways," the 1969 edition of AASHO "Geometric Design Standards for Highways Other Than Freeways" and the June 20, 1967 revised AASHO publication "A Policy on Design Standards, Interstate System" should be used for other design criteria.

(1) "Design Year" shall be year of initial construction plus 20 years.

(2) 0.08 feet per foot maximum superelevation rate.

(3) Measured clearances are from the edge of pavement. The desirable dimensions may be reduced to the minimum lateral clearances whenever it is not feasible to meet the specified desirable lateral clearances. Traffic may be protected from obstacles with guard rail when desirable but guard rail may be deleted if considered more hazardous than the obstacle. Signs, light standards and similar objects may be provided with breakaway bases and may then be placed inside of the minimum lateral clearance.

(4) Right-of-Way width should be not less than that required for all elements of the cross section and appropriate border areas.

* It is anticipated that in some special cases, utilization of existing facilities will be expedient. In such cases, expressway design will conform to the criteria set out under the appropriate traffic volume subdivision of the "Major Arterial" category.

** A 25 year "Q" is to be used on box culverts and pipes located in rural areas.

*** Design Speed 65 MPH except in rolling terrain.

**** The maximum grades may be 1 percent steeper in short sections less than 500 feet in length, or one-way downgrades. For extreme cases, at some underpass and bridge approaches, steeper grades for relatively short lengths may be considered. (For roadways with design numbers DR5 and DR6, highway grades may be 2 percent steeper.)

† 12 Feet lane width desirable.

†† When shoulder surfacing is warranted by "Warrants for Surfaced Shoulders," the width of the surfacing shall be 2 feet less than full shoulder width.

††† Where surfaced shoulders are required by the surfaced shoulder policy, design number DR5 will be used.

Curb Ramps for the Handicapped shall be included on all New Construction and Reconstruction of Curbs in Municipalities, Residential Developments and Sanitary and Improvement Districts beyond the Zoning Jurisdiction of the Municipalities. (See page 3-21)

FIGURE 21

CASE STUDY NO. 1

ROADSIDE COST-EFFECTIVENESS FORM

GENERAL INFORMATION

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

HP & R 79-4

HIGHWAY DESIGN NO. DR-01 HIGHWAY NO. I-80 DATE 7/7/82

IBM CARD NO. 1

ENVIRONMENTAL CONDITIONS (Mo./Yr.)		AUTOMOBILE SPLIT CATEGORIES (%)			ECONOMIC FACTORS	
WET	SUB-FREEZING	1,700 lb.	2,250 lb.	4,500 lb.	PROJECT LIFE (Yr.)	INTEREST RATE (%)
1	3	5 6	8 9	11 12	14 15	17 18 19 20 21
1	2	10	30	60	20	08.000
G10	G12	G13	G14	G15	G16	G17

SOCIETAL ACCIDENT COSTS		
FATAL ($)	INJURY ($)	PDO ($)
23 24 25 26 27 28 29	31 32 33 34 35	37 38 39 40
0427600	05900	1200
G18	G19	G20

Rev. Date 08-08-81

FIGURE 22
CASE STUDY NO. 1

ROADSIDE COST-EFFECTIVENESS FORM

GUARDRAIL COLLISION REPAIR COSTS

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

HP & R 79-4

IBM CARD NO. 2

LENGTH OF NEED SECTION ($/L.F.) DATE 7/7/82

Type	Card columns	Value	Type	Card columns	Value	Type	Card columns	Value	Type	Card columns	Value
G1	1 2 3 4	04.89	G4(1W)	21 22 23 24		MB1	41 42 43 44		MB4W	61 62 63 64	
G2	6 7 8 9		G4(2W)	26 27 28 29	09.90	MB2	46 47 48 49		MB4S	66 67 68 69	
G3	11 12 13 14		G4(1S)	31 32 33 34		MB3	51 52 53 54			71 72 73 74	
G9	16 17 18 19		G4(2S)	36 37 38 39		MB9	56 57 58 59			76 77 78 79	

IBM CARD NO. 3

END TERMINAL ($/EA.)

End terminal	Designation	Card columns	Value
NOT ANCHORED	*GRE1	1 2 3 4 5	
ANCHORED (W-BEAM)	*GRE2	7 8 9 10 11	
ANCHORED (CABLE)	*GRE3	13 14 15 16 17	503.51
TURN DOWN	*GRE4	19 20 21 22 23	
TURN DOWN (BREAKAWAY)	*GRE5	25 26 27 28 29	636.12

CRASHWORTHY ENDS

Designation	Card columns	Value
GET 1	31 32 33 34 35 36	
GET 2	38 39 40 41 42 43	
MBET 1	45 46 47 48 49 50	
MBET 2	52 53 54 55 56 57	

*NON-AASHTO DESIGNATION

Rev. Date 08-08-81

FIGURE 23
CASE STUDY NO. 1

ROADSIDE HAZARD INVENTORY FORM

DATE 7/7/82

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

INVENTORY CONDUCTED BY ______

BOX 1 — HIGHWAY (checked)

H1 (H50 Highway Design No.)	H2	H3 (H51 Highway No.)	H4	H5 Posted Speed Limit (mph)	H6 ADT (Both Directions)	H7 Lane Width (Ft.)	H8 Median Width (Ft.)	H9 Degree of Curve	H10 Grade (%) Up	H11 Grade (%) Dn	H12 Shoulder Paved Width (Ft.)	H13 Shoulder Usable Width (Ft.)	H14 Shoulder Surface Type	H15 Shoulder Drop-off (In.)	H16 Shoulder Condition Rut
1	0,1	3	0,8,0	5,5	6,0,0,0,0	1,2	4,0	0	0	0	1,0	1,0	1	0	0

H1: 1. [illegible] 2. [illegible] 3. [illegible] 4. [illegible] 5. [illegible]
H3: 1. [illegible] 2. [illegible] 3. [illegible] 4. [illegible]
H14: 1. SOD 2. GRAVEL 3. SOIL
H16: 0. NONE 1. SHALLOW 2. DEEP

BOX 2 — HAZARD CLASSIFICATION (checked)

DESCRIPTION ______

H17 Hazard No.	H18 Ident. No.	H19 Descr. Code	H20 Offset Code	H21 Group No.
0,1	0,7	0,2	1	0,1

H20: 1. RIGHT SIDE 2. LEFT SIDE

MILE - POINT OF HAZARD

H22 Beginning	H23 Ending
0,0,1,0,0,0	0,0,1,2,1,5

BOX 3 — POINT HAZARD (Utility Pole, Tree, Sign, Support, Culvert Headwall, Drainage Inlet) (not checked)

H30	H31 Lateral Offset (Ft.)	H32 Width (Ft.)	H33 Length (Ft.)	H34 Drainage Height (Ft.)	H35 Inlets (Only) Depth (Ft.)	H36 Number Point Hazards in Group
1						

BOX 4 — LONGITUDINAL HAZARD (Guardrail, Bridgerail, CMB, Wall, Curb) (not checked)

H30	H31 Lateral Offset (Ft.)
2	

NOTE: If Guardrail, Complete Box 6

BOX 5 — SLOPE HAZARD (Fill Slope, Cut Slope, Channel Slope, Ditch) (checked)

SIDE SLOPES / CROSS CHANNEL

H30	H31 Hinge Point Offset (Ft.)	H32 Avg. Front Slope	H33 Avg. Front Slope Height (Ft.)	H34 Ditch Width (Ft.)	H35 Depth of Water in Ditch	H36 Avg. Back Slope	H37 Avg. Back Slope Height (Ft.)	H38 Condition of Slopes	H39 Avg. Transverse Channel Slope	H40 Avg. Channel Height (Ft.)
3	1,0	2:1	1,0	0,2	1	0,2:1	0,5	1	0,0	0,0

H35: 1. NONE 2. LESS THAN 2 FT. 3. GREATER THAN 2 FT.
H38: 1. SMOOTH 2. ROUGH

BOX 6 — GUARDRAIL (not checked)

H49 Guardrail Location	H33 Lateral Offsets (Ft.) Begin	H34 Tangent	H35 End	H36 Flare Rate (a:b) Begin	H37 End	H38 Avg. Shoulder Slopes Tangent	H39 Flared	H40 Top Height (In.)	H41 Post Spacing (Ft.)	H42 Block Out	H43 Rub Rail
						8:1	8:1			1	

H49: 1. EMBANKMENT 2. BRIDGE ENDS 3. POINT HAZARDS
H42: 1. YES 2. NO
H43: 1. YES 2. NO

BRIDGE APPROACH / END TREATMENTS

H44 Reduced Post Spacing	H45 Double W-Beam	H46 End Treatments Begin	H47 End	H48 Post Backfill Material
				2

H44: 1. YES 2. NO
H45: 1. YES 2. NO
H46/H47: 1. ANCHORED 2. NOT ANCHORED 3. TURN DOWN (B/A) 4. TURN DOWN (Not B/A) CRASHWORTHY TERMINALS 5. GET1 6. GET2 7. MGET1 8. MGET 2
H48: 1. NON-COHESIVE 2. COHESIVE

BOX 7 — PROGRAM CONTROL DATA (checked)

1 IBM CARD TYPE

RECOMMENDATIONS ______

FIGURE 24

CASE STUDY NO. 1 (ALTERNATIVE NO. 1)

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

IMPROVEMENT RECOMMENDED Cable Guardrail DATE 7/7/82

HAZARD NO. 1 HAZARD GROUP NO. 1 (Max. 5 hazards per group) IMPR. ALT. NO. 1 (Max. 4)

BOX 1 — HIGHWAY

C50 HIGHWAY DESIGN NO. — C51 HIGHWAY NO.

C1: 1 C2: 0.1 C3: 3 C4: 080

CLEAR ZONE (Ft.) C5: 1.0

BOX 2 — COSTS

CAPITAL ($1,000) C11: 00066

COLLISION MAINTENANCE ($100/ACCID.) (Excludes Guardrail and Bridgerail) HAZARD C12: 00.0 IMPROVEMENT C13: 0.00

NORMAL MAINTENANCE ($100/YR.) HAZARD C14: 0.01 IMPROVEMENT C15: 0.02

BOX 3 — POINT HAZARD IMPROVEMENTS

C16: 1 C17: 1 REDUCE SEVERITY C18 — LATERAL OFFSET (Ft.) C19

C16: 1 C17: 2 INSTALL GUARDRAIL (Complete Boxes 7 & 8) C18 — DESCRIPTOR CODE C19

C16: 1 C17: 3 INSTALL CRASH CUSHION (Complete Box 8) C18 — DESCRIPTOR CODE C19

BOX 4 — LONGITUDINAL HAZARD IMPROVEMENTS

C16: 2 C17: 1 CURB (Complete Box 8) C18

C16: 2 C17: 2 GUARDRAIL (Complete Boxes 7 & 8) C18 — DESCRIPTOR CODE C19

C16: 2 C17: 3 BRIDGERAIL (Complete Box 8) C18 — DESCRIPTOR CODE C19

BOX 5 — SLOPE IMPROVEMENTS

C16: 3 C17: 1 INSTALL GUARDRAIL (Complete Boxes 7 & 8) C18: 2 — DESCRIPTOR CODE C19: 02

C16: 3 C17: 2 MODIFY SLOPE (Complete Box 8) — SIDE SLOPES: HINGE POINT OFFSET (Ft.) C28; AVG. FRONT SLOPE C29; AVG. FRONT SLOPE HEIGHT C20; DITCH WIDTH (Ft.) C21; DEPTH OF WATER IN DITCH C22; AVG. BACK SLOPE C23; AVG. BACK SLOPE HEIGHT (Ft.) C24; CONDITION OF SLOPES C25 — CROSS CHANNEL: AVG. TRANSVERSE CHANNEL SLOPE C26; AVG. CHANNEL HEIGHT (Ft.) C27

BOX 6 — NO IMPROVEMENT

C16: 4

BOX 7 — GUARDRAIL

GUARDRAIL LOCATION	LATERAL OFFSETS (Ft.)			FLARE RATES		AVG. SHOULDER SLOPES		TOP HEIGHT (In.)	POST SPACING (Ft.)	BLOCK OUT	RUB RAIL
C39: 1	C21: 1.0	C22: 1.0	C23: 1.0	C24: 9.9	C25: 9.9	C26: 8:1	C27: 8:1	C28: 3.0	C29: 1.6	C30: 1	C31: 2

BRIDGE APPROACH: REDUCE POST SPACING C32; DOUBLE W-BEAM C33

END TREATMENTS: C34: 1 C35: 1

POST BACKFILL MATERIAL C36: 2

BOX 8 — MILE POINTS OF IMPROVEMENT

BEGINNING C37: 0.00988

ENDING C38: 0.01203

BOX 9 — DATE

C40: 07 C41: 07 C42: 82

PROGRAM CONTROL DATA

2 IBM CARD TYPE

FIGURE 25

CASE STUDY NO. 1 (LATERNATIVE NO. 2)

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

IMPROVEMENT RECOMMENDED W-Beam Guardrail DATE 7/7/82

HAZARD NO. 1 HAZARD GROUP NO. 1 (Max. 6 hazards per group) IMPR. ALT. NO. 2 (Max. 4)

BOX 1 — HIGHWAY

C30 HIGHWAY DESIGN NO. — C31 HIGHWAY NO.

C1: 1 C2: 01 C3: 3 C4: 080

CLEAR ZONE (Ft.) C5: 0.8

BOX 2 — COSTS

CAPITAL ($1,000) C11: 0.0.12.8

COLLISION MAINTENANCE ($100/ACCID.) — HAZARD C12: 0.0.0; IMPROVEMENT C13: 0.0.0

NORMAL MAINTENANCE ($100/YR.) — HAZARD C14: 0.0.1; IMPROVEMENT C15: 0.0.2

BOX 3 — POINT HAZARD IMPROVEMENTS

C16 1, C17 1 — REDUCE SEVERITY — C18: 1. [illegible] 2. MAKE BREAKAWAY 3. RELOCATE AND MAKE BREAKAWAY 4. RECONSTRUCT TO SAFE DESIGN 5. RELOCATE — LATERAL OFFSET (FT.) C19

C16 1, C17 2 — INSTALL GUARDRAIL (Complete Boxes 7 & 8) — C18 — DESCRIPTOR CODE C19

C16 1, C17 3 — INSTALL CRASH CUSHION (Complete Box 4) — C18 — DESCRIPTOR CODE C19

BOX 4 — LONGITUDINAL HAZARD IMPROVEMENTS

C16 2, C17 1 — CURB (Complete Box 8) — C18: 1. REMOVE AND REGRADE 2. INSTALL WEDGE MODIFICATION

C16 2, C17 2 — GUARDRAIL (Complete Boxes 7 & 8) — C18: 1. REMOVE 2. MODIFY 3. REPLACE WITH NEW DESIGN 4. INSTALL NEW DESIGN — DESCRIPTOR CODE C19

C16 2, C17 3 — BRIDGERAIL (Complete Box 8) — C18: 1. MODIFY TO SAFE DESIGN 2. REPLACE WITH NEW DESIGN — DESCRIPTOR CODE C19

BOX 5 — SLOPE IMPROVEMENTS ☑

C16 3, C17 1 — INSTALL GUARDRAIL (Complete Boxes 7 & 8) — C18 2: 1. AT BRIDGE 2. NOT AT BRIDGE — DESCRIPTOR CODE C19: 06

MODIFY SLOPE (Complete Box 8) — C16 3, C17 2 — SIDE SLOPES: HINGE POINT OFFSET (FT.) C28; AVG. FRONT SLOPE C29 :1; AVG. FRONT SLOPE HEIGHT C30; DITCH WIDTH (FT.) C31; DEPTH OF WATER IN DITCH C32 (1. NONE 2. LESS THAN 2 FT. 3. GREATER THAN 2 FT.); AVG. BACK SLOPE C23 :1; AVG. BACK SLOPE HEIGHT (FT.) C24; CONDITION OF SLOPES C25 — CROSS CHANNEL: AVG. TRANSVERSE CHANNEL SLOPE C26 :1; AVG. CHANNEL HEIGHT (FT.) C27

BOX 6 — NO IMPROVEMENT — C16 4

BOX 7 — GUARDRAIL ☑

GUARDRAIL LOCATION C20: 1 (1. EMBANKMENT 2. BRIDGE ENDS 3. POINT HAZARDS)

LATERAL OFFSETS (FT.): C21 1.0, C22 0.8, C23 1.0

FLARE RATES: C24 2.0, C25 2.0

AVG. SHOULDER SLOPES: C26 8:1, C27 8:1

TOP HEIGHT (IN.): C28 27

POST SPACING (FT.): C29 06

BLOCK OUT: C30 1 (1. YES 2. NO)

RUB RAIL: C31 2 (1. YES 2. NO)

BRIDGE APPROACH — REDUCE POST SPACING C32 (1. YES 2. NO); DOUBLE W-BEAM C33 (1. YES 2. NO)

END TREATMENTS — C34 5; C35 5: 1. ANCHORED 2. NOT ANCHORED 3. TURNED DOWN (GAL) 4. TURNED DOWN (NOT SUAL) CRASHWORTHY TERMINALS 5. [illegible] 6. [illegible] 7. [illegible] 8. [illegible]

POST BACKFILL MATERIAL C36: 2 (1. NON-COHESIVE 2. COHESIVE)

BOX 8 — MILE POINTS OF IMPROVEMENT

BEGINNING C37: 0.00.98.3 — ENDING C38: 0.0.1.20.3

BOX 9 — DATE

MO. C40: 07 — DA. C41: 07 — YR. C42: 82

PROGRAM CONTROL DATA — 1. END OF GROUP 2. END OF GROUP PROGRAM — 2 IBM CARD TYPE

FIGURE 26

SAMPLE OUTPUT LISTING

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- 1
TYPE HIGHWAY = IS- 80
DESIGN SPEED = 55 MPH
ADT = 60000

AUTOMOBILE SPLITS
4,450 (LB) = 60 %
2,250 (LB) = 30 %
1,750 (LB) = 10 %

ENVIROMENTAL CONDITIONS
DRY = 9 MO/YR
WET = 1 MO/YR
SUB-FREEZING = 2 MO/YR

SOCIETAL ACCIDENT COSTS
PDO = $ 1200
INJURY = $ 5900
FATAL = $ 427600

ECONOMIC FACTORS
PROJECT LIFE = 20.0 YRS
INTEREST RATE = 8.000 %

DATE = 7- 7-82

***** H A Z A R D *****								******* I M P R O V E M E N T *******											
HAZ NO	GR NO	HAZ CODE	SIDE OF ROAD	MILE-POST BEG	MILE-POST END	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	IMPR ALT	IMPR CODE	MILE-POST BEG	MILE-POST END	CLEAR ZONE (FT)	FIRST COST ($1000)	TOTAL HWY COST ($/YR)	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	COST EFFECT RATIO ($/INJ)	BENEFIT COST RATIO
1	1	7- 2	1	1.000	1.215	1.2820	33281	1	3-1-2-2	0.988	1.203	10.0	6.6	2191	0.9842	8717	7358	11.21
1	1	7- 2	1	1.000	1.215	1.2820	33281	2	3-1-2-6	0.983	1.203	8.0	12.8	2522	1.2247	12511	44032	8.23

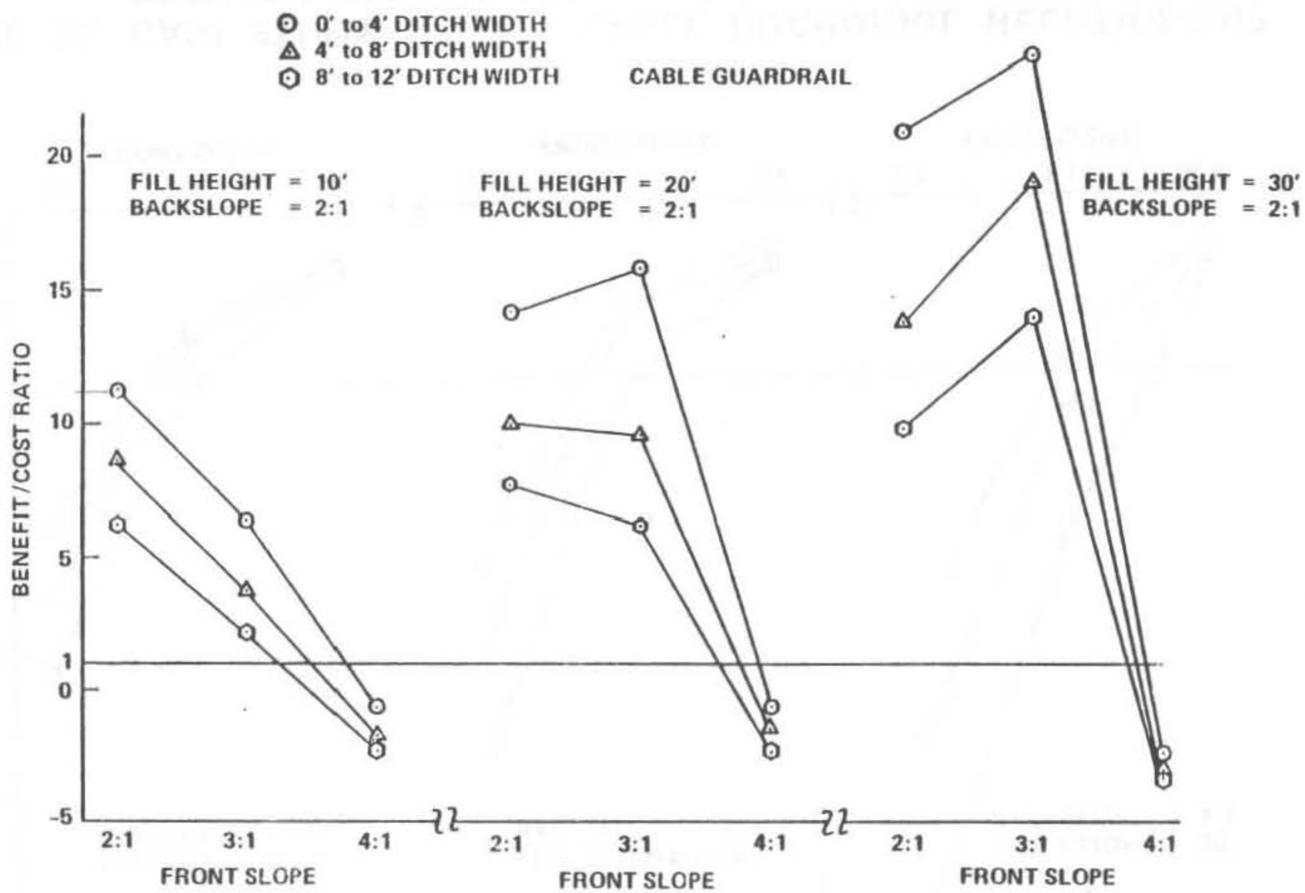


FIGURE 27. CASE STUDY NO. 1 – CABLE GUARDRAIL RELATIONSHIP BETWEEN BENEFIT-COST RATIO AND FRONT FILL SLOPE AS FUNCTION OF VARIOUS FILL HEIGHTS AND 2:1 BACKSLOPE

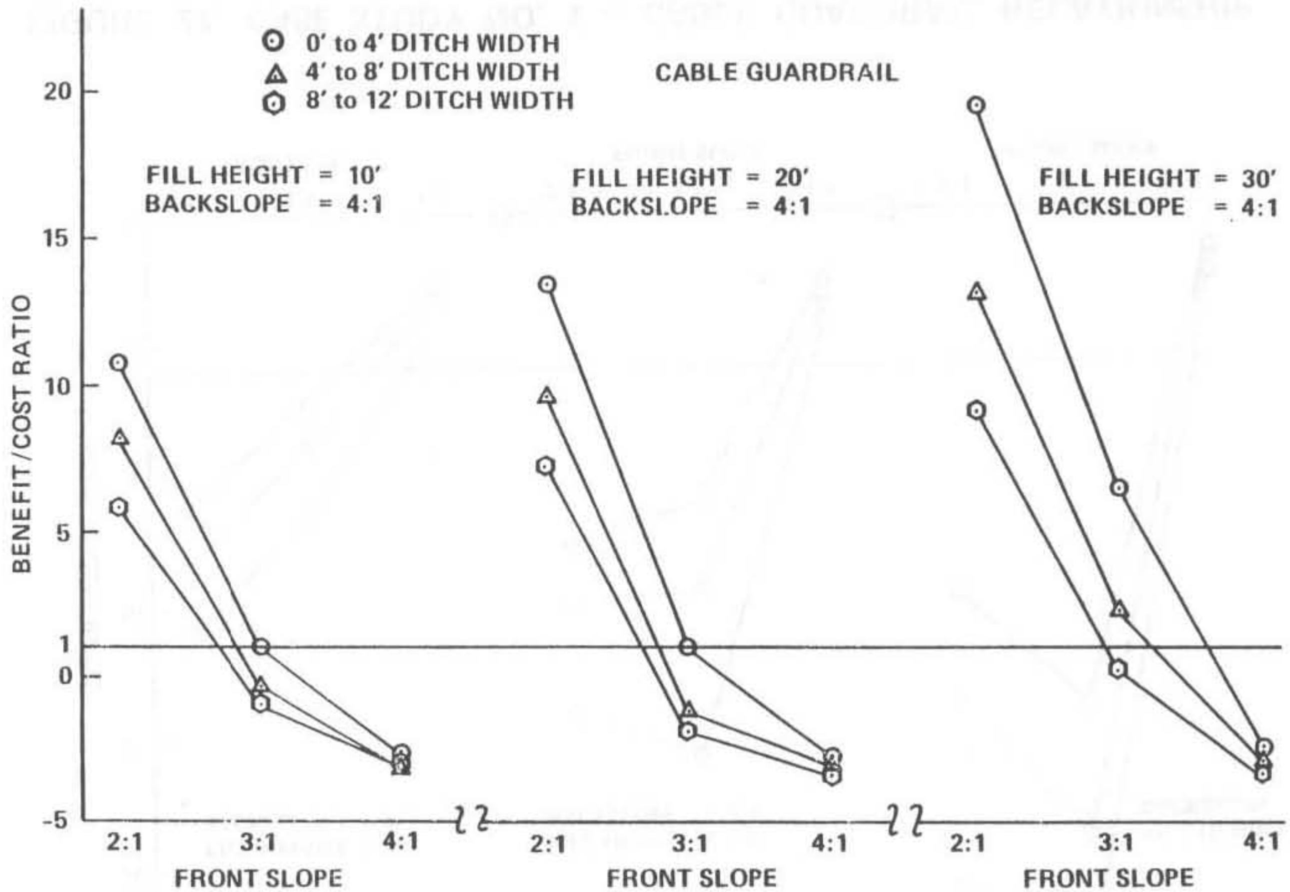


FIGURE 28. CASE STUDY NO. 1 – CABLE GUARDRAIL RELATIONSHIP BETWEEN BENEFIT-COST RATIO AND FRONT FILL SLOPE AS FUNCTION OF VARIOUS FILL HEIGHTS AND 4:1 BACKSLOPE

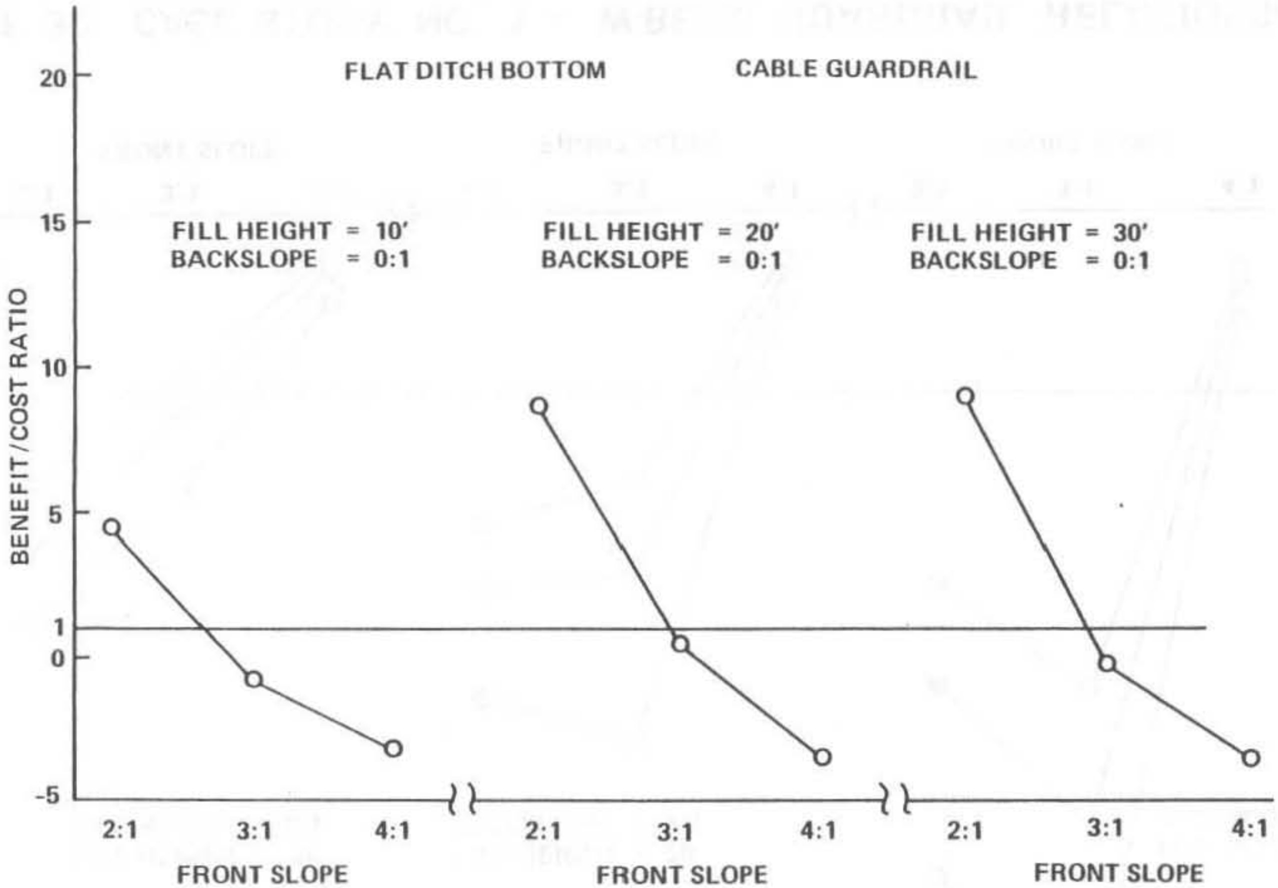


FIGURE 29. CASE STUDY NO. 1 – CABLE GUARDRAIL RELATIONSHIP BETWEEN BENEFIT-COST RATIO AND FRONT FILL SLOPE AS FUNCTION OF VARIOUS FILL HEIGHTS AND FLAT BACKSLOPE RUNOUT

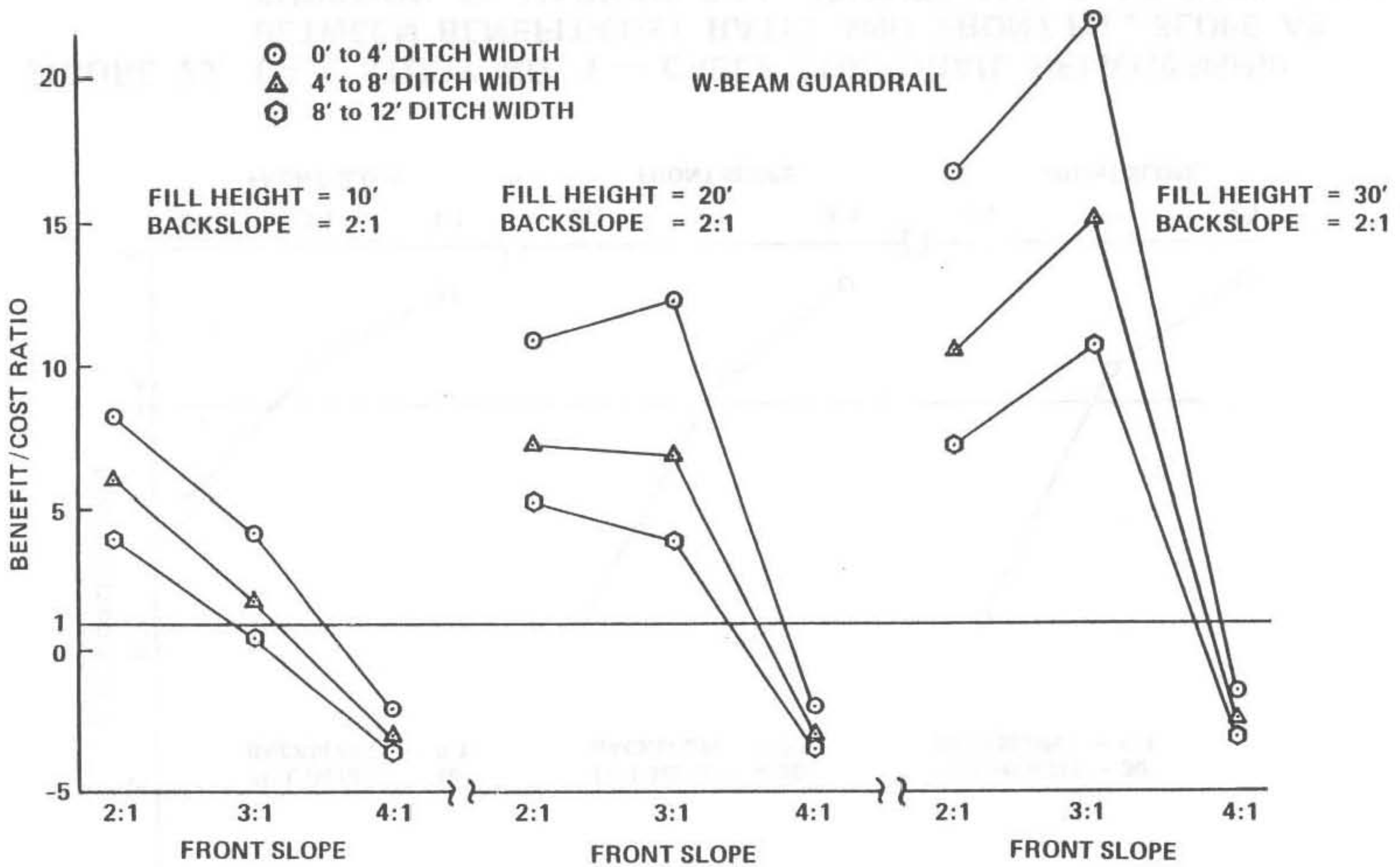


FIGURE 30. CASE STUDY NO. 1 – W-BEAM GUARDRAIL RELATIONSHIP BETWEEN BENEFIT-COST RATIO AND FRONT FILL SLOPE AS FUNCTION OF VARIOUS FILL HEIGHTS AND 2:1 BACKSLOPE

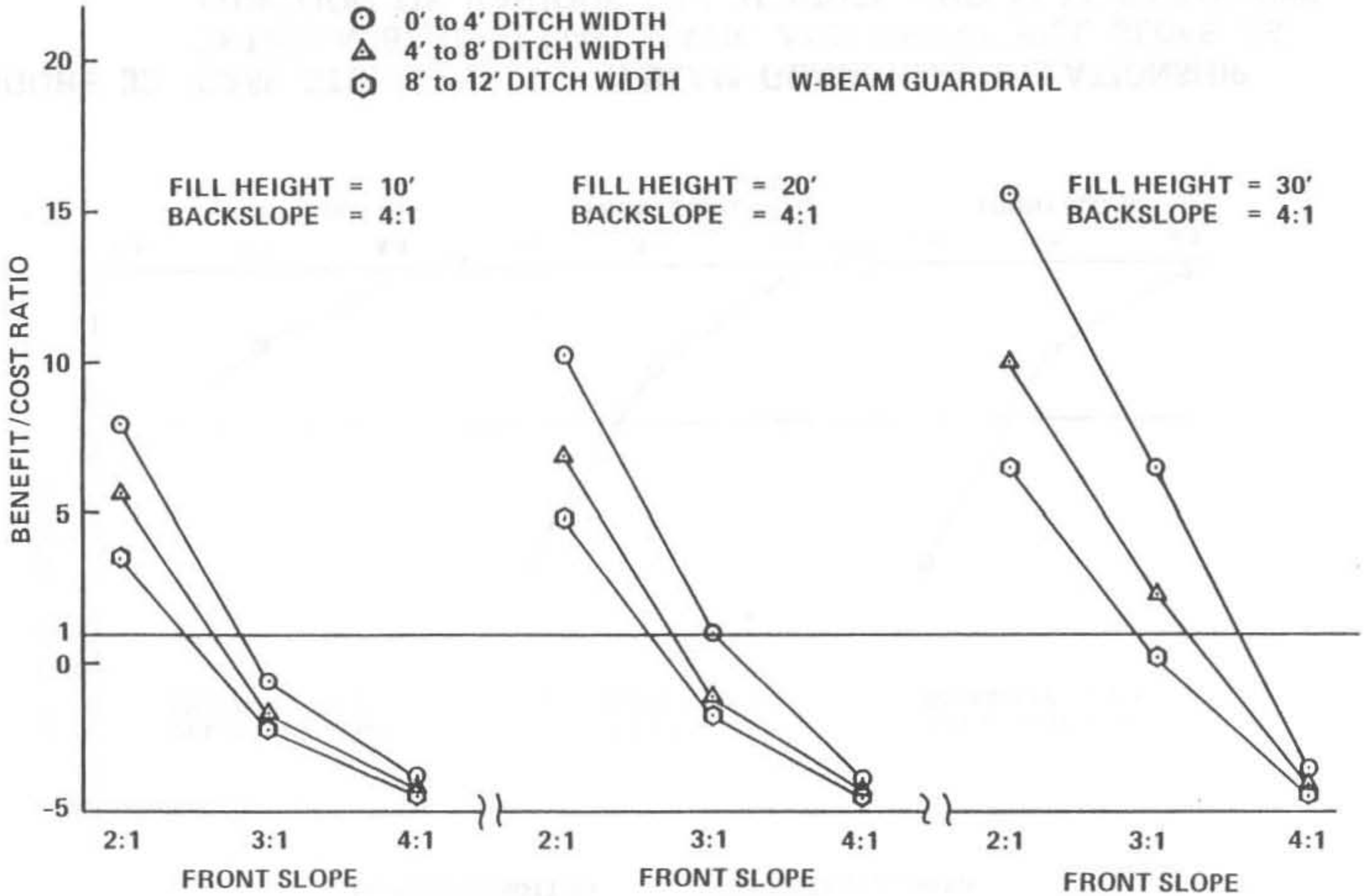


FIGURE 31. CASE STUDY NO. 1 – W-BEAM GUARDRAIL RELATIONSHIP BETWEEN BENEFIT-COST RATIO AND FRONT FILL SLOPE AS FUNCTION OF VARIOUS FILL HEIGHTS AND 4:1 BACKSLOPE

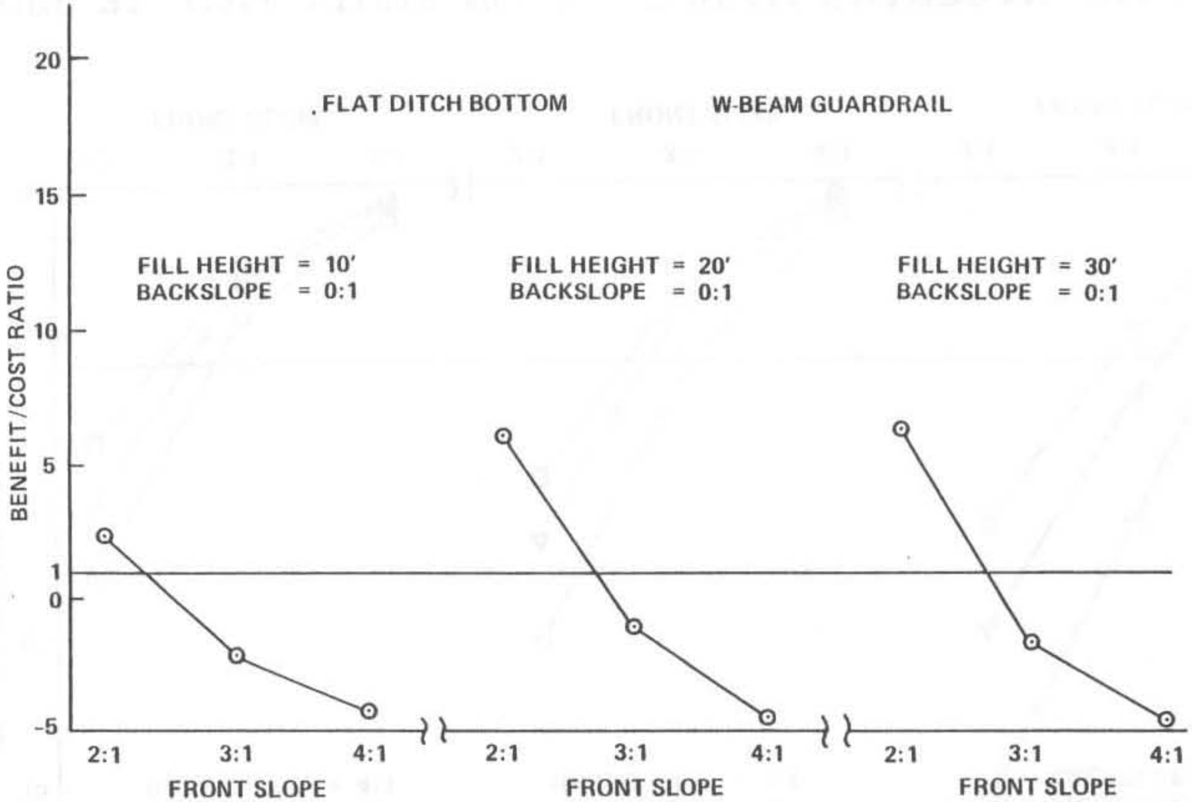


FIGURE 32. CASE STUDY NO. 1 – W-BEAM GUARDRAIL RELATIONSHIP BETWEEN BENEFIT-COST RATIO AND FRONT FILL SLOPE AS FUNCTION OF VARIOUS FILL HEIGHTS AND FLAT BACKSLOPE RUNOUT

slope, a fill height of 10 ft., a ditch width of 10 ft., and a back slope of 4:1. Referring to Figure 27, the benefit-cost ratio for a cable guardrail installation will be equal to 2.1; whereas, referring to Figure 30, the benefit-cost ratio for a W-beam guardrail installation will be equal to 0.4. Therefore, it can be concluded that the cable guardrail would have been the only cost-effective guardrail improvement alternative for the defined embankment configuration.

The benefit-cost relationships shown in Figures 27 thru 32 were based on an assumed ADT volume of 60,000. Since benefit-cost is directly proportional to the ADT, the benefit-cost of guardrail installations on rural interstate highways carrying different ADT volumes can be easily computed by multiplying the benefit-cost ratios in Figures 27 thru 32 by the following adjustment factor:

$$\text{Benefit-Cost Ratio Adjustment Factor} = \frac{\text{ADT}}{60{,}000}$$

To illustrate the use of the benefit-cost ratio adjustment factor, assume that the ADT in the previous example problem was 30,000 instead of 60,000. In this case the adjustment factor will be equal to 0.5, and the benefit-cost ratios for the installation of cable guardrail and W-beam safety guardrail will be equal to 1.0 and 0.2, respectively. Therefore, it can be concluded that neither cable or W-beam safety guardrail would have been cost-effective with the lower traffic volume.

Referring to the benefit-cost relationships shown in Figures 27 thru 32, it was possible to reach the following generalized conclusions:

1. In all of the cases considered, the installation of cable guardrail was more attractive than the installation of W-beam safety guardrail.
2. The installation of cable guardrail and W-beam safety guardrail were justified on embankments with 2:1 front slopes.

3. The installation of cable guardrail and W-beam safety guardrail were not justified on embankments with 3:1 and flatter front slopes and "flat" runout ditch bottoms.

4. The ditch width and back slope were significant factors to take into consideration in the installation of both cable and W-beam safety guardrail.

   (a) Flattening the back slope from 2:1 to 4:1 will eliminate the need for the installation of cable guardrail and W-beam safety guardrail on embankments with front slopes of 3:1 and flatter and ill heights from 10 to 20 ft.

   (b) The installation of both cable guardrail and W-beam safety guardrail were justified on embankments with 3:1 and steeper front slopes, ditch widths less than 8 ft, and back slopes of 4:1 and steeper.

   (c) Irrespective of ditch width and back slope, the installation of cable guardrail and W-beam safety guardrail were not justified on embankments with front slopes of 4:1.

7.2 CASE STUDY NO. 2...RURAL 2-LANE HIGHWAY: W-BEAM GUARDRAIL VS CABLE GUARDRAIL

The purpose of this case study was to conduct a cost-effectiveness and benefit-cost comparative study on the installation of cable guardrail and W-beam safety guardrail on typical embankment configurations of a rural 2-lane highway.

The rural 2-lane highway being considered conformed to Nebraska DR-3 Minimum Design Standards (14) presented in Table 23. The roadway was assumed to be carrying a high ADT volume of 5,000. Data on the assumed environmental conditions, automobile split categories, economic factors, and societal accident costs are shown on General Information Input Coding Form in Figure 33.

FIGURE 33

CASE STUDY NO. 2

ROADSIDE COST-EFFECTIVENESS FORM

GENERAL INFORMATION

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

HP & R 79-4

HIGHWAY DESIGN NO. DR-03 HIGHWAY NO. N-100 DATE 09 July 87

IBM CARD NO. 1

ENVIRONMENTAL CONDITIONS (Mo./Yr.)		AUTOMOBILE SPLIT CATEGORIES (%)			ECONOMIC FACTORS	
WET	SUB-FREEZING	1,700 lb.	2,250 lb.	4,500 lb.	PROJECT LIFE (Yr.)	INTEREST RATE (%)
1	3	5 6	8 9	11 12	14 15	17 18 19 20 21
2	2	10	30	60	20	15.000
G10	G12	G13	G14	G15	G16	G17

SOCIETAL ACCIDENT COSTS		
FATAL ($)	INJURY ($)	PDO ($)
23 24 25 26 27 28 29	31 32 33 34 35	37 38 39 40
0427600	05900	1200
G18	G19	G20

Rev. Date 08-08-81

The four guardrail improvement alternatives considered in this study were as follows:

Improv. Alt. No. 1...27-in. W-Beam Guardrail with No Rub-Rail

Improv. Alt. No. 2...27-in. W-Beam Guardrail with Rub-Rail

Improv. Alt. No. 3...24-in. W-Beam Guardrail with No Rub-Rail

Improv. Alt. No. 4...Cable Guardrail

Since the highway was of 2-lane construction, the guardrail was of sufficient length to redirect errant vehicles from both directions of travel. The lengths of the cable and W-beam guardrails were 495 and 570 ft., respectively. The W-beam guardrail was longer because (a) of it's width, it was 2 ft. closer to the roadway than cable guardrail, and (b) it's turndown length was longer than that of cable guardrail. In determining the length-of-need of guardrail, the policy of the NDR is to provide a length equal to the distance between the points of intersection of the lateral offset distance with a line drawn at a 15 deg. angle from a critical point on the front slope at each end of the embankment. The critical point on the slope is based upon the warrants in AASHTO (11)

Both end sections of the W-beam were flared at a ratio of 20:1 and were of a non-breakaway turned-down design. The ends of the cable guardrail were not flared.

Collision maintenance repair costs of the cable and W-beam safety guardrail are shown on the Computer Input Coding Form in Figure 34.

7.2.1 Embankment With Flat Ditch Bottom

Data on the selected typical roadside embankment configuration are shown in the Hazard Inventory Input Coding Form in Figure 35. The embankment consisted of a 2:1 front slope, a slope height of 30 ft., and a "flat" ditch bottom runout. The hinge point of the embankment was offset a distance of 12 ft., and the length of the embankment was 400 ft.

FIGURE 34

CASE STUDY NO. 2

ROADSIDE COST-EFFECTIVENESS FORM

GUARDRAIL COLLISION REPAIR COSTS

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

HP & R 79-4

IBM CARD NO. 2

LENGTH OF NEED SECTION ($/L.F.) DATE [illegible]

Item	Columns	Value	Item	Columns	Value	Item	Columns	Value	Item	Columns	Value
G1	1 2 3 4	04.89	G4(1W)	21 22 23 24		MB1	41 42 43 44		MB4W	61 62 63 64	
G2	6 7 8 9		G4(2W)	26 27 28 29	09.90	MB2	46 47 48 49		MB4S	66 67 68 69	
G3	11 12 13 14		G4(1S)	31 32 33 34		MB3	51 52 53 54			71 72 73 74	
G9	16 17 18 19		G4(2S)	36 37 38 39		MB9	56 57 58 59			76 77 78 79	

IBM CARD NO. 3

END TERMINAL ($/EA.)

Type	Designation	Columns	Value	CRASHWORTHY ENDS	Columns	Value
NOT ANCHORED	*GRE1	1 2 3 4 5				
ANCHORED (W-BEAM)	*GRE2	7 8 9 10 11		GET 1	31 32 33 34 35 36	0745.10
ANCHORED (CABLE)	*GRE3	13 14 15 16 17	503.51	GET 2	38 39 40 41 42 43	
TURN DOWN	*GRE4	19 20 21 22 23		MBET 1	45 46 47 48 49 50	
TURN DOWN (BREAKAWAY)	*GRE5	25 26 27 28 29	636.12	MBET 2	52 53 54 55 56 57	

*NON-AASHTO DESIGNATION

Rev. Date 08-08-81

FIGURE 35

CASE STUDY NO. 2 (FLAT DITCH RUNOUT)

ROADSIDE HAZARD INVENTORY FORM

DATE 09 July 1982

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

INVENTORY CONDUCTED BY E. R. Post

BOX 1 ☑ HIGHWAY

H50 HIGHWAY DESIGN NO. (1)	(2-3)	H51 HIGHWAY NO. (4)	(5-7)	POSTED SPEED LIMIT (mph) (8-9)	ADT (Both Directions) (10-14)	LANE WIDTH (Ft.) (15-16)	MEDIAN WIDTH (Ft.) (17-18)	DEGREE OF CURVE (19)	GRADE (%) Up (20)	GRADE (%) Dn (21)	SHOULDER: PAVED WIDTH (Ft.) (22-23)	USABLE WIDTH (Ft.) (24-25)	SURFACE TYPE (26)	DROP-OFF (In.) (27)	CONDITION RUT (28)
H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16
1	03	1	100	55	05000	12					08	08	1		

H1: 1. DR 2. DM 3. RDA 4. RC 5. RL
H3: 1. N 2. US 3. I 4. SEC
H14: 1. SOD 2. GRAVEL 3. SOIL
H16: 0. NONE 1. SHALLOW 2. DEEP

BOX 2 ☑ HAZARD CLASSIFICATION

DESCRIPTION ____________

HAZARD NO. (29-30)	IDENT. NO. (31-32)	DESCR. CODE (33-34)	OFFSET CODE (35)	GROUP NO. (36-37)
H17	H18	H19	H20	H21
01	07	02	1	01

H20: 1. RIGHT SIDE 2. LEFT SIDE

MILE - POINT OF HAZARD

BEGINNING (38-43)	ENDING (44-49)
H22	H23
001.000	001.476

BOX 3 ☐ POINT HAZARD (Utility Pole, Tree, Sign, Support, Culvert Headwall, Drainage Inlet)

(50)	LATERAL OFFSET (Ft.) (51-52)	WIDTH (Ft.) (53-54)	LENGTH (Ft.) (55-57)	DRAINAGE HEIGHT (Ft.) (58)	INLETS (Only) DEPTH (Ft.) (59)	NUMBER POINT HAZARDS IN GROUP (60-62)
H30	H31	H32	H33	H34	H35	H36
1						

BOX 4 ☐ LONGITUDINAL HAZARD (Guardrail, Bridgerail, CMB, Wall, Curb)

(50)	LATERAL OFFSET (Ft.) (51-52)
H30	H31
2	

NOTE: If Guardrail, Complete Box 6

BOX 5 ☑ SLOPE HAZARD (Fill Slope, Cut Slope, Channel Slope, Ditch)

	SIDE SLOPES									CROSS CHANNEL	
(50)	HINGE POINT OFFSET (Ft.) (51-52)	AVG. FRONT SLOPE (53)	AVG. FRONT SLOPE HEIGHT (Ft.) (54-55)	DITCH WIDTH (Ft.) (56-57)	DEPTH OF WATER IN DITCH (58)	AVG. BACK SLOPE (59-60)	AVG. BACK SLOPE HEIGHT (Ft.) (61-62)	CONDITION OF SLOPES (63)	AVG. TRANSVERSE CHANNEL SLOPE (64-65)	AVG. CHANNEL HEIGHT (Ft.) (66-67)
H30	H31	H32	H33	H34	H35	H36	H37	H38	H39	H40
3	12	2:1	30	99	1	00:1	00	1		

H35: 1. NONE 2. LESS THAN 2 FT. 3. GREATER THAN 2 FT.
H38: 1. SMOOTH 2. ROUGH

BOX 6 ☐ GUARDRAIL

GUARDRAIL LOCATION (53)	LATERAL OFFSETS (Ft.) Begin (54-55)	Tangent (56-57)	End (58-59)	FLARE RATE (a:b) Begin (60-61)	End (62-63)	AVG. SHOULDER SLOPES Tangent (64)	Flared (65)	TOP HEIGHT (In.) (66-67)	POST SPACING (Ft.) (68-69)	BLOCK OUT (70)	RUB RAIL (71)
H49	H33	H34	H35	H36	H37	H38	H39	H40	H41	H42	H43
						8:1	8:1			1	

H49: 1. EMBANKMENT 2. BRIDGE ENDS 3. POINT HAZARDS
H42: 1. YES 2. NO
H43: 1. YES 2. NO

BRIDGE APPROACH: REDUCED POST SPACING (72)	DOUBLE W-BEAM (73)	END TREATMENTS Begin (74)	End (75)	POST BACKFILL MATERIAL (76)
H44	H45	H46	H47	H48
				2

H44: 1. YES 2. NO
H45: 1. YES 2. NO
H46/H47: 1. ANCHORED 2. NOT ANCHORED 3. TURN DOWN (S/A) 4. TURN DOWN (Not S/A) CRASHWORTHY TERMINALS 5. GET1 6. GET2 7. MEET1 8. MEET 2
H48: 1. NON-COHESIVE 2. COHESIVE

BOX 7 ☑ PROGRAM CONTROL DATA

(80) 1 IBM CARD TYPE

RECOMMENDATIONS ____________

7.2.1.1 Improvement Alternative No. 1

Improvement Alternative No. 1 consisted of a 27-in. W-beam guardrail with no rub-rail. The guardrail conforms to the AASHTO (11) G4(2W) design designation. Data on the guardrail improvement alternative are shown on the Hazard Improvement Input Coding Form in Figure 36.

The output listing of the computer program is shown in Figure 40. As can be seen, the value of the cost-effectiveness was a negative $60,742 and the value of the benefit-cost was 0.45. In conclusion, this guardrail design improvement alternative was not attractive because (a) the benefits of $481/yr were less than the total highway costs of $1,078, and (b) the hazard-index of the guardrail improvement of 0.0793 inj/yr was higher than the hazard-index of the existing slope of 0.0615 inj/yr.

7.2.1.2 Improvement Alternative No. 2

Improvement Alternative No. 2 consisted of a 27-in. W-beam guardrail with a rub-rail. The purpose of the rub-rail was to eliminate the snagging of the wheels of the small size automobiles on the guardrail posts. Data on the improvement alternative are shown on the Computer Input Coding Form in Figure 37.

As can be seen in the output listing of Figure 40, the value of the cost-effectiveness was a negative $65,342 and the value of the benefit-cost was 0.49. In conclusion, this guardrail design improvement alternative was not attractive.

7.2.1.3 Improvement Alternative No. 3

Improvement No. 3 consisted of a 24-in. W-beam guardrail. The purpose of using a lower height guardrail was to eliminate the need for adding a rub-rail. Data on the improvement alternative are shown on the Computer Input Coding Form in Figure 38.

As can be seen in the output listing of Figure 40, the value of the cost-

FIGURE 36

CASE STUDY NO. 2 (ALTERNATIVE NO. 1)

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

IMPROVEMENT RECOMMENDED W-Bm GR No Rub Rail DATE 09 July 82

HAZARD NO. 1 HAZARD GROUP NO. 01 (Max. 8 hazards per group) IMPR. ALT. NO. 1 (Max. 4)

BOX 1

HIGHWAY

C50 HIGHWAY DESIGN NO.		C51 HIGHWAY NO.	
C1	C2	C3	C4
1	03	1	100

CLEAR ZONE (Ft.) C5: 10

BOX 2

COSTS

CAPITAL ($1,000)	COLLISION MAINTENANCE ($100/ACCID.) (Excludes Guardrail and Bridgerail) HAZARD	IMPROVEMENT	NORMAL MAINTENANCE ($100/YR.) HAZARD	IMPROVEMENT
C11	C12	C13	C14	C15
0006.1			00.1	00.2

BOX 3

POINT HAZARD IMPROVEMENTS

C16: 1 C17: 1 REDUCE SEVERITY C18:
1. REMOVE AND/OR RELOCATE TO SAFE LOCATION
2. MAKE BREAKAWAY
3. RELOCATE AND MAKE BREAKAWAY
4. RECONSTRUCT TO SAFE DESIGN
5. RELOCATE

LATERAL OFFSET (Ft.) C19:

C16: 1 C17: 2 INSTALL GUARDRAIL (Complete Boxes 7 & 8) C18: DESCRIPTOR CODE C19:

C16: 1 C17: 3 INSTALL CRASH CUSHION (Complete Box 8) C18: DESCRIPTOR CODE C19:

BOX 4

LONGITUDINAL HAZARD IMPROVEMENTS

C16: 2 C17: 1 CURB (Complete Box 8) C18:
1. REMOVE AND REGRADE
2. INSTALL WEDGE MODIFICATION

C16: 2 C17: 2 GUARDRAIL (Complete Boxes 7 & 8) C18:
1. REMOVE
2. MODIFY
3. REPLACE WITH NEW DESIGN
4. INSTALL NEW DESIGN

DESCRIPTOR CODE C19:

C16: 2 C17: 3 BRIDGERAIL (Complete Box 8) C18:
1. MODIFY TO SAFE DESIGN
2. REPLACE WITH NEW DESIGN

DESCRIPTOR CODE C19:

BOX 5

SLOPE IMPROVEMENTS

C16: 3 C17: 1 INSTALL GUARDRAIL (Complete Boxes 7 & 8) C18: 2
1. AT BRIDGE
2. NOT AT BRIDGE

DESCRIPTOR CODE C19: 06

MODIFY SLOPE (Complete Box 8) C16: 3 C17: 2

SIDE SLOPES: HINGE POINT OFFSET (Ft.) C28; AVG. FRONT SLOPE C29 :1; AVG. FRONT SLOPE HEIGHT C20; DITCH WIDTH (Ft.) C21; DEPTH OF WATER IN DITCH C22; AVG. BACK SLOPE C23 :1; AVG. BACK SLOPE HEIGHT (Ft.) C24; CONDITION OF SLOPES C25

CROSS CHANNEL: AVG. TRANSVERSE CHANNEL SLOPE C26 :1; AVG. CHANNEL HEIGHT (Ft.) C27

1. NONE
2. LESS THAN 2 FT.
3. GREATER THAN 2 FT.

BOX 6

NO IMPROVEMENT C16: 4

BOX 7

GUARDRAIL

GUARDRAIL LOCATION	LATERAL OFFSETS (Ft.) Begin	Tangent	End	FLARE RATES (a:b) Begin	End	AVG. SHOULDER SLOPES		TOP HEIGHT (in.)	POST SPACING (Ft.)	BLOCK OUT	RUB RAIL
C39	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31
1	12	10	12	20	20	8:1	8:1	27	06	1	2

Guardrail location:
1. EMBANKMENT
2. BRIDGE ENDS
3. POINT HAZARDS

Block out / Rub rail: 1. YES 2. NO

BRIDGE APPROACH: REDUCE POST SPACING C32 (1. YES 2. NO); DOUBLE W-BEAM C33 (1. YES 2. NO)

END TREATMENTS: Begin C34: 3; End C35: 3
1. ANCHORED
2. NOT ANCHORED
3. TURN DOWN (B/A)
4. TURN DOWN (NOT B/A)

CRASHWORTH TERMINALS
5. SET1
6. SET2
7. MBET1
8. MBET2

POST BACKFILL MATERIAL C36: 2
1. NON-COHESIVE
2. COHESIVE

BOX 8

MILE POINTS OF IMPROVEMENT

BEGINNING C37: 00038.1

ENDING C38: 001.089

BOX 9

DATE

Mo.	Dy.	Yr.
C40	C41	C42
07	09	82

PROGRAM CONTROL DATA

C79:
1. END OF GROUP
2. END OF GROUP PROGRAM

2 IBM CARD TYPE

FIGURE 37

CASE STUDY NO. 2 (ALTERNATIVE NO. 2)

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

IMPROVEMENT RECOMMENDED W-Bm GR w/ Rub Rail DATE 09 July 82

HAZARD NO. 01 HAZARD GROUP NO. 01 (Max. 6 hazards per group) IMPR. ALT. NO. 2 (Max. 4)

BOX 1 — HIGHWAY

C50 HIGHWAY DESIGN NO. — C1: 1, C2: 03
C51 HIGHWAY NO. — C3: 1, C4: 100

CLEAR ZONE (Ft.) — C5: 10

BOX 2 — COSTS

CAPITAL ($1,000) — C11: 0006.1

COLLISION MAINTENANCE ($100/ACCID.) (Excludes Guardrail and Bridgerail) — HAZARD C12: ; IMPROVEMENT C13:

NORMAL MAINTENANCE ($100/YR.) — HAZARD C14: 001; IMPROVEMENT C15: 002

BOX 3 — POINT HAZARD IMPROVEMENTS

C16: 1, C17: 1 — REDUCE SEVERITY — C18:
1. REMOVE AND/OR RELOCATE TO SAFE LOCATION
2. MAKE BREAKAWAY
3. RELOCATE AND MAKE BREAKAWAY
4. RECONSTRUCT TO SAFE DESIGN
5. RELOCATE

LATERAL OFFSET (Ft.) C19:

C16: 1, C17: 2 — INSTALL GUARDRAIL (Complete Boxes 7 & 8) — C18 — C19: DESCRIPTOR CODE

C16: 1, C17: 3 — INSTALL CRASH CUSHION (Complete Box 8) — C18 — C19: DESCRIPTOR CODE

BOX 4 — LONGITUDINAL HAZARD IMPROVEMENTS

C16: 2, C17: 1 — CURB (Complete Box 8) — C18:
1. REMOVE AND REGRADE
2. INSTALL WEDGE MODIFICATION

C16: 2, C17: 2 — GUARDRAIL (Complete Boxes 7 & 8) — C18:
1. REMOVE
2. MODIFY
3. REPLACE WITH NEW DESIGN
4. INSTALL NEW DESIGN

C19: DESCRIPTOR CODE

C16: 2, C17: 3 — BRIDGERAIL (Complete Box 8) — C18:
1. MODIFY TO SAFE DESIGN
2. REPLACE WITH NEW DESIGN

C19: DESCRIPTOR CODE

BOX 5 — SLOPE IMPROVEMENTS

C16: 3, C17: 1 — INSTALL GUARDRAIL (Complete Boxes 7 & 8) — C18: 2
1. AT BRIDGE
2. NOT AT BRIDGE

C19: DESCRIPTOR CODE 06

C16: 3, C17: 2 — MODIFY SLOPE (Complete Box 8)

SIDE SLOPES: HINGE POINT OFFSET (Ft.) C28; AVG. FRONT SLOPE C29 :1; AVG. FRONT SLOPE HEIGHT C20; DITCH WIDTH (Ft.) C21; DEPTH OF WATER IN DITCH C22; AVG. BACK SLOPE C23 :1; AVG. BACK SLOPE HEIGHT (Ft.) C24; CONDITION OF SLOPES C25

1. NONE
2. LESS THAN 2 FT.
3. GREATER THAN 2 FT.

CROSS CHANNEL: AVG. TRANSVERSE CHANNEL SLOPE C26 :1; AVG. CHANNEL HEIGHT (Ft.) C27

BOX 6 — NO IMPROVEMENT

C16: 4

BOX 7 — GUARDRAIL

GUARDRAIL LOCATION	LATERAL OFFSETS (Ft.) Begin	Tangent	End	FLARE RATES (a:b) Begin	End	AVG. SHOULDER SLOPES		TOP HEIGHT (In.)	POST SPACING (Ft.)	BLOCK OUT	RUB RAIL
C39: 1	C21: 12	C22: 10	C23: 12	C24: 20	C25: 20	C26: 8:1	C27: 8:1	C28: 27	C29: 06	C30: 1	C31: 1

GUARDRAIL LOCATION: 1. EMBANKMENT 2. BRIDGE ENDS 3. POINT HAZARDS

BLOCK OUT / RUB RAIL: 1. YES 2. NO

BRIDGE APPROACH: REDUCE POST SPACING C32: (1. YES 2. NO); DOUBLE W-BEAM C33: (1. YES 2. NO)

END TREATMENTS: Begin C34: 3; End C35: 3
1. ANCHORED
2. NOT ANCHORED
3. TURN DOWN (S/A)
4. TURN DOWN (NOT S/A)

CRASHWORTHY TERMINALS
5. GET1
6. GET2
7. MBET1
8. MBET2

POST BACKFILL MATERIAL C36: 2
1. NON-COHESIVE
2. COHESIVE

BOX 8 — MILE POINTS OF IMPROVEMENT

BEGINNING C37: 000381
ENDING C38: 001089

BOX 9 — DATE

Mo. C40: 07; Dy. C41: 05; Yr. C42: 82

PROGRAM CONTROL DATA
1. END OF GROUP
2. END OF GROUP PROGRAM

2 IBM CARD TYPE

FIGURE 38

CASE STUDY NO. 2 (ALTERNATIVE NO. 3)

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

IMPROVEMENT RECOMMENDED 24" W-Bm GR No Brdg. Rail DATE 09 July 82

HAZARD NO. 01 HAZARD GROUP NO. 01 (Max. 6 hazards per group) IMPR. ALT. NO. 3 (Max. 4)

BOX 1 — HIGHWAY

C50 HIGHWAY DESIGN NO.: C1 1, C2 03
C51 HIGHWAY NO.: C3 1, C4 100
CLEAR ZONE (Ft.): C5 10

BOX 2 — COSTS

CAPITAL ($1,000): C11 0006.1
COLLISION MAINTENANCE ($100/ACCID.) (Excludes Guardrail and Bridgerail): HAZARD C12; IMPROVEMENT C13
NORMAL MAINTENANCE ($100/YR.): HAZARD C14 001; IMPROVEMENT C15 002

BOX 3 — POINT HAZARD IMPROVEMENTS

C16 1, C17 1 REDUCE SEVERITY — C18: 1. REMOVE AND/OR RELOCATE TO SAFE LOCATION 2. MAKE BREAKAWAY 3. RELOCATE AND MAKE BREAKAWAY 4. RECONSTRUCT TO SAFE DESIGN 5. RELOCATE — LATERAL OFFSET (Ft.) C19

C16 1, C17 2 INSTALL GUARDRAIL (Complete Boxes 7 & 8) — C18 — C19 DESCRIPTOR CODE

C16 1, C17 3 INSTALL CRASH CUSHION (Complete Box 8) — C18 — C19 DESCRIPTOR CODE

BOX 4 — LONGITUDINAL HAZARD IMPROVEMENTS

C16 2, C17 1 CURB (Complete Box 8) — C18: 1. REMOVE AND REGRADE 2. INSTALL WEDGE MODIFICATION

C16 2, C17 2 GUARDRAIL (Complete Boxes 7 & 8) — C18: 1. REMOVE 2. MODIFY 3. REPLACE WITH NEW DESIGN 4. INSTALL NEW DESIGN — C19 DESCRIPTOR CODE

C16 2, C17 3 BRIDGERAIL (Complete Box 8) — C18: 1. MODIFY TO SAFE DESIGN 2. REPLACE WITH NEW DESIGN — C19 DESCRIPTOR CODE

SLOPE IMPROVEMENTS

C16 3, C17 1 INSTALL GUARDRAIL (Complete Boxes 7 & 8) — C18 2: 1. AT BRIDGE 2. NOT AT BRIDGE — C19 04 DESCRIPTOR CODE

BOX 5

C16 3, C17 2 MODIFY SLOPE (Complete Box 8) — SIDE SLOPES: HINGE POINT OFFSET (Ft.) C28; AVG. FRONT SLOPE C29 :1; AVG. FRONT SLOPE HEIGHT C30; DITCH WIDTH (Ft.) C31; DEPTH OF WATER IN DITCH C22 (1. NONE 2. LESS THAN 2 FT. 3. GREATER THAN 2 FT.); AVG. BACK SLOPE C23 :1; AVG. BACK SLOPE HEIGHT (Ft.) C24; CONDITION OF SLOPES C25 — CROSS CHANNEL: AVG. TRANSVERSE CHANNEL SLOPE C26 :1; AVG. CHANNEL HEIGHT (Ft.) C27

BOX 6 — NO IMPROVEMENT C16 4

BOX 7 — GUARDRAIL

GUARDRAIL LOCATION C39 1 (1. EMBANKMENT 2. BRIDGE ENDS 3. POINT HAZARDS)
LATERAL OFFSETS (Ft.): Begin C21 12; Tangent C22 10; End C23 12
FLARE RATES (a:b): Begin C24 20; End C25 20
AVG. SHOULDER SLOPES: C26 8:1; C27 8:1
TOP HEIGHT (In.) C28 24
POST SPACING (Ft.) C29 06
BLOCK OUT C30 1 (1. YES 2. NO)
RUB RAIL C31 2 (1. YES 2. NO)
BRIDGE APPROACH: REDUCE POST SPACING C32 (1. YES 2. NO); DOUBLE W-BEAM C33 (1. YES 2. NO)
END TREATMENTS: Begin C34 3; End C35 3 — 1. ANCHORED 2. NOT ANCHORED 3. TURN DOWN (S/A) 4. TURN DOWN (NOT S/A) CRASHWORTHY TERMINALS 5. GETI 6. GETS 7. MGETI 8. MGETS
POST BACKFILL MATERIAL C36 2 (1. NON-COHESIVE 2. COHESIVE)

BOX 8 — MILE POINTS OF IMPROVEMENT

BEGINNING C37 000.981
ENDING C38 001.089

BOX 9 — DATE

Mo. C40 07; Dy. C41 05; Yr. C42 82

PROGRAM CONTROL DATA: 1. END OF GROUP 2. END OF GROUP PROGRAM — 2 IBM CARD TYPE

FIGURE 39

CASE STUDY NO. 2 (ALTERNATIVE NO. 4)

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

IMPROVEMENT RECOMMENDED Cable GR DATE 09 July 82

HAZARD NO. 01 HAZARD GROUP NO. 01 (Max. 6 hazards per group) IMPR. ALT. NO. 4 (Max. 4)

BOX 1 — HIGHWAY

C50 HIGHWAY DESIGN NO.; C51 HIGHWAY NO.

C1: 1 C2: 03 C3: 1 C4: 100

CLEAR ZONE (Ft.) C5: 12

BOX 2 — COSTS

CAPITAL ($1,000) C11: 00033

COLLISION MAINTENANCE ($100/ACCID.) (Excludes Guardrail and Bridgerail) HAZARD C12; IMPROVEMENT C13

NORMAL MAINTENANCE ($100/YR.) HAZARD C14: 001; IMPROVEMENT C15: 002

BOX 3 — POINT HAZARD IMPROVEMENTS

C16: 1 C17: 1 REDUCE SEVERITY C18: 1. REMOVE AND/OR RELOCATE TO SAFE LOCATION 2. MAKE BREAKAWAY 3. RELOCATE AND MAKE BREAKAWAY 4. RECONSTRUCT TO SAFE DESIGN 5. RELOCATE; LATERAL OFFSET (Ft.) C19

C16: 1 C17: 2 INSTALL GUARDRAIL (Complete Boxes 7 & 8) C18; DESCRIPTOR CODE C19

C16: 1 C17: 3 INSTALL CRASH CUSHION (Complete Box 8) C18; DESCRIPTOR CODE C19

BOX 4 — LONGITUDINAL HAZARD IMPROVEMENTS

C16: 2 C17: 1 CURB (Complete Box 8) C18: 1. REMOVE AND REGRADE 2. INSTALL WEDGE MODIFICATION

C16: 2 C17: 2 GUARDRAIL (Complete Boxes 7 & 8) C18: 1. REMOVE 2. MODIFY 3. REPLACE WITH NEW DESIGN 4. INSTALL NEW DESIGN; DESCRIPTOR CODE C19

C16: 2 C17: 3 BRIDGERAIL (Complete Box 8) C18: 1. MODIFY TO SAFE DESIGN 2. REPLACE WITH NEW DESIGN; DESCRIPTOR CODE C19

BOX 5 — SLOPE IMPROVEMENTS ✓

C16: 3 C17: 1 INSTALL GUARDRAIL (Complete Boxes 7 & 8) C18: 2 (1. AT BRIDGE 2. NOT AT BRIDGE); DESCRIPTOR CODE C19: 02

MODIFY SLOPE (Complete Box 8) C16: 3 C17: 2 — SIDE SLOPES: HINGE POINT OFFSET (Ft.) C28; AVG. FRONT SLOPE C29 :1; AVG. FRONT SLOPE HEIGHT C20; DITCH WIDTH (Ft.) C21; DEPTH OF WATER IN DITCH C22 (1. NONE 2. LESS THAN 2 FT. 3. GREATER THAN 2 FT.); AVG. BACK SLOPE C23 :1; AVG. BACK SLOPE HEIGHT (Ft.) C24; CONDITION OF SLOPES C25; CROSS CHANNEL: AVG. TRANSVERSE CHANNEL SLOPE C26 :1; AVG. CHANNEL HEIGHT (Ft.) C27

BOX 6 — NO IMPROVEMENT C16: 4

BOX 7 — GUARDRAIL ✓

GUARDRAIL LOCATION C39: 1 (1. EMBANKMENT 2. BRIDGE ENDS 3. POINT HAZARDS)

LATERAL OFFSETS (Ft.) C21: 12 C22: 12 C23: 12; FLARE RATES (a:b) C24: 00 C25: 00; AVG. SHOULDER SLOPES C26: 8:1 C27: 8:1; TOP HEIGHT (In.) C28: 30; POST SPACING (Ft.) C29: 16; BLOCK OUT C30: 1 (1. YES 2. NO); RUB RAIL C31: 2 (1. YES 2. NO)

BRIDGE APPROACH: REDUCE POST SPACING C32 (1. YES 2. NO); DOUBLE W-BEAM C33 (1. YES 2. NO)

END TREATMENTS: Begin C34: 1; End C35: 1 (1. ANCHORED 2. NOT ANCHORED 3. TURN DOWN (B/A) 4. TURN DOWN (NOT B/A) CRASHWORTHY TERMINALS 5. SET1 6. SET2 7. MELT1 8. MELT2)

POST BACKFILL MATERIAL C36: 2 (1. NON-COHESIVE 2. COHESIVE)

BOX 8 — MILE POINTS OF IMPROVEMENT ✓

BEGINNING C37: 000989; ENDING C38: 001083

BOX 9 — DATE: Mo. C40: 07 Dy. C41: 09 Yr. C42: 82

PROGRAM CONTROL DATA: C79: 2 (1. END OF GROUP 2. END OF GROUP PROGRAM); C80: 2 IBM CARD TYPE

FIGURE 40

CASE STUDY NO. 2--LISTING OF COMPUTER OUTPUT FOR FLAT DITCH RUNOUT

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 = NH-100
DESIGN SPEED = 55 MPH
ADT = 5000

AUTOMOBILE SPLITS
4,450 (LB) = 60 %
2,250 (LB) = 30 %
1,750 (LB) = 10 %

ENVIRONMENTAL CONDITIONS
DRY = 8 MO/YR
WET = 2 MO/YR
SUB-FREEZING = 2 MO/YR

SOCIETAL ACCIDENT COSTS
PDO = $ 1200
INJURY = $ 5900
FATAL = $ 427600

ECONOMIC FACTORS
PROJECT LIFE = 20.0 YRS
INTEREST RATE = 15.000 %

DATE = 7- 9-82

***** H A Z A R D *****								******* I M P R O V E M E N T *******											
HAZ NO	GR NO	HAZ CODE	SIDE OF ROAD	MILE-POST BEG	MILE-POST END	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	IMPR ALT	IMPR CODE	MILE-POST BEG	MILE-POST END	CLEAR ZONE (FT)	FIRST COST ($1000)	TOTAL HWY COST ($/YR)	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	COST EFFECT RATIO ($/INJ)	BENEFIT COST RATIO
1	1	7- 2	1	1.000	1.076	0.0615	1330	1	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0793	849	-60742	0.45
1	1	7- 2	1	1.000	1.076	0.0615	1330	2	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0780	800	-65342	0.49
1	1	7- 2	1	1.000	1.076	0.0615	1330	3	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0781	800	-65301	0.49
1	1	7- 2	1	1.000	1.076	0.0615	1330	4	3-1-2-2	0.989	1.083	12.0	3.3	707	0.0564	501	136420	1.17

effectiveness was a negative $65,301 and the value of the benefit-cost was 0.49. In conclusion, this guardrail design improvement alternative was not attractive.

7.2.1.4 Improvement Alternative No. 4

Improvement Alternative No. 4 consisted of a cable guardrail. The guardrail conforms to AASHTO G1 design designation. Data on the improvement alternative are shown on the Computer Imput Coding Form in Figure 39.

As can be seen in the output listing in Figure 40, the value of the cost-effectiveness was $136,420 and the value of the benefit-cost was 1.17. In conclusion, this guardrail design improvement alternative was attractive because (a) the benefits of $829/yr exceeded the total $707/yr, and (b) the hazard-index of the guardrail of 0.0564 inj/yr was less than the hazard-index of the existing slope of 0.0615 inj/yr.

7.2.2 Embankment With Ditch Bottom

The embankment configuration in this section was the same as in the previous section (Section 7.2.1), except that the flat bottomed runout ditch was replaced with a ditch 7 ft. in width and a backslope of 2:1. Data on the embankment are shown in the Hazard Inventory Input Coding Form in Figure 41.

The four guardrail improvements in this section were the same as in Section 7.2.1. Data on the guardrail improvement alternatives were shown in Figures 36. thru 39.

The output listing from the computer program for the four guardrail improvement alternatives are shown in Figure 42. As can be seen in Figure 42, none of the W-beam guardrail improvement alternatives (Nos. 1-3) with benefit-cost ratios less the the unity were attractive. However, the cable guardrail improvement alternative (No.4) with benefit-cost ratio of 1.77 was attractive.

FIGURE 41

CASE STUDY NO. 2 (7 FT. DITCH AND 2:1 BACKSLOPE)

ROADSIDE HAZARD INVENTORY FORM

DATE 09 July 1982

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

INVENTORY CONDUCTED BY E. R. Post

BOX 1 — HIGHWAY

H1 (H50)	H2	H3 (H51)	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16
Highway Design No. (1)	(2 3)	Highway No. (4)	(5 6 7)	Posted Speed Limit (mph) (8 9)	ADT (Both Directions) (10 11 12 13 14)	Lane Width (Ft.) (15 16)	Median Width (Ft.) (17 18)	Degree of Curve (19)	Grade (%) Up (20)	Grade (%) Dn (21)	Shoulder Paved Width (Ft.) (22 23)	Shoulder Usable Width (Ft.) (24 25)	Shoulder Surface Type (26)	Shoulder Drop-off (In.) (27)	Shoulder Condition Rut (28)
1	03	1	100	55	05000	12					08	08	1		

H1: 1. DR 2. DM 3. RGA 4. RC 5. RL
H3: 1. N 2. US 3. I 4. SEC
H14: 1. SOD 2. GRAVEL 3. SOIL
H16: 0. NONE 1. SHALLOW 2. DEEP

BOX 2 — HAZARD CLASSIFICATION

DESCRIPTION ____________

Hazard No. (29 30) H17	Ident. No. (31 32) H18	Descr. Code (33 34) H19	Offset Code (35) H20	Group No. (36 37) H21
01	07	02	1	01

H20: 1. RIGHT SIDE 2. LEFT SIDE

MILE - POINT OF HAZARD

Beginning (38 39 40 41 42 43) H22	Ending (44 45 46 47 48 49) H23
001.000	001.076

BOX 3 — POINT HAZARD (Utility Pole, Tree, Sign, Support, Culvert Headwall, Drainage Inlet)

(50) H30	Lateral Offset (Ft.) (51 52) H31	Width (Ft.) (53 54) H32	Length (Ft.) (55 56 57) H33	Drainage Height (Ft.) (58) H34	Inlets (Only) Depth (Ft.) (59) H35	Number Point Hazards in Group (60 61 62) H36
1						

BOX 4 — LONGITUDINAL HAZARD (Guardrail, Bridgerail, CMB, Wall, Curb)

(50) H30	Lateral Offset (Ft.) (51 52) H31
2	

NOTE: If Guardrail, Complete Box 6

BOX 5 — SLOPE HAZARD (Fill Slope, Cut Slope, Channel Slope, Ditch)

(50) H30	Side Slopes: Hinge Point Offset (Ft.) (51 52) H31	Avg. Front Slope (53) H32	Avg. Front Slope Height (Ft.) (54 55) H33	Ditch Width (Ft.) (56 57) H34	Depth of Water in Ditch (58) H35	Avg. Back Slope (59 60) H36	Avg. Back Slope Height (Ft.) (61 62) H37	Condition of Slopes (63) H38	Cross Channel: Avg. Transverse Channel Slope (64 65) H39	Avg. Channel Height (Ft.) (66 67) H40
3	12	2:1	30	07	1	02:1	05	1		

H35: 1. NONE 2. LESS THAN 2 FT. 3. GREATER THAN 2 FT.
H38: 1. SMOOTH 2. ROUGH

BOX 6 — GUARDRAIL

Guardrail Location (53) H49	Lateral Offsets (Ft.) Begin (54 55) H33	Tangent (56 57) H34	End (58 59) H35	Flare Rate (a:b) Begin (60 61) H36	End (62 63) H37	Avg. Shoulder Slopes Tangent (64) H38	Flared (65) H39	Top Height (In.) (66 67) H40	Post Spacing (Ft.) (68 69) H41	Block Out (70) H42	Rub Rail (71) H43
						8:1	8:1			1	

H49: 1. EMBANKMENT 2. BRIDGE ENDS 3. POINT HAZARDS
H42, H43: 1. YES 2. NO

Bridge Approach: Reduced Post Spacing (72) H44	Double W-Beam (73) H45	End Treatments: Begin (74) H46	End (75) H47	Post Backfill Material (76) H48
				2

H44, H45: 1. YES 2. NO
End Treatments: 1. ANCHORED 2. NOT ANCHORED 3. TURN DOWN (B/A) 4. TURN DOWN (Not B/A) CRASHWORTHY TERMINALS 5. GET1 6. GET2 7. MBET1 8. MBET 2
H48: 1. NON-COHESIVE 2. COHESIVE

BOX 7 — PROGRAM CONTROL DATA

(80) 1 IBM CARD TYPE

RECOMMENDATIONS ____________

FIGURE 42

CASE STUDY NO. 2 (7 FT DITCH AND 2:1 BACKSLOPE)

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 = NH-100
DESIGN SPEED = 55 MPH
ADT = 5000

AUTOMOBILE SPLITS
4,450 (LB) = 60 %
2,250 (LB) = 30 %
1,750 (LB) = 10 %

ENVIROMENTAL CONDITIONS
DRY = 8 MO/YR
WET = 2 MO/YR
SUB-FREEZING = 2 MO/YR

SOCIETAL ACCIDENT COSTS
PDO = $ 1200
INJURY = $ 5900
FATAL = $ 427600

ECONOMIC FACTORS
PROJECT LIFE = 20.0 YRS
INTEREST RATE = 15.000 %

DATE = 7- 9-82

***** H A Z A R D *****								******* I M P R O V E M E N T *******										
HAZ NO	GR NO	HAZ CODE	SIDE OF ROAD	MILE-POST BEG	MILE-POST END	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	IMPR ALT	IMPR CODE	MILE-POST BEG	MILE-POST END	CLEAR ZONE (FT)	FIRST COST ($1000)	TOTAL HWY COST ($/YR)	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	COST EFFECT RATIO ($/INJ)	BENEFIT COST RATIO
1	1	7- 2	1	1.000	1.076	0.0706	1749	1	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0793	849	-124084	0.83
1	1	7- 2	1	1.000	1.076	0.0706	1749	2	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0780	800	-144925	0.88
1	1	7- 2	1	1.000	1.076	0.0706	1749	3	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0781	800	-144723	0.88
1	1	7- 2	1	1.000	1.076	0.0706	1749	4	3-1-2-2	0.989	1.083	12.0	3.3	707	0.0564	501	49637	1.77

The increased severity associated with embankments with ditches and backslopes in comparison with flat bottomed runout ditches is readily apparent by comparing the benefit-cost ratio of the cable guardrail installation in this section with the benefit-cost ratio in the previous section. In Figure 42, the benefit-cost ratio of installing cable guardrail on an embankment with a 7 ft. ditch and 2:1 backslope was equal to a value of 1.77; whereas, in Figure 40, the benefit-cost ratio of installing cable guardrail on an embankment with a flat bottomed runout ditch was equal to a smaller value of 1.17.

7.2.3 Embankment with Water in Ditch Bottom

The embankment configuration in this section was the same as in the previous section (Section 7.2.2), except that there was 2 ft. or less of water in the ditch bottom. Data on the embankment are shown in the Hazard Inventory Input Coding Form in Figure 43.

The four guardrail improvements in this section were the same as in Section 7.2.1. Data on the guardrail improvement alternatives were shown in Figures 36 thru 39.

The output listing from the computer program for the four guardrail improvement alternatives are shown in Figure 44. As can be seen in Figure 44, the 27-in. W-beam guardrail improvement alternative (No.1) with no rub-rail had a benefit-cost ratio just slightly under unity, whereas, the 27-in. W-beam guardrail improvement alternative (No. 2) with rub-rail and the 24-in. W-beam guardrail improvement alternative (No. 3) both had benefit-cost ratios just slightly above unity. It is to be noted that negative cost-effectiveness values for Improvement Alternatives Nos. 2 and 3, as a result of the very small difference in the hazard-indices, are contradictory to the barely attractive benefit-cost ratios, however, since these two improvement alternatives are, in essence, borderline cases, this error is not considered to be of any serious concern.

FIGURE 43

CASE STUDY NO. 2 (7 FT DITCH WITH WATER AND 2:1 BACKSLOPE)

ROADSIDE HAZARD INVENTORY FORM

DATE 09 July 1982

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

INVENTORY CONDUCTED BY E.R. Bst

BOX 1 — HIGHWAY (☒)

H50: HIGHWAY DESIGN NO.		H51: HIGHWAY NO.		POSTED SPEED LIMIT (mph)	ADT (Both Directions)	LANE WIDTH (Ft.)	MEDIAN WIDTH (Ft.)	DEGREE OF CURVE	GRADE (%) Up	GRADE (%) Dn	SHOULDER: PAVED WIDTH (Ft.)	SHOULDER: USABLE WIDTH (Ft.)	SHOULDER: SURFACE TYPE	SHOULDER: DROP-OFF (In.)	SHOULDER: CONDITION RUT
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	28
1	03	1	1,0,0	55	05000	1,2					08	08	1		
H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16

H1: 1. DR 2. DM 3. RGA 4. RC 5. RL
H3: 1. N 2. US 3. I 4. SEC
H14: 1. SOD 2. GRAVEL 3. SOIL
H16: 0. NONE 1. SHALLOW 2. DEEP

BOX 2 — HAZARD CLASSIFICATION (☒)

DESCRIPTION ______

HAZARD NO.	IDENT. NO.	DESCR. CODE	OFFSET CODE	GROUP NO.
29 30	31 32	33 34	35	36 37
0,1	0,7	0,2	1	0,1
H17	H18	H19	H20	H21

H20: 1. RIGHT SIDE 2. LEFT SIDE

MILE - POINT OF HAZARD

BEGINNING	ENDING
38 39 40 41 42 43	44 45 46 47 48 49
0,0,1,0,0,0	0,0,1,0,7,6
H22	H23

BOX 3 — POINT HAZARD (Utility Pole, Tree, Sign, Support, Culvert Headwall, Drainage Inlet) (☐)

	LATERAL OFFSET (Ft.)	WIDTH (Ft.)	LENGTH (Ft.)	DRAINAGE HEIGHT (Ft.)	INLETS (Only) DEPTH (Ft.)	NUMBER POINT HAZARDS IN GROUP
50	51 52	53 54	55 56 57	58	59	60 61 62
1						
H30	H31	H32	H33	H34	H35	H36

BOX 4 — LONGITUDINAL HAZARD (Guardrail, Bridgerail, CMB, Wall, Curb) (☐)

	LATERAL OFFSET (Ft.)
50	51 52
2	
H30	H31

NOTE: If Guardrail, Complete Box 6

BOX 5 — SLOPE HAZARD (Fill Slope, Cut Slope, Channel Slope, Ditch) (☑)

	SIDE SLOPES: HINGE POINT OFFSET (Ft.)	AVG. FRONT SLOPE	AVG. FRONT SLOPE HEIGHT (Ft.)	DITCH WIDTH (Ft.)	DEPTH OF WATER IN DITCH	AVG. BACK SLOPE	AVG. BACK SLOPE HEIGHT (Ft.)	CONDITION OF SLOPES	CROSS CHANNEL: AVG. TRANSVERSE CHANNEL SLOPE	CROSS CHANNEL: AVG. CHANNEL HEIGHT (Ft.)
50	51 52	53	54 55	56 57	58	59 60	61 62	63	64 65	66 67
3	1,2	2:1	3,0	0,7	2	0,2:1	0,5	1		
H30	H31	H32	H33	H34	H35	H36	H37	H38	H39	H40

H35: 1. NONE 2. LESS THAN 2 FT. 3. GREATER THAN 2 FT.
H38: 1. SMOOTH 2. ROUGH

BOX 6 — GUARDRAIL (☐)

GUARDRAIL LOCATION	LATERAL OFFSETS (Ft.) Begin	LATERAL OFFSETS (Ft.) Tangent	LATERAL OFFSETS (Ft.) End	FLARE RATE (a:b) Begin	FLARE RATE (a:b) End	AVG. SHOULDER SLOPES Tangent	AVG. SHOULDER SLOPES Flared	TOP HEIGHT (In.)	POST SPACING (Ft.)	BLOCK OUT	RUB RAIL
53	54 55	56 57	58 59	60 61	62 63	64	65	66 67	68 69	70	71
						8:1	8:1			1	
H49	H33	H34	H35	H36	H37	H38	H39	H40	H41	H42	H43

H49: 1. EMBANKMENT 2. BRIDGE ENDS 3. POINT HAZARDS
H42: 1. YES 2. NO
H43: 1. YES 2. NO

BRIDGE APPROACH: REDUCED POST SPACING	BRIDGE APPROACH: DOUBLE W-BEAM	END TREATMENTS: Begin	END TREATMENTS: End	POST BACKFILL MATERIAL
72	73	74	75	76
				2
H44	H45	H46	H47	H48

H44: 1. YES 2. NO
H45: 1. YES 2. NO
H46/H47: 1. ANCHORED 2. NOT ANCHORED 3. TURN DOWN (B/A) 4. TURN DOWN (Not B/A) CRASHWORTHY TERMINALS 5. GET1 6. GET2 7. MBET1 8. MBET 2
H48: 1. NON-COHESIVE 2. COHESIVE

BOX 7 — PROGRAM CONTROL DATA (☒)

80: 1 IBM CARD TYPE

RECOMMENDATIONS ______

FIGURE 44

CASE STUDY NO. 2 (7 FT DITCH WITH WATER AND 2:1 BACKSLOPE)

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 = NH-100
DESIGN SPEED = 55 MPH
ADT = 5000

AUTOMOBILE SPLITS
4,450 (LB) = 60 %
2,250 (LB) = 30 %
1,750 (LB) = 10 %

ENVIROMENTAL CONDITIONS
DRY = 8 MO/YR
WET = 2 MO/YR
SUB-FREEZING = 2 MO/YR

SOCIETAL ACCIDENT COSTS
PDO = $ 1200
INJURY = $ 5900
FATAL = $ 427600

ECONOMIC FACTORS
PROJECT LIFE = 20.0 YRS
INTEREST RATE = 15.000 %

***** H A Z A R D *****								******* I M P R O V E M E N T *******										
HAZ NO	GR NO	HAZ CODE	SIDE OF ROAD	MILE-POST BEG	MILE-POST END	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	IMPR ALT	IMPR CODE	MILE-POST BEG	MILE-POST END	CLEAR ZONE (FT)	FIRST COST ($1000)	TOTAL HWY COST ($/YR)	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	COST EFFECT RATIO ($/INJ)	BENEFIT COST RATIO
1	1	7- 2	1	1.000	1.076	0.0740	1907	1	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0793	849	-201868	0.98
1	1	7- 2	1	1.000	1.076	0.0740	1907	2	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0780	800	-263520	1.03
1	1	7- 2	1	1.000	1.076	0.0740	1907	3	3-1-2-6	0.981	1.089	10.0	6.1	1078	0.0781	800	-262854	1.03
1	1	7- 2	1	1.000	1.076	0.0740	1907	4	3-1-2-2	0.989	1.083	12.0	3.3	707	0.0564	501	40190	1.99

In Figure 44, it is also to be noted that the cable guardrail improvement alternative (No.4) with a benefit-cost ratio of 1.99 was more attractive than that in the previous section where no water was in the ditch.

7.3 CASE STUDY NO. 3...RURAL 2-LANE HIGHWAY: CABLE GUARDRAIL VS SLOPE FLATTENING

The purpose of this case study was to conduct a cost-effectiveness and benefit-cost comparative study on the installation of cable guardrail versus flattening of the front slope.

The existing embankment configuration, which was the same as in Case Study No. 2, Section 7.2.1, consisted of a 2:1 front slope, a slope height of 30 ft., and a "flat" ditch bottom runout. The hinge point of the embankment was offset a distance of 12 ft., and the length of the embankment was 400 ft. Data on the selected typical roadside embankment configuration are shown in the Hazard Inventory Input Coding Form in Figure 35.

The rural 2-lane highway being considered conformed to Nebraska DR-3 Minumum Design Standards (14) presented in Table 23. The roadway was assumed to be carrying a high ADT volume of 5,000. Data on the assumed environmental conditions, automobile split categories, economic factors, and societal accident costs are shown on General Information Input Coding Form in Figure 33.

The three improvement alternatives considered in this case study were as follows:

Impr. Alt. No. 1...Cable Guardrail

Impr. Alt. No. 2...Flatten Front Slope to 3:1

Impr. Alt. No. 3...Flatten Front Slope to 4:1

The design details of the cable guardrail were the same as in Case Study No. 2, Section 7.2. Since the highway was of 2-lane construction, the guardrail was of sufficient length to redirect errant vehicles from both directions of travel. The length of the cable guardrail was 495 ft. Collision maintenance repair costs and design details of the cable guardrail are shown in Computer Input Coding Forms in Figures 34 and 39, respectively. The guardrail conforms to the AASHTO (11) G1 design designation.

Data on the flattening of the front fill slopes to 3:1 and 4:1 are shown in the Computer Input Coding Forms in Figures 45 and 46, respectively. The unit bid obtained from NDR for large embankment construction projects was $2.19/cyd. For making small spot type of improvements, it was assumed that the construction costs would double to $4.38/cyd.

The computer output listing of the three improvement alternatives is shown in Figure 47. In comparison to the cable guardrail (Alt. No.1) benefit-cost ratio of 1.17, which was the same as in Case Study No. 2, it can be seen that cost-effectiveness values and the benefit-cost values for flattening of the front-slopes to 2:1 (Alt. No.2) and 3:1 (Alt. No. 3) were not worthy of consideration.

FIGURE 45

CASE STUDY NO. 3 ALTERNATIVE NO. 2)

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

IMPROVEMENT RECOMMENDED Flatten Slope to 5:1 DATE 13 Aug 1982

HAZARD NO. 1 HAZARD GROUP NO. 01 (Max. 8 hazards per group) IMPR. ALT. NO. 2 (Max. 4)

BOX 1 — HIGHWAY

C50 HIGHWAY DESIGN NO. — C51 HIGHWAY NO.

C1 (1)	C2 (2-3)	C3 (4)	C4 (5-7)
1	03	1	100

CLEAR ZONE (Ft.) C5 (9-10): 12

BOX 2 — COSTS

CAPITAL ($1,000) C11 (11-15): 00146 (crossed out; 90.9 written above)

COLLISION MAINTENANCE ($100/ACCID.) (Excludes Guardrail and Bridgerail) — HAZARD C12 (16-18); IMPROVEMENT C13 (19-21)

NORMAL MAINTENANCE ($100/YR.) — HAZARD C14 (22-24); IMPROVEMENT C15 (25-27)

BOX 3 — POINT HAZARD IMPROVEMENTS

C16: 1, C17: 1 — REDUCE SEVERITY — C18:
1. REMOVE AND/OR RELOCATE TO SAFE LOCATION
2. MAKE BREAKAWAY
3. RELOCATE AND MAKE BREAKAWAY
4. RECONSTRUCT TO SAFE DESIGN
5. RELOCATE

LATERAL OFFSET (Ft.) C19 (31-32)

C16: 1, C17: 2 — INSTALL GUARDRAIL (Complete Boxes 7 & 8) — C18 — C19 DESCRIPTOR CODE

C16: 1, C17: 3 — INSTALL CRASH CUSHION (Complete Box 8) — C18 — C19 DESCRIPTOR CODE

BOX 4 — LONGITUDINAL HAZARD IMPROVEMENTS

C16: 2, C17: 1 — CURB (Complete Box 8) — C18:
1. REMOVE AND REGRADE
2. INSTALL WEDGE MODIFICATION

C16: 2, C17: 2 — GUARDRAIL (Complete Boxes 7 & 8) — C18:
1. REMOVE
2. MODIFY
3. REPLACE WITH NEW DESIGN
4. INSTALL NEW DESIGN

C19 DESCRIPTOR CODE

C16: 2, C17: 3 — BRIDGERAIL (Complete Box 8) — C18:
1. MODIFY TO SAFE DESIGN
2. REPLACE WITH NEW DESIGN

C19 DESCRIPTOR CODE

BOX 5 — SLOPE IMPROVEMENTS (checked)

C16: 3, C17: 1 — INSTALL GUARDRAIL (Complete Boxes 7 & 8) — C18:
1. AT BRIDGE
2. NOT AT BRIDGE

C19 DESCRIPTOR CODE

MODIFY SLOPE (Complete Box 8) — SIDE SLOPES — CROSS CHANNEL

C16	C17	C28 Hinge Point Offset (Ft.)	C29 Avg. Front Slope	C20 Avg. Front Slope Height	C21 Ditch Width (Ft.)	C22 Depth of Water in Ditch	C23 Avg. Back Slope	C24 Avg. Back Slope Height (Ft.)	C25 Condition of Slopes	C26 Avg. Transverse Channel Slope	C27 Avg. Channel Height (Ft.)
3	2	12	3:1	30	99	1	00:1	00	1	:1	

Depth of water in ditch:
1. NONE
2. LESS THAN 2 FT.
3. GREATER THAN 2 FT.

BOX 6 — NO IMPROVEMENT C16: 4

BOX 7 — GUARDRAIL

GUARDRAIL LOCATION C39:
1. EMBANKMENT
2. BRIDGE ENDS
3. POINT HAZARDS

LATERAL OFFSETS (Ft.) C21, C22, C23 — FLARE RATES C24, C25 — AVG. SHOULDER SLOPES C26: 8:1, C27: 8:1 — TOP HEIGHT (In.) C28 — POST SPACING (Ft.) C29 — BLOCK OUT C30: 1 (1. YES 2. NO) — RUB RAIL C31 (1. YES 2. NO)

BRIDGE APPROACH: REDUCE POST SPACING C32 (1. YES 2. NO); DOUBLE W-BEAM C33 (1. YES 2. NO)

END TREATMENTS: Begin C34; End C35
1. ANCHORED
2. NOT ANCHORED
3. TURN DOWN (S/A)
4. TURN DOWN (NOT S/A)

CRASHWORTHY TERMINALS
5. SET1
6. SET2
7. MSET1
8. MSET2

POST BACKFILL MATERIAL C36: 2
1. NON-COHESIVE
2. COHESIVE

BOX 8 — MILE POINTS OF IMPROVEMENT (checked)

BEGINNING C37: 001000 — ENDING C38: 001076

BOX 9 — DATE

Mo. C40: 08 — Dy. C41: 10 — Yr. C42: 82

PROGRAM CONTROL DATA

C (79):
1. END OF GROUP
2. END OF GROUP PROGRAM

(80): 2 IBM CARD TYPE

FIGURE 46

CASE STUDY NO. 3 (ALTERNATIVE NO. 3)

ROADSIDE HAZARD IMPROVEMENT FORM

NEBRASKA DEPARTMENT OF ROADS
UNIVERSITY OF NEBRASKA - LINCOLN

IMPROVEMENT RECOMMENDED Flatten Slope to 4:1 DATE 10 Aug 1982

HAZARD NO. 1 HAZARD GROUP NO. 01 (Max. 6 hazards per group) IMPR. ALT. NO. 3 (Max. 4)

BOX 1 — HIGHWAY

C50 HIGHWAY DESIGN NO. (C1)	(C2)	C51 HIGHWAY NO. (C3)	(C4)	CLEAR ZONE (Ft.) (C5)
1	03	1	100	12

BOX 2 — COSTS

CAPITAL ($1,000) C11	COLLISION MAINTENANCE ($100/ACCID.) HAZARD C12	COLLISION MAINTENANCE IMPROVEMENT C13	NORMAL MAINTENANCE ($100/YR.) HAZARD C14	NORMAL MAINTENANCE IMPROVEMENT C15
00292				

BOX 3 — POINT HAZARD IMPROVEMENTS

REDUCE SEVERITY: C16 1, C17 1, C18 ___
1. REMOVE AND/OR RELOCATE TO SAFE LOCATION
2. MAKE BREAKAWAY
3. RELOCATE AND MAKE BREAKAWAY
4. RECONSTRUCT TO SAFE DESIGN
5. RELOCATE

LATERAL OFFSET (Ft.) C19 ___

INSTALL GUARDRAIL (Complete Boxes 7 & 8): C16 1, C17 2, C18; DESCRIPTOR CODE C19 ___

INSTALL CRASH CUSHION (Complete Box 8): C16 1, C17 3, C18; DESCRIPTOR CODE C19 ___

BOX 4 — LONGITUDINAL HAZARD IMPROVEMENTS

CURB (Complete Box 8): C16 2, C17 1, C18 ___
1. REMOVE AND REGRADE
2. INSTALL WEDGE MODIFICATION

GUARDRAIL (Complete Boxes 7 & 8): C16 2, C17 2, C18 ___
1. REMOVE
2. MODIFY
3. REPLACE WITH NEW DESIGN
4. INSTALL NEW DESIGN

DESCRIPTOR CODE C19 ___

BRIDGERAIL (Complete Box 8): C16 2, C17 3, C18 ___
1. MODIFY TO SAFE DESIGN
2. REPLACE WITH NEW DESIGN

DESCRIPTOR CODE C19 ___

BOX 5 — SLOPE IMPROVEMENTS

INSTALL GUARDRAIL (Complete Boxes 7 & 8): C16 3, C17 1, C18 ___
1. AT BRIDGE
2. NOT AT BRIDGE

DESCRIPTOR CODE C19 ___

MODIFY SLOPE (Complete Box 8) C16	C17	SIDE SLOPES: HINGE POINT OFFSET (Ft.) C28	AVG. FRONT SLOPE C29	AVG. FRONT SLOPE HEIGHT C20	DITCH WIDTH (Ft.) C21	DEPTH OF WATER IN DITCH C22	AVG. BACK SLOPE C23	AVG. BACK SLOPE HEIGHT (Ft.) C24	CONDITION OF SLOPES C25	CROSS CHANNEL: AVG. TRANSVERSE CHANNEL SLOPE C26	AVG. CHANNEL HEIGHT (Ft.) C27
3	2	12	4:1	30	99	1	00:1	00	1	:1	

Depth of water in ditch: 1. NONE 2. LESS THAN 2 FT. 3. GREATER THAN 2 FT.

BOX 6 — NO IMPROVEMENT C16 4

BOX 7 — GUARDRAIL

GUARDRAIL LOCATION C39	LATERAL OFFSETS (Ft.) Begin C21	Transition C22	End C23	FLARE RATES (a:b) Begin C24	End C25	AVG. SHOULDER SLOPES C26	C27	TOP HEIGHT (In.) C28	POST SPACING (Ft.) C29	BLOCK OUT C30	RUB RAIL C31
						8:1	8:1			1	

Guardrail location: 1. EMBANKMENT 2. BRIDGE ENDS 3. POINT HAZARDS

Block out: 1. YES 2. NO — Rub rail: 1. YES 2. NO

BRIDGE APPROACH: REDUCE POST SPACING C32 (1. YES 2. NO); DOUBLE W-BEAM C33 (1. YES 2. NO)

END TREATMENTS: Begin C34; End C35
1. ANCHORED
2. NOT ANCHORED
3. TURN DOWN (B/A)
4. TURN DOWN (NOT B/A)
CRASHWORTH TERMINALS
5. SET1
6. SET2
7. MSET1
8. MSET2

POST BACKFILL MATERIAL C36: 2 (1. NON-COHESIVE 2. COHESIVE)

BOX 8 — MILE POINTS OF IMPROVEMENT

BEGINNING C37	ENDING C38
00/000	00/476

BOX 9 — DATE

Mo. C40	Dy. C41	Yr. C42
08	10	82

PROGRAM CONTROL DATA: 1 (1. END OF GROUP 2. END OF GROUP PROGRAM); 2 IBM CARD TYPE

FIGURE 47

CASE STUDY NO. 3 LISTING OF COMPUTER OUTPUT

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 = NH-100
DESIGN SPEED = 55 MPH
ADT = 5000

AUTOMOBILE SPLITS
4,450 (LB) = 60 %
2,250 (LB) = 30 %
1,750 (LB) = 10 %

ENVIROMENTAL CONDITIONS
DRY = 8 MO/YR
WET = 2 MO/YR
SUB-FREEZING = 2 MO/YR

SOCIETAL ACCIDENT COSTS
PDO = $ 1200
INJURY = $ 5900
FATAL = $ 427600

ECONOMIC FACTORS
PROJECT LIFE = 20.0 YRS
INTEREST RATE = 15.000 %

DATE = 7- 9-82

***** H A Z A R D *****								******* I M P R O V E M E N T *******											
HAZ NO	GR NO	HAZ CODE	SIDE OF ROAD	MILE-POST BEG	MILE-POST END	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	IMPR ALT	IMPR CODE	MILE-POST BEG	MILE-POST END	CLEAR ZONE (FT)	FIRST COST ($1000)	TOTAL HWY COST ($/YR)	HAZARD INDEX (INJ/YR)	TOTAL ACCIDENT COST ($/YR)	COST EFFECT RATIO ($/INJ)	BENEFIT COST RATIO
1	1	7- 2	1	1.000	1.076	0.0615	1330	1	3-1-2-2	0.989	1.083	12.0	3.3	707	0.0564	501	136420	1.17
1	1	7- 2	1	1.000	1.076	0.0615	1330	2	3-2-0-0	1.000	1.076	12.0	29.2	4665	0.0353	368	177974	0.21
1	1	7- 2	1	1.000	1.076	0.0615	1330	3	3-2-0-0	1.000	1.076	12.0	58.4	9330	0.0046	49	163784	0.14

8

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 SUMMARY AND CONCLUSIONS

The computer program in this study was developed to expedite the lengthy and tedious cost-effectiveness and benefit-cost computations for (a) installing cable guardrail on roadside embankments, (b) installing W-beam safety guardrail on roadside embankments, or (c) making embankment modifications. For example, investigating the feasibility of four embankment improvement alternatives requires less than 1-min. of computer execution time in comparison to an estimated four or five man-days of hand type calculations.

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 administratiors 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.

The results of the computer program were validated with the findings contained in NCHRP 148 (15). The main difference between the two studies is that the severities in NCHRP 148 were based on accident data, whereas, the severities in the computer program were based on an analyses of the vehicle accelerations obtained from (a) the vehicle-barrier computer model named BARRIER VII (7,8), and (b) the vehicle-terrain computer model named HVOSM (3). The findings in NCHRP 148 are limited in scope in that the severities (a) do not take into consideration vehicles size, impact speed, and encroachment angle (b) do not differentiate between "end" type W-beam guardrail impacts and "side" type impacts, and (c) are dependent only on the steepness of the front slope and do not take into consideration the height of the embankment, ditch width, and back slope.

In addition to validating the computer program results with NCHRP 148, detailed sensititivity studies were conducted to ascertain that the results from the computer program were reasonable and consistent with engineering judgment determinations.

The findings in this study showed that the installation of cable guardrail was, in all situations investigated, more attractive than the installation of W-beam safety guardrail. In fact, in some situtations, it was found that cable guardrail was attractive, whereas, W-beam guardrail was not attractive.

The findings in this study also showed that the configuration of the roadside embankment was a very significant factor in justifying the installation of guardrail. For example, on an interstate type highway, it was found that:

1. The installation of both cable guardrail and W-beam safety guardrail were justified on embankments with 2:1 front slopes.
2. The installation of cable guardrail and W-beam safety guardrail were not justified on embankments with 3:1 and flatter front slopes and "flat" runout ditch bottoms.
3. The ditch width and back slope were significant factors to take into consideration in the installation of both cable and W-beam safety guardrail.
   (a) Flattening the back slope from 2:1 to 4:1 will eliminate the need for the installation of cable guardrail and W-beam safety guardrail on embankments with front slopes of 3:1 and flatter and fill heights from 10 to 20 ft.
   (b) The installation of both cable guardrail and W-beam safety guardrail were justified on embankments with 3:1 and steeper front slopes, ditch widths less than 8 ft, and back slopes of 4:1 and steeper.
   (c) Irrespective of ditch width and back slope, the installation of cable guardrail and W-beam safety guardrail were not justified on embankments with front slopes of 4:1.

It is to be emphasized that the above findings were based on the assumption that there were no "point" hazards on or near the embankment such as culverts and trees. Just as the configuration of the embankment was found to be important in determining the need for the installation of guardrail, it is the opinion of the researchers that it is of equal or greater importance that point hazards also be taken into consideration.

RECOMMENDATIONS

8.2.1 Incorporate Program into NDR Road Design System

Because of the ease and rapidity in using the computer program to conduct a detailed analysis of each roadside embankment situation, it is the opinion of the researchers that there is no real need to attempt to develop generalized guardrail guidelines and policies. It is therefore recommended that NDR incorporate the computer program into their Road Design System currently being used.

8.2.2. Program Expansion

A flow chart of the MAIN PROGRAM, which was shown earlier in Figure 18, is shown again in Figure 48. As can be seen, the MAIN PROGRAM was subdivided into seven sub-main programs, names MAIN1, MAIN2, ..., and MAIN7. In this study, only the MAIN3 sub-main program on "Slope Hazards Only" was programmed. Ultimately, MAIN1 will encompass all of the preceding sub-main programs. The reason for the stage development of the program was to simplify the task in debugging the program.

The recommended sequence and estimated manpower requirements in the development of the remaining sub-main programs is shown in Table 24.

TABLE 24

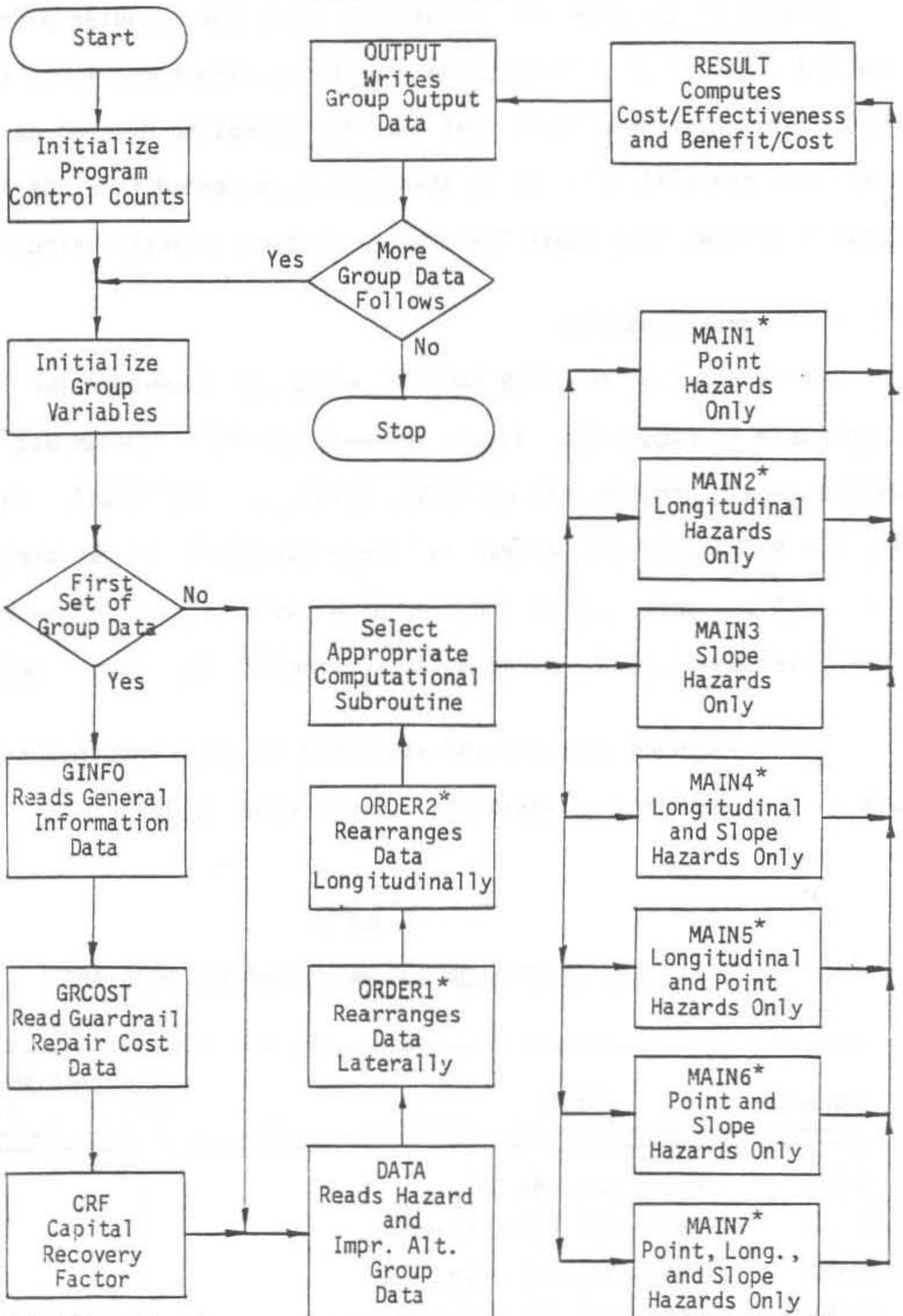
PLAN TO DEVELOP SUB-MAIN COMPUTER PROGRAMS

Sequence	Title	Time (man-mo)	
		Prof.	Students
MAIN1	Point Hazards Only	1	2
MAIN6	Point and Slope Hazards	2	3
MAIN2	Long. Hazards Only	1	2
MAIN4	Long. and Slope Hazards	2	3
MAIN5	Long. and Point Hazards	2	3
MAIN7	Point, Long., and Slope Hazards	4	4

FIGURE 48

FLOW CHART OF MAIN AND SUB-MAIN COMPUTER PROGRAMS

MAIN PROGRAM



* Not Programmed

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A P P E N D I X

A. 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

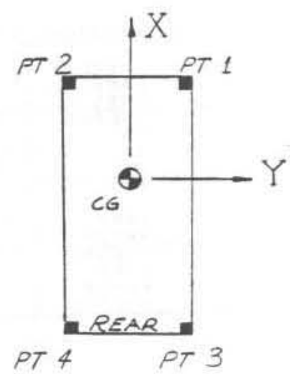
PHIO =	2.761	DEGREES	XCO' =	264.000	INCHES	PO =	0.0	DEG/SEC
THETAO=	-0.741	"	YCO' =	168.000	"	QO =	0.0	"
PSIO =	15.000	"	ZCO' =	92.232	"	RO =	0.0	"
PHIRO =	0.0	"	DELTA1=	0.0	"	D(PHIP)/DT=	0.0	"
PSIFIO=	0.0	"	DELTA2=	0.0	"	D(PSIF)/DT=	0.0	RAD/SC
			DELTA3=	0.0	"			

UO	=1232.000	IN/SEC
VO	= 0.0	"
WO	= 0.0	"
D(DEL1)/DT=	0.0	"
D(DEL2)/DT=	0.0	"
D(DEL3)/DT=	0.0	"

TIRE DATA		TERRAIN TABLE ARGUMENTS
KT	1098.000 LB/IN	
SIGMAT	= 3.000	
LAMBDAT	= 10.000	
AO	=4400.000	SOIL DAMPING= 0.001 SPI
A1	= 8.276	SOIL FRICT. = 0.250
A2	=2900.000	SSTIFF = 4000. LB/IN
A3	= 1.780	NO.X TEMPS. = 2
A4	=3900.000	NO.Y TEMPS. = 5
AMU	= 0.200	NO. VAR AMU = 1
OMEGT	= 1.000	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-NDP GUAPDPAIL STUDY      HVOSM SIMULATIONS ON EMBANKMENT FILLS
70 MPH AND 15 DEG ENCPOACHMENT (RUN NC. 130)  F.S.=3:1, H.S.=4:1

        PROGPAM CONTPOL 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
INDCPR                 =   -1   (=0.NO CUPR.=1 CUPR.=-1 STEER DEG.OF FREEDOM)
MODE OF INTEGRATION    =    1   (=0 VAR.ADAMS-MOULT.,=1 RUNGE-KUTTA.=2FIX.AM)
DTCMPI                 =   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          KF       = 100.000 LB./IN.
  B     = 64.4830   ''            KR       = 105.000 LB./IN.
  TF    = 61.0000   ''            CF'      =  30.000 LBS.
  TP    = 60.0000   ''            CP'      =  45.000 LBS.
  ZF    = 10.1380   ''          EPSILONF=     0.001 IN./SEC.
  ZR    = 12.0880   ''          EPSILONR=     0.001 IN./SEC.
  RHO   = -2.0000   ''            CF       =   3.500 LB-SEC/IN
  RW    = 14.0000   ''            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-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.	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	-1.409	26.43	2.50	7.50	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	-1.690	-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	4.57	-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	5.95	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

B. HVOSM TERRAIN LAYOUT (TYPICAL)

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UNL-NDR GUARDRAIL STUDY     HVOSM 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

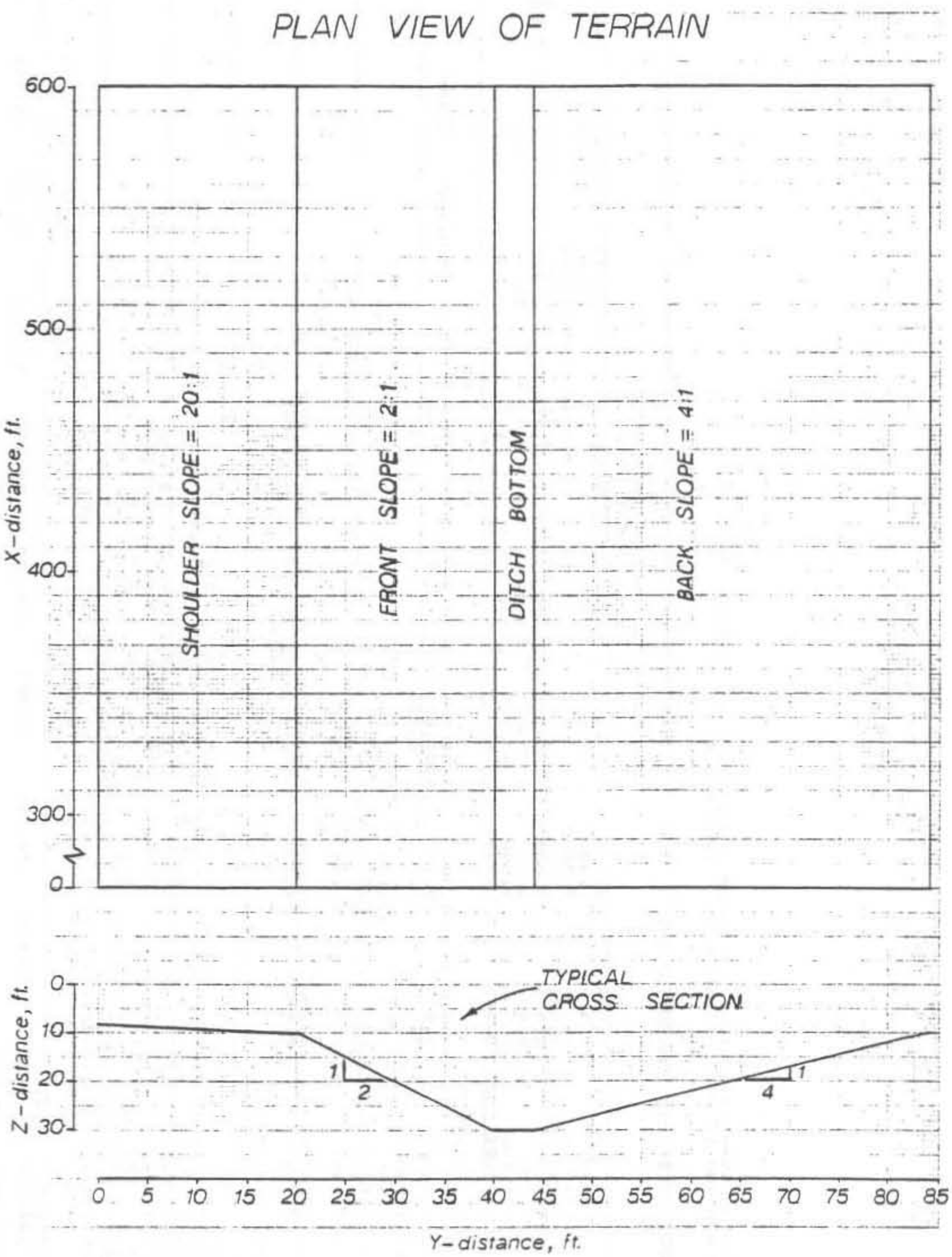
INPUT READ BY CALSVA

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       9.000     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
```



PLAN VIEW OF TERRAIN
600
500
400
300
0
X-distance, ft.
SHOULDER SLOPE = 20:1
FRONT SLOPE = 2:1
DITCH BOTTOM
BACK SLOPE = 4:1
TYPICAL CROSS SECTION
0
10
20
30
Z-distance, ft.
1
2
1
4
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Y-distance, ft.

A P P E N D I X

C. 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	ACCELERATIONS: 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	↓	↓	0.1	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	Front Slope to Ditch: Long. (G)	Front Slope to Ditch: Lat. (G)	Front Slope to Ditch: Vert. (G)	Front Slope to Ditch: SI	Ditch to Back Slope: Long. (G)	Ditch to Back Slope: Lat. (G)	Ditch to Back Slope: Vert. (G)	Ditch to Back Slope: SI	Max. Roll (deg)	Distance Airborne (ft)	Max. Speed (mph)	Heading @ Ditch Contact (deg)	Injury Prob. (%)
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	+22 -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					+17 -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					+15 -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	+17 -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	ACCELERATIONS: 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	+21 -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 -03		62.9	+34	20
	↓	30	↓	↓	3.2	0.0	1.5	0.6	—	—	—	—	+22 -31		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 -13		61.5	+13	16
	↓	20	↓	↓	2.3	1.4	4.0	0.8	1.2	1.4	5.0	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	+67	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 -07		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	3.6	0.6	+20 -19		64.1	+16	24
	↓	30	↓	↓	1.0	2.0	4.0	0.8	0.0	0.3	4.3	0.9	+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	5
	↓	20	↓	↓	0.1	0.1	2.0	0.3	—	—	—	—	+13 -06		63.2	[illegible]	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 -19		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

					ACCELERATIONS												
					Front Slope to Ditch				Ditch to Back Slope								
	Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	Long. (G)	Lat. (G)	Vert. (G)	S.I	Long. (G)	Lat. (G)	Vert. (G)	S.I	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	ACCELERATIONS: 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	+21 −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	ACCELERATIONS: 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 [illegible]

Speed (mph)	Run No.	Front Slope	Fill Ht. (ft)	Ditch Conf.	Back Slope	Front Slope to Ditch: Long (G)	Lat. (G)	Vert (G)	SI	Ditch to [illegible]: Long. (G)	Lat. (G)	Vert. (G)	SI	Max Roll (deg)	Distance Airborne (ft)	Max [illegible]	[illegible]	[illegible]
50	201	2:1	10	A	0:1	0.8	1.6	2.2	0.5									
60	202		10	(7.5°)		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	0:1	0.2	0.1	4.7	0.8									
60	205		10	(15°)		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	0:1	3.2	4.2	6.0	1.4									
60	208		10	(25°)		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	0:1	0.8	2.7	4.4	0.9									
60	211		20	(7.5°)		0.7	2.8	5.2	1.0									
70	212		20			0.6	2.4	5.2	1.0									
50	213	2:1	20	A	0:1	1.8	1.7	3.5	0.7									
60	214		20	(15°)		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	0:1	0.2	1.3	5.3	0.9									
60	217		20	(25°)		5.6	10.7	11.1	2.9									
70	218		20			4.7	8.2	9.7	2.4									

HVOSM Simulations on Embankment Fills

Speed	Run No.	Front Slope	Fill Ht. (ft)	Ditch Shape	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. [illegible]	Max. [illegible]	[illegible]
50	219	2:1	30	A	0:1	0.7	3.5	6.2	1.3									
60	220	↓	30	(7.5°)	↓	0.6	3.4	6.0	1.2									
70	221	↓	30	↓	↓	0.7	[illegible]	6.3	1.3									
50	222	2:1	30	A	0:1	2.7	1.4	5.1	1.0									
60	223	↓	30	(15°)	↓	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	0:1	3.7	2.8	4.5	1.1									
60	226	↓	30	(25°)	↓	[illegible]	1.9	5.1	1.1									
70	227	↓	30	↓	↓	0.9	0.9	9.1	1.5									
50	228	2:1	10	A	2:1	0.8	1.5	2.3	0.5	0.1	1.6	2.1	0.5					
60	229	↓	10	(7.5°)	↓	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	2:1	2.0	2.5	7.0	1.3	1.8	1.0	5.0	0.9					
60	232	↓	10	(15°)	↓	[illegible]	[illegible]	4.8	0.8	0.1	0.4	3.8	0.6					
70	233	↓	10	↓	↓	[illegible]	6.8	6.2	1.8	1.1	2.7	2.1	0.8					
50	234	2:1	10	A	2:1	8.8	13.4	7.3	3.2	0.5	3.7	2.5	0.9					
60	235	↓	10	(25°)	↓	7.7	[illegible]	7.4	2.9	0.7	2.5	4.2	0.9					
70	236	↓	10	↓	↓	7.3	[illegible]	7.6	2.8	0.8	0.5	10.6	1.8					

HVOSM Simulations [illegible]

	Run No.	Front Slope	Fill Ht. (ft)	Ditch [illegible]	Back [illegible]	ACCELERATIONS: Front [illegible] to Ditch: Long (G)	Lat. (G)	Vert. (G)	SI	Ditch [illegible]: Long (G)	Lat. (G)	Vert. (G)	SI	Max Ro. (deg)	Distance [illegible] (ft)	Min. [illegible]	[illegible] Ditch (ft)	Injury [illegible]
50	237	2:1	20	A	2:1	0.7	2.7	4.4	0.9	0.5	0.9	3.8	0.7					
60	238		20	(7.5)		[illegible]	3.8	5.2	1.0	0.5	1.0	4.5	0.5					
70	239	↓	20	↓	↓	0.6	2.4	5.2	1.0	0.5	1.3	4.1	0.7					
50	240	3:1	20	A	2:1	2.9	0.4	5.2	1.0	0.1	0.1	3.4	0.6					
60	241		20	(15°)		4.0	4.5	6.2	1.5	2.7	0.2	5.0	0.9					
70	242	↓	20	↓	↓	5.9	6.7	7.8	2.0	0.3	2.8	3.9	0.9					
50	243	2:1	20	A	2:1	7.3	8.3	8.7	2.4	0.1	0.3	2.9	0.5					
60	244		20	(25°)		5.6	10.7	11.1	2.9	1.1	0.5	6.0	1.0					
70	245	↓	20	↓	↓	12.1	21.5	5.4	4.7	0.7	8.8	4.4	1.9					
50	246	2:1	30	A	2:1	0.8	3.5	6.1	1.2	0.2	1.4	3.8	0.7					
60	247		30	(7.5)		0.7	3.6	6.1	1.2	0.5	1.8	6.8	1.2					
70	248	↓	30	↓	↓	0.8	3.7	6.5	1.3	0.5	1.9	6.5	1.2					
50	249	2:1	30	A	2:1	[illegible]	5.2	8.3	2.0	4.7	1.6	6.2	1.3					
60	250		30	(15°)		8.3	4.7	10.8	2.4	8.3	4.7	10.8	2.4					
70	251	↓	30	↓	↓	6.9	4.4	10.4	2.2	4.1	2.2	2.9	0.8					
50	252	2:1	30	A	2:1	5.1	4.5	6.0	1.5	3.9	0.4	8.7	1.6					
60	253		30	(25°)		10.0	9.9	9.4	2.9	[illegible]	3.6	9.7	1.8					
70	254	↓	30	↓	↓	[illegible]	6.2	10.0	3.0	2.4	[illegible]	7.3	1.3					

A P P E N D I X

D. 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

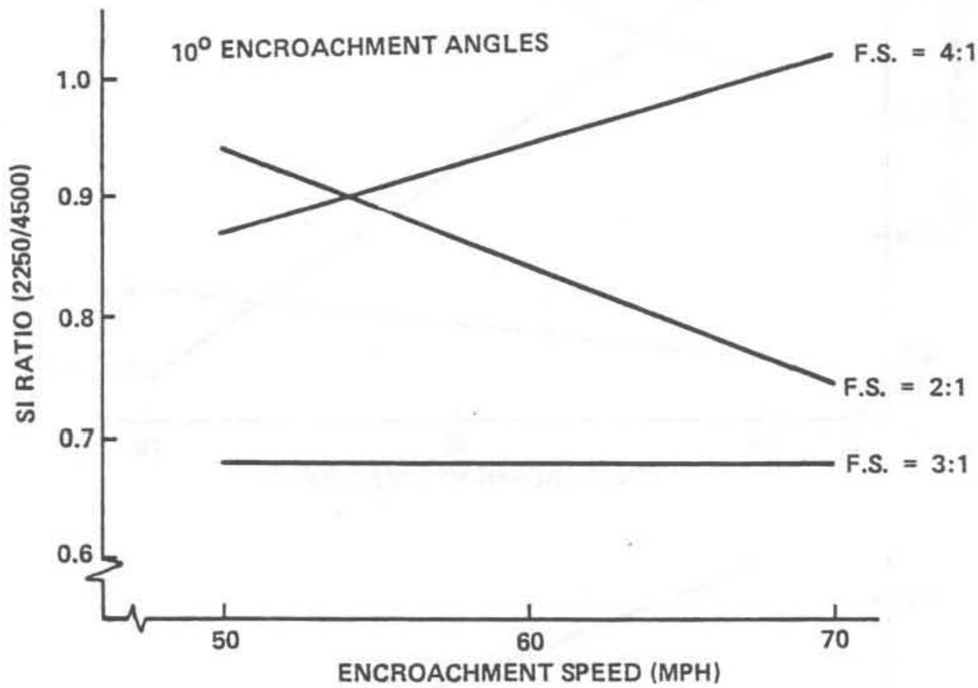
Adjustment factor to type B ditches = 0.81

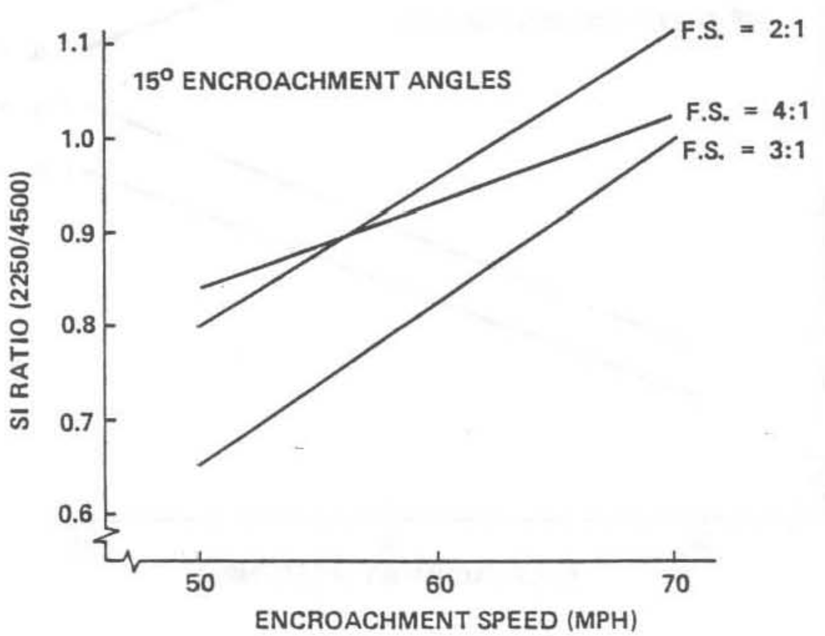
Adjustment factor to type C ditches = 0.70

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

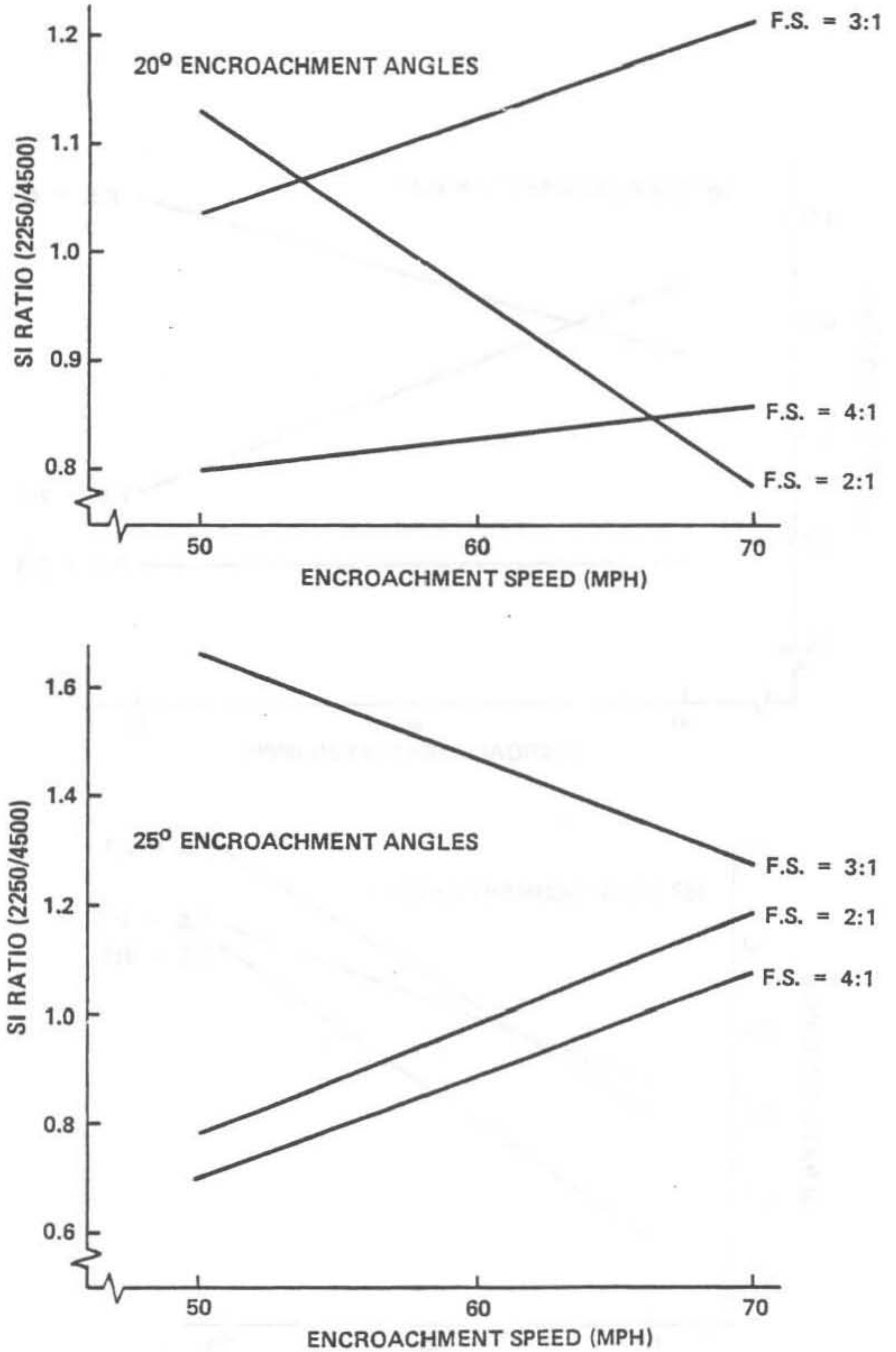
A P P E N D I X

E. FILL SLOPE SEVERITY-INDEX ADJUSTMENT FACTORS FOR COMPACT SIZE AUTOMOBILE





FILL SLOPE SEVERITY-INDEX ADJUSTMENT FACTORS



FILL SLOPE SEVERITY-INDEX ADJUSTMENT FACTORS

A P P E N D I X

F. 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)	=	1.340D 01	1.840D 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

INITIAL POSITION AND VELOCITIES OF AUTO

SPECIFIED BOUNDARY POINT	=	13
X ORDINATE OF POINT	=	800.00
Y ORDINATE OF POINT	=	0.0
ANGLE FROM X AXIS TO R AXIS (DEG)	=	15.00
VELOCITY IN R DIRECTION (M.P.H)	=	50.00
VELOCITY IN S DIRECTION (M.P.H)	=	0.0
ANGULAR VELOCITY (RAD/SEC)	=	0.0
MINIMUM RESULTANT VELOCITY (M.P.H)	=	5.00
TRANSLATIONAL KINETIC ENERGY (K.IN)	=	3831.87
ROTATIONAL KINETIC ENERGY (K.IN)	=	0.0
TOTAL INITIAL KINETIC ENERGY (K.IN)	=	3831.87

AUTO TRAJECTORY RESULTS

TIME = 0.0 SECS

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
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

BARRIER 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-GRD	Y-GRD	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-GRD	Y-GRD
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	-6.50	1	1
20	20	21	102	14.55	6.50	-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	-12.76	1	1
34	34	35	102	15.03	12.76	-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	1.06	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

<u>Posts (300 Series)</u>

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

APPENDIX

G. W-BEAM AND CABLE GUARDRAIL SEVERITY-INDEX EQUATIONS

Guardrail Type: AASHTO G1 (Cable)

Automobile Weight (lbs.)	Impact Angle (deg.)	Severity-Index Equations (V in mph)
4500	5	SI = 0.0083*V - 0.0293
	10	SI = 0.0125*V - 0.1292
	15	SI = 0.0100*V - 0.1529
	20	SI = 0.0073*V + 0.4960
	25	SI = 0.0183*V + 0.0833
2500	5	SI = 0.0200*V - 0.4963
	10	SI = 0.0193*V - 0.1990
	15	SI = 0.0233*V - 0.1733
	20	SI = 0.0326*V - 0.3910
	25	SI = 0.0333*V - 0.1333
1700	5	SI = 0.0240*V - 0.5956
	10	SI = 0.0232*V - 0.2388
	15	SI = 0.0280*V - 0.2080
	20	SI = 0.0391*V - 0.4692
	25	SI = 0.0400*V - 0.1600

Guardrail Type: AASHTO G4(2W), G4(1W) (W-beam)

Automobile Weight (lbs.)	Impact Angle (deg.)	Severity-Index Equations (V in mph)	12'-06" Adjustment
4500	5	SI = 0.0148*V - 0.2660	0.89
	10	SI = 0.0123*V - 0.0470	0.91
	15	SI = 0.0122*V - 0.2470	0.93
	20	SI = 0.0145*V - 0.1678	1.01
	25	SI = 0.0173*V - 0.1827	1.12
2500	5	SI = 0.0188*V - 0.3908	0.89
	10	SI = 0.0208*V - 0.3025	0.91
	15	SI = 0.0235*V - 0.2050	0.93
	20	SI = 0.0255*V - 0.1650	1.01
	25	SI = 0.0288*V - 0.1342	1.12
1700	5	SI = 0.0248*V - 0.5159	1.03
	10	SI = 0.0275*V - 0.3993	1.06
	15	SI = 0.0310*V - 0.2706	1.08
	20	SI = 0.0337*V - 0.2178	1.17
	25	SI = 0.0380*V - 0.1771	1.30

A P P E N D I X

H. ULTIMATE BENDING STRESSES IN W-BEAM GUARDRAIL POSTS UNDER FROZEN SOIL CONDITIONS

WEIGHT = 4500 lbs.

GR Height = 27 in.

A = 0.45

L = 19.0 ft.

2B = 6.6 ft.

Computed Bending Stresses (psi)

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1280	2610	3950	5320	6750
50	2010	4070	6180	8320	10470
60	2890	5870	6910	11980	15080
70	3940	7980	12110	16350	20530
80	5130	10580	15820	21290	26810

Weight = 4500 lbs.

GR Height = 24 in.

Computed Bending Stresses (psi)

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1100	2230	3400	4500	5750
50	1720	3490	5300	7130	9000
60	2480	5030	7630	10260	12930
70	3360	6840	10400	14000	17600
80	4390	1065	13500	18250	22980

WEIGHT = 2500 lbs.

GR Height = 27 in.

A = 0.45

L = 14.7 ft.

2B = 5.5 ft.

Computed Bending Stresses (psi)

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	920	1880	2850	3840	4840
50	1440	2940	4460	6010	7580
60	2075	4230	6440	8600	10910
70	2830	5750	8740	11770	14840
80	3700	7510	11400	15370	19390

Weight = 2500 lbs.

GR Height = 24 in.

Computed Bending Stresses (psi)

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	790	1610	2440	3290	4150
50	1240	2520	3820	5150	6490
60	1760	3620	5520	7410	9350
70	2430	4925	7490	10090	12720
80	3170	6440	9770	13175	16620

WEIGHT = 1700 lbs.

GR Height = 27 in.

A = 0.45

L = 12.7 ft.

2B = 4.8 ft.

Computed Bending Stresses (psi)

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	750	1530	2310	3120	3930
50	1170	2370	3610	4870	6140
60	1690	3420	5200	7010	8850
70	2290	4650	7080	9540	12040
80	2990	6090	9250	12470	15730

Weight = 1700 lbs.

GR Height = 24 in.

Computed Bending Stresses (psi)

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	640	1310	1980	2680	3380
50	1010	2440	3100	4175	5260
60	1450	2930	4460	6010	7590
70	1960	3990	6070	8180	10320
80	2570	5220	7920	10680	13460

APPENDIX

I. SEVERITY-INDEX ADJUSTMENT FACTORS FOR W-BEAM GUARDRAIL

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 4500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 27 in.

Block-Out = Yes

Rub-Rail = No

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Wet

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.0	1.0	0.95	0.90	0.90
50	1.0	0.95	0.95	0.90	0.85
60	1.0	0.95	0.90	0.85	5.00*
70	1.0	0.95	0.85	5.00*	5.00*
80	0.95	0.90	0.85	5.00*	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 4500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 27 in.

Block-Out = Yes

Rub-Rail = Yes

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Wet

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.0	1.0	0.95	0.90	0.90
50	1.0	0.95	0.95	0.90	0.85
60	1.0	0.95	0.90	0.85	5.00*
70	1.0	0.95	0.85	5.00*	5.00*
80	0.95	0.90	0.85	5.00*	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 2500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 27 in.

Block-Out = Yes

Rub-Rail = No

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Wet

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.0	1.0	0.95	0.95	0.95
50	1.0	1.0	0.95	0.95	0.90
60	1.0	1.0	0.95	0.90	2.00**
70	1.0	0.95	0.90	2.00**	2.00**
80	1.0	0.95	0.90	2.00**	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 2500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 27 in.

Block-Out = Yes

Rub-Rail = Yes

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Wet

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.0	1.0	0.95	0.95	0.95
50	1.0	1.0	0.95	0.95	0.90
60	1.0	1.0	0.95	0.90	0.85
70	1.0	0.95	0.90	0.90	0.85
80	1.0	0.95	0.90	0.85	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 1700 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 27 in.

Block-Out = Yes

Rub-Rail = No

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Wet

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.0	1.0	1.0	0.95	0.95
50	1.0	1.0	0.95	0.95	0.90
60	1.0	1.0	0.95	0.95	2.50**
70	1.0	0.95	0.95	2.50**	2.50**
80	1.0	0.95	0.95	2.50**	2.50**

* Vaulting/Penetration

** Snagging

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 1700 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 27 in.

Block-Out = Yes

Rub-Rail = Yes

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Wet

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.0	1.0	1.0	0.95	0.95
50	1.0	1.0	0.95	0.95	0.90
60	1.0	1.0	0.95	0.95	0.90
70	1.0	0.95	0.95	0.90	0.85
80	1.0	0.95	0.95	0.90	0.85

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 4500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 24 in.

Block-Out = Yes

Rub-Rail = No

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Wet

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.0	1.0	0.95	0.90	0.90
50	1.0	0.95	0.95	0.90	5.00*
60	1.0	0.95	0.90	5.00*	5.00*
70	1.0	0.95	0.85	5.00*	5.00*
80	0.95	0.90	5.00*	5.00*	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 2500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 24 in.

Block-Out = Yes

Rub-Rail = No

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Wet

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.0	1.0	1.0	0.95	0.95
50	1.0	1.0	0.95	0.95	0.90
60	1.0	0.95	0.95	0.90	0.85
70	1.0	0.95	0.90	0.90	5.00*
80	1.0	0.95	0.90	5.00*	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 1700 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 24 in.

Block-Out = Yes

Rub-Rail = No

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Wet

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.0	1.0	1.0	0.95	0.95
50	1.0	1.0	0.95	0.95	0.90
60	1.0	1.0	0.95	0.95	0.90
70	1.0	0.95	0.95	0.90	0.85
80	1.0	0.95	0.95	0.90	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 4500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 27 in.

Block-Out = Yes

Rub-Rail = No

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Frozen

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.07	1.20	1.30	1.41	1.51
50	1.20	1.33	1.49	1.62	5.00*
60	1.24	1.44	1.66	5.00*	5.00*
70	1.30	1.59	5.00*	5.00*	5.00*
80	1.36	5.00*	5.00*	5.00*	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 4500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 27 in.

Block-Out = Yes

Rub-Rail = Yes

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Frozen

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.07	1.20	1.30	1.41	1.51
50	1.20	1.33	1.49	1.62	5.00*
60	1.24	1.44	1.66	5.00*	5.00*
70	1.30	1.59	5.00*	5.00*	5.00*
80	1.36	5.00*	5.00*	5.00*	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 2500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 27 in.

Block-Out = Yes

Rub-Rail = No

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Frozen

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.07	1.15	1.22	1.30	1.38
50	1.10	1.24	1.34	1.46	1.58
60	1.18	1.31	1.50	1.65	5.00*
70	1.22	1.44	1.67	5.00*	5.00*
80	1.28	1.57	5.00*	5.00*	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 2500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 27 in.

Block-Out = Yes

Rub-Rail = Yes

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Frozen

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.07	1.15	1.22	1.30	1.38
50	1.10	1.24	1.34	1.46	1.58
60	1.18	1.31	1.50	1.65	5.00*
70	1.22	1.44	1.67	5.00*	5.00*
80	1.26	1.57	5.00*	5.00*	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 1700 lbs.
Guardrail Type = W-Beam
Post Spacing = 6 ft. 3 in.
Rail Height = 27 in.
Block-Out = Yes
Rub-Rail = No
Terrain Slope = 8 : 1
Soil Type = Cohesive
Soil Condition = Frozen

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.06	1.10	1.16	1.25	1.29
50	1.13	1.17	1.28	1.38	1.46
60	1.12	1.26	1.40	2.50**	2.50**
70	1.18	1.36	1.55	2.50**	5.00*
80	1.24	1.47	2.50**	5.00*	5.00*

* Vaulting/Penetration

** Snagging

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 1700 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 27 in.

Block-Out = Yes

Rub-Rail = Yes

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Frozen

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.06	1.10	1.16	1.25	1.29
50	1.13	1.17	1.28	1.38	1.46
60	1.12	1.26	1.40	1.53	1.68
70	1.18	1.36	1.55	1.73	5.00*
80	1.24	1.47	1.71	5.00*	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 4500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 24 in.

Block-Out = Yes

Rub-Rail = No

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Frozen

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.07	1.20	1.30	1.41	1.51
50	1.20	1.33	1.49	1.62	1.80
60	1.24	1.44	1.66	5.00*	5.00*
70	1.30	1.59	5.00*	5.00*	5.00*
80	1.36	1.80	5.00*	5.00*	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 2500 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 24 in.

Block-Out = Yes

Rub-Rail = No

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Frozen

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.07	1.15	1.22	1.30	1.38
50	1.10	1.24	1.34	1.46	1.58
60	1.18	1.31	1.50	1.65	1.84
70	1.22	1.44	1.67	5.00*	5.00*
80	1.23	1.57	5.00*	5.00*	5.00*

* Vaulting/Penetration

SEVERITY-INDEX ADJUSTMENT FACTORS

Automobile Weight = 1700 lbs.

Guardrail Type = W-Beam

Post Spacing = 6 ft. 3 in.

Rail Height = 24 in.

Block-Out = Yes

Rub-Rail = No

Terrain Slope = 8 : 1

Soil Type = Cohesive

Soil Condition = Frozen

Impact Angle (deg)

Speed (mph)	5	10	15	20	25
40	1.06	1.10	1.16	1.25	1.29
50	1.13	1.17	1.28	1.38	1.46
60	1.12	1.26	1.40	1.53	1.68
70	1.18	1.36	1.55	1.73	5.00 *
80	1.24	1.47	1.71	5.00 *	5.00 *

* Vaulting/Penetration

A P P E N D I X

J. DISCUSSIONS OF SWRI AND TTI COST-EFFECTIVENESS COMPUTER PROGRAMS

EVALUATION
of
SwRI COST-EFFECTIVENESS PROGRAM

The design and selection procedures in NCHRP 118 (21) and the AASHTO (11) design guide policies specify that the minimum unobstructed distances behind cable guardrail must be equal to or greater than (a) 12 ft for the G1 design (operational status), and (b) 7 ft for the GR 1 design (R&D status).

The meaning of the phrase "minimum unobstructed distance" for guardrail use on roadside embankments is ambiguous. An attempt to define the meaning of this phrase was made by the Southwest Research Institute, SwRI (10) in a recent FHWA report, entitled "Development of a Cost-Effectiveness Model for Guardrail Selection". In their model, SwRI idealized an embankment as a fictitious fixed obstacle located 5 ft behind the guardrail. SwRI then assumed that under those vehicle impact conditions in which the unobstructed deflections of the guardrail were greater than the distance between the guardrail and the obstacle that the severity of the impact would produce 50% fatalities and 50% injuries. In our estimation, both of these assumptions made by the SwRI are oversimplified and unreasonable.

The full-scale vehicle crash tests conducted by New York (22) demonstrated that cable guardrail performed satisfactorily in redirecting a standard size automobile even though the guardrail deflections extended out as far as 9.5 ft beyond the hinge point of a steep 2 to 1 embankment. Therefore, it is clearly evident that the assumptions made by SwRI were not compatible with the test results of New York. The 5 ft deflection and the high injury severity limits imposed by SwRI in their model would unnecessarily restrict the use of cable guardrail on embankments.

The SwRI model handles both "real" fixed obstacles (i.e., bridge piers) and "fictitious" fixed obstacles (i.e., embankments) in the same manner in defining the injury severities of 50% fatalities and 50% injuries whenever the deflected guardrail would bottom-out on the obstacle. For real fixed obstacles, this assumption is apparently an attempt to account for vehicle wheel shagging; whereas, for embankments, this assumption is apparently an attempt to account for vehicle vaulting and/or rollover for guardrail deflections greater than 5 ft. This assumption for cable guardrail on embankments is unreasonable based on the full-scale test results of New York discussed earlier; however, for W-beam guardrail with 12 ft-6 in. post spacings, this assumption would be reasonable for some high-speed and high-angle impacts as demonstrated by California (12) in conducting full-scale crash tests with a standard size automobile. Likewise, for real fixed obstacles the assumption made by SwRI is oversimplified because no attempt was made to account for the degree of snagging. For example, the severity for guardrail deflections of several inches past the obstacle would certainly be much lower than the severity for guardrail deflections of several feet past the obstacle.

The SwRI cost-effectiveness model contains other oversimplified assumptions when computing benefit-cost ratios. In order to compute a benefit-cost ratio, the severity of the existing fixed obstacle or embankment must be determined prior to the installation of guardrail. The SwRI assumed from limited accident data that the severity of (a) impacting a fixed obstacle would produce 50% fatalities and 50% injuries, and (b) traversing an embankment would produce 5% fatalities and 50% injuries. Assuming a severity for impacting a fixed obstacle was unnecessary because a simple model such as that developed by Emori (23) could have been used. The Emori model takes into consideration impact speed and vehicle size in terms of front-end crushing stiffness. Likewise, assuming a severity for traversing an embankment was unnecessary because the HVOSM versions of the FHWA (24) or the Texas Transportation Institute (3) could have been used. The HVOSM takes into consideration vehicle design and tire characteristics, encroachment speeds and angles, as well as a 3-dimensional description of the embankment (front slope, fill height, ditch shape, and back slope). Computing severities by these two models would have at least been consistent with the procedure used by SwRI in determining unobstructed guardrail impact severities using the BARRIER VII program (6,7).

EVALUATION
of
TTI COST-EFFECTIVENESS PROGRAM

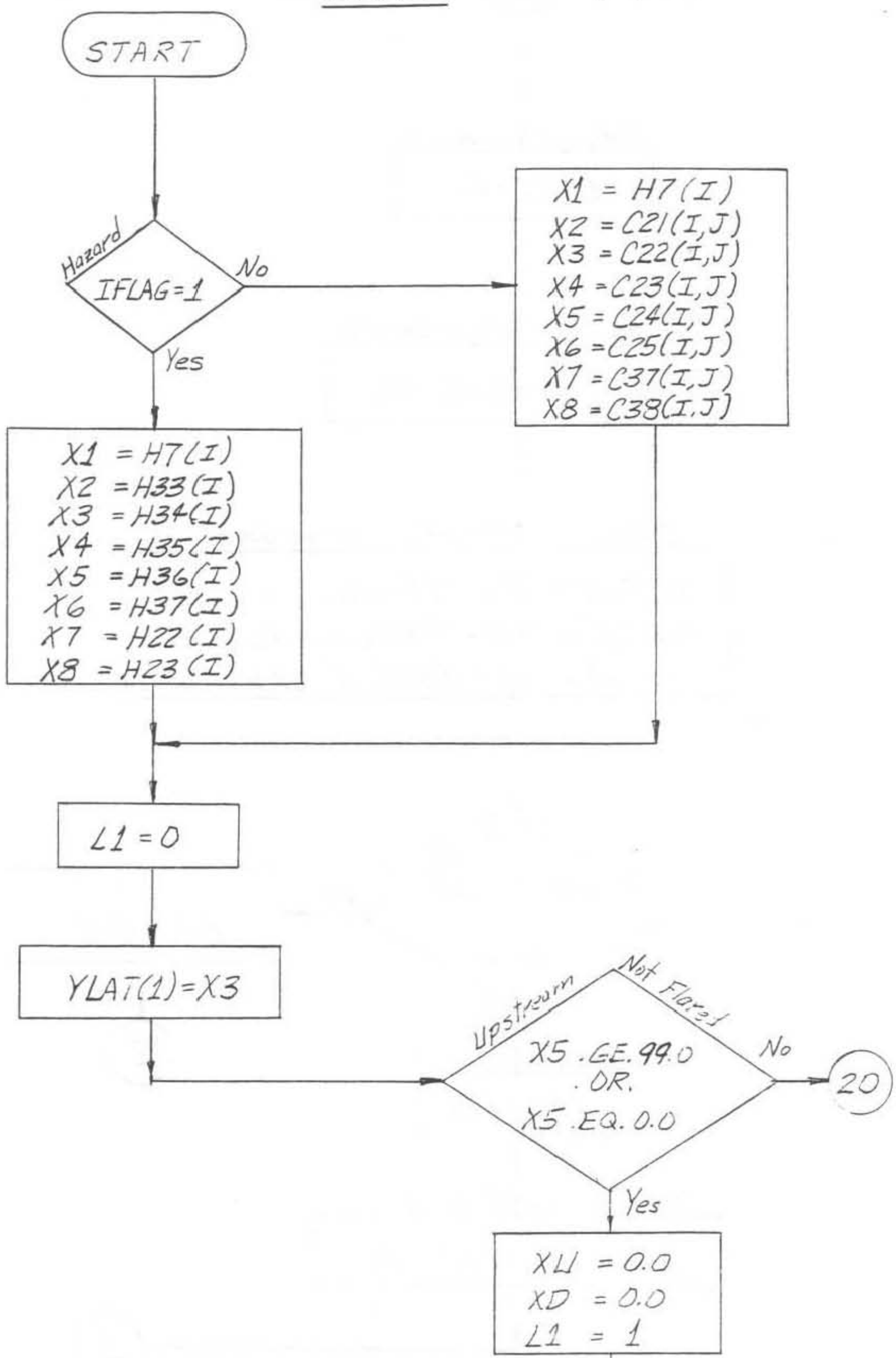
In the cost-effectiveness program developed by the TTI (13), the impact severities of vehicles impacting roadside obstacles or traversing embankments were based upon the judgment determinations of professionals in fields related to highway safety, design, operations, maintenance, law enforcement, and administration. This was accomplished by the circulation of a questionnaire requesting that the respondents estimate the severity of 52 roadside hazards and conditions on a scale from 0 to 10. A rating of 0 indicated negligible injury to vehicle occupants, whereas, a rating of 10 indicated a probable fatality.

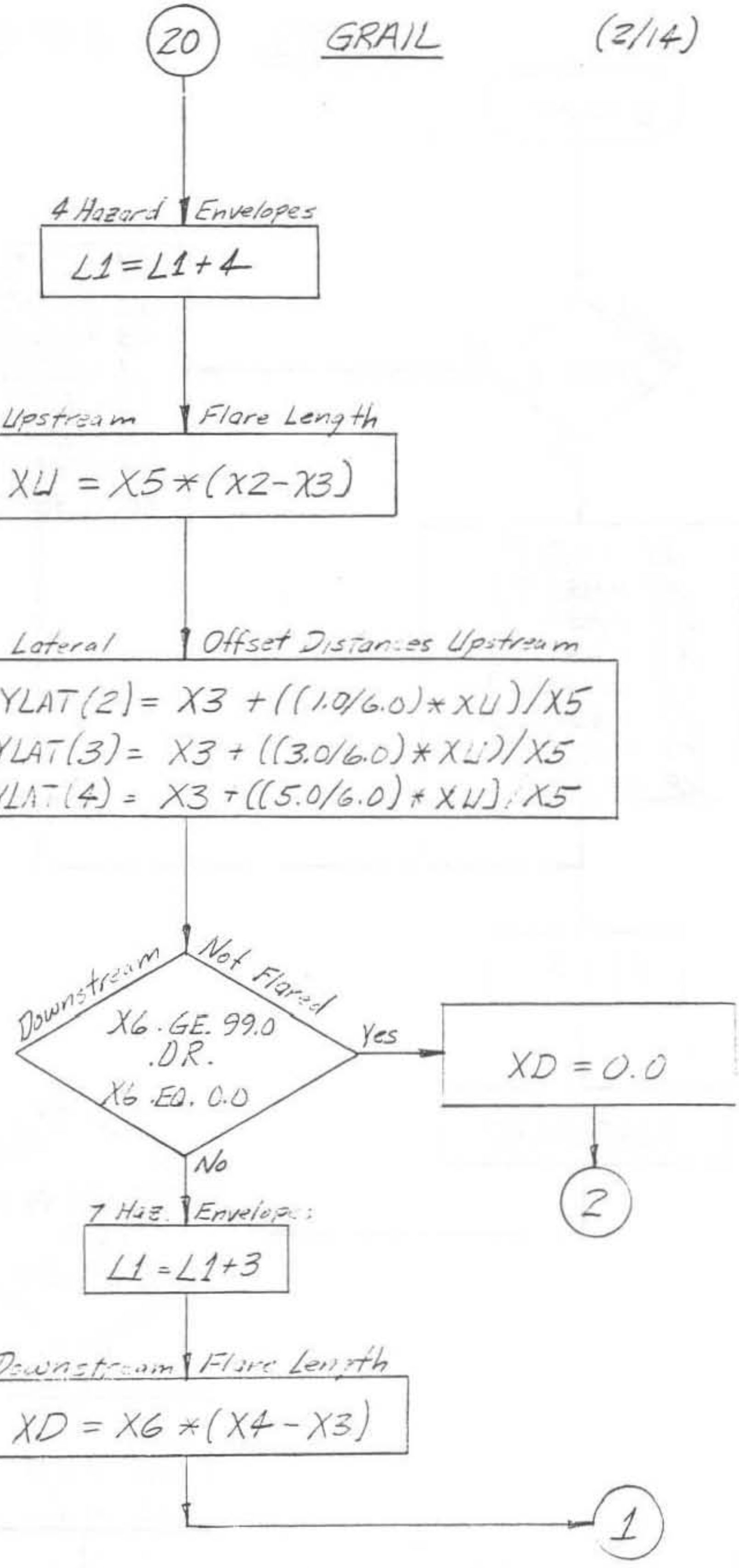
The TTI procedure of determing severities is unquestionably much more sound than the procedure used by SwRI (10). However, it is our opinion that using computer models such as BARRIER VII (6,7) and HVOSM (24,3) will produce more realistic estimates of impact severities. The cost-effectiveness program developed by UNL and NDR (20) was a refinement of the TTI program by using computer models to determine impact severities.

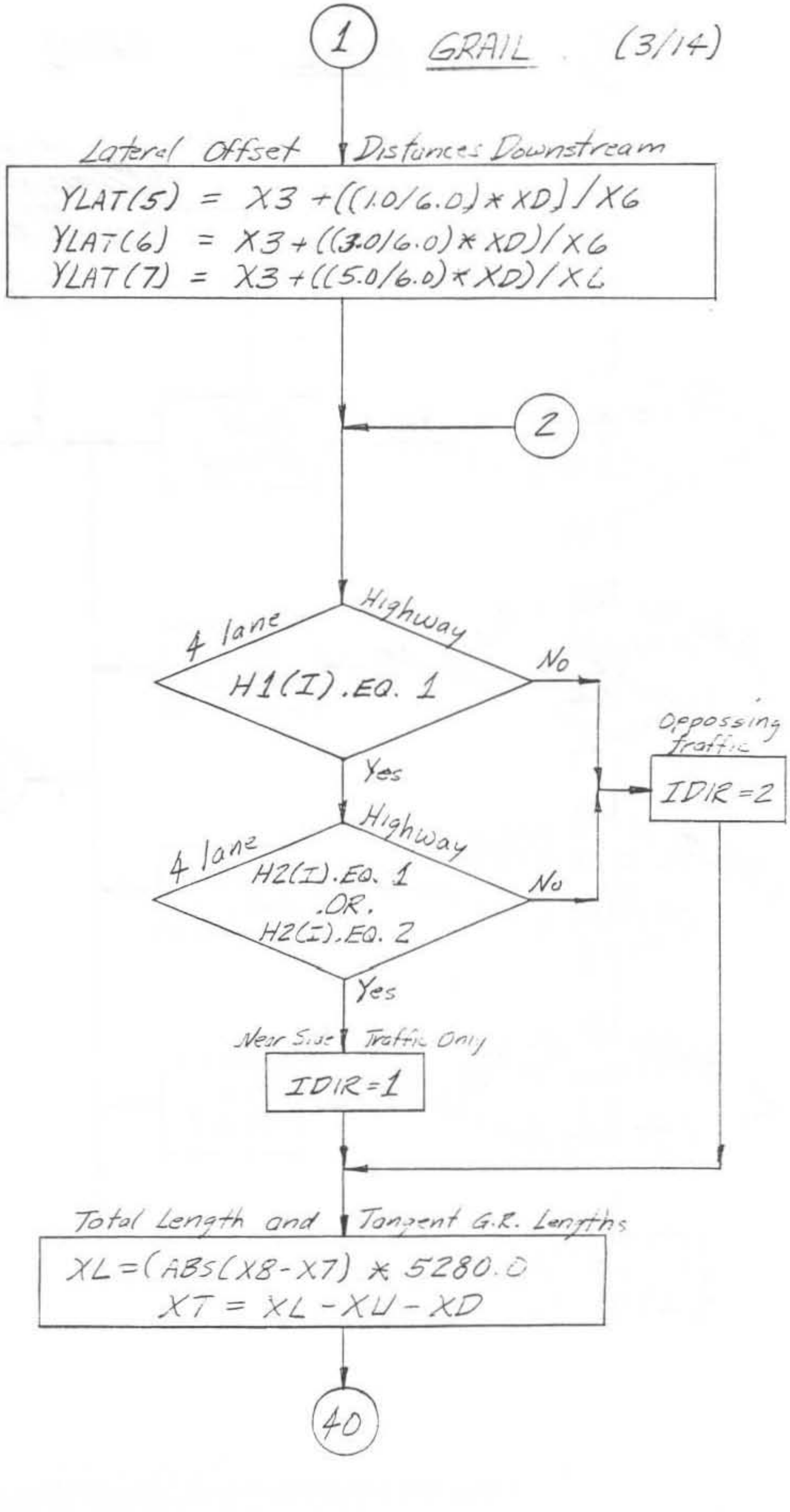
A P P E N D I X

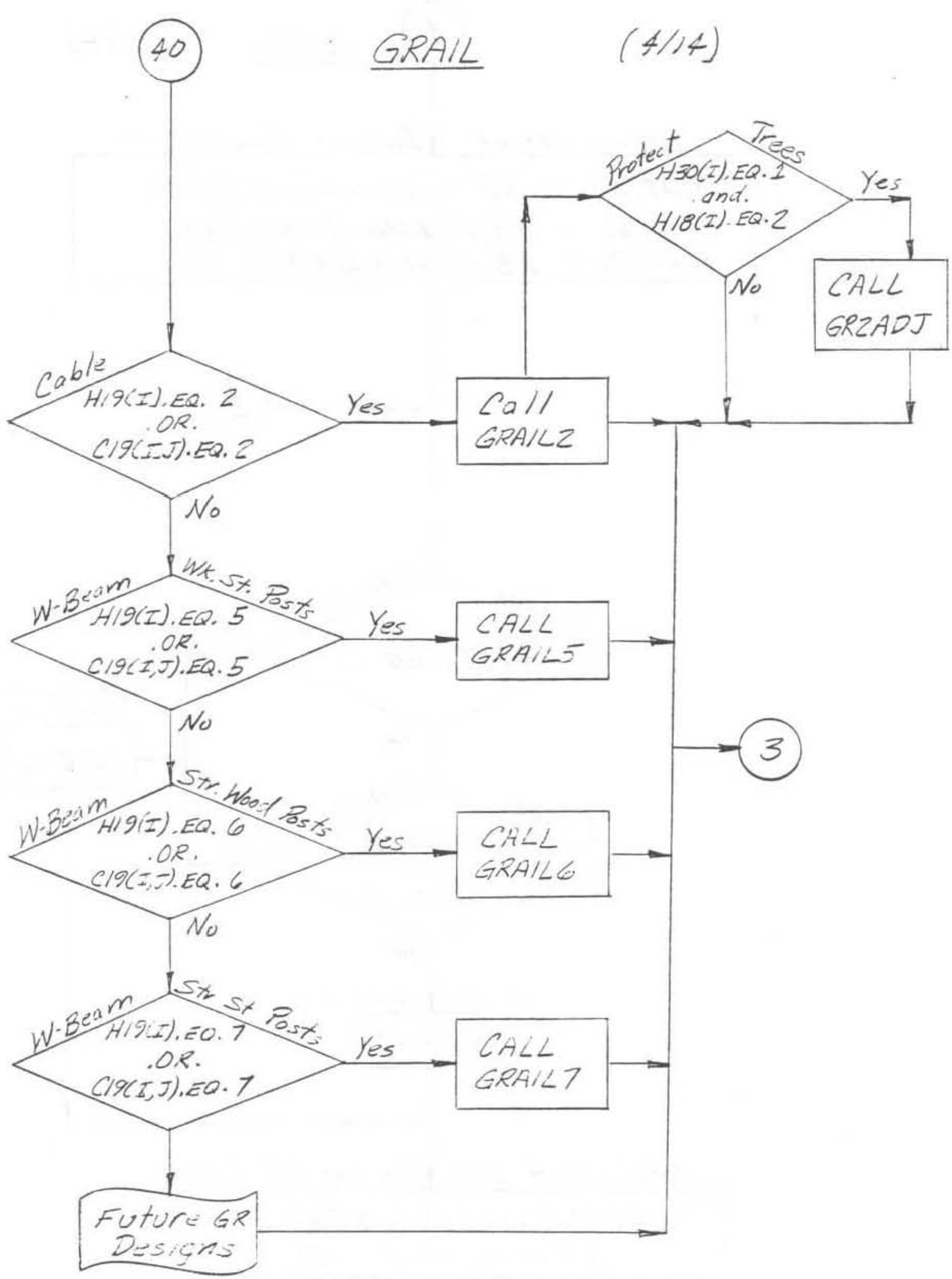
K. FLOW CHARTS OF COMPUTER PROGRAM

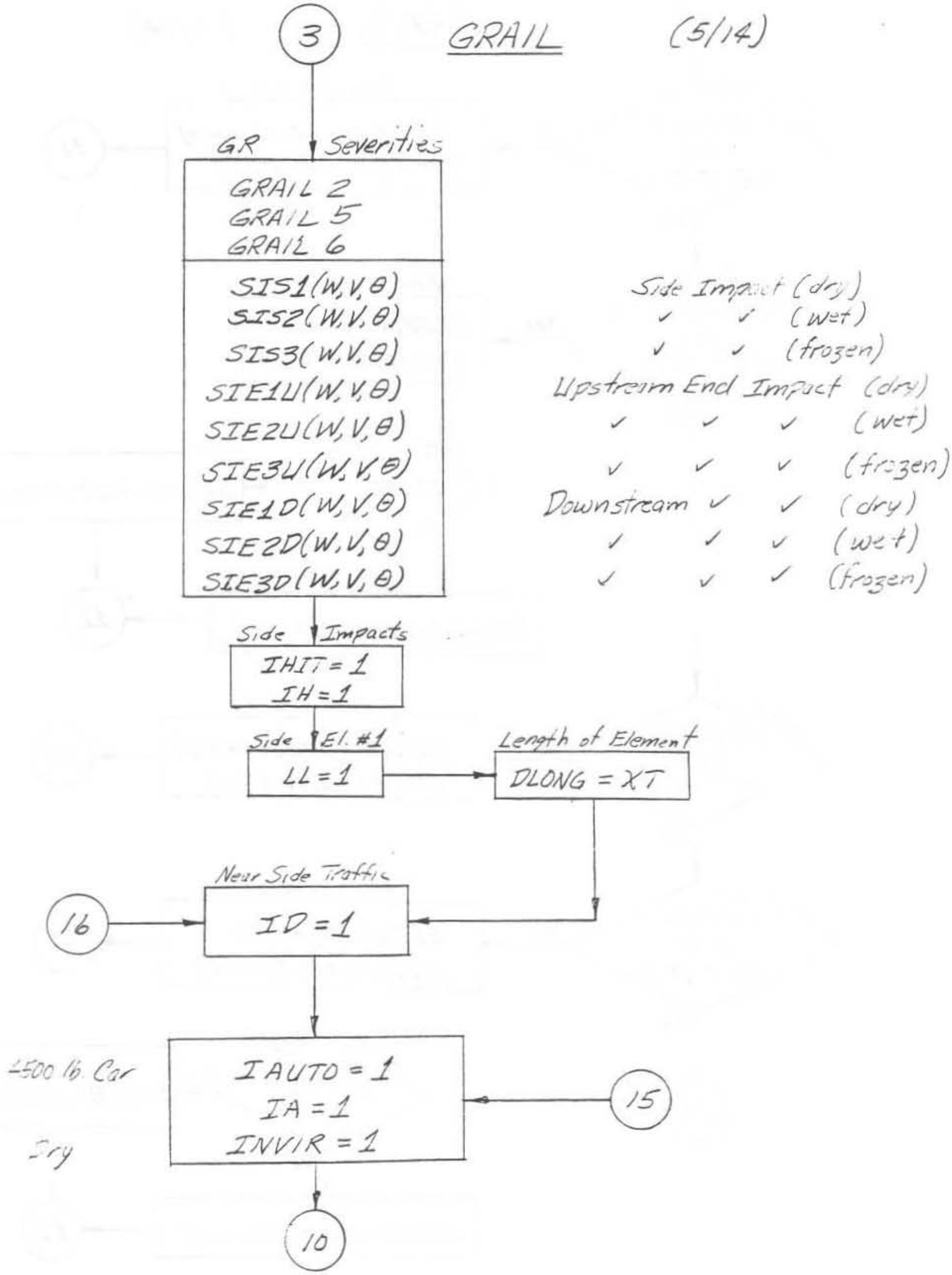
GRAIL (1/14)


START
Hazard
IFLAG=1
No
Yes
X1 = H7(I)
X2 = C21(I,J)
X3 = C22(I,J)
X4 = C23(I,J)
X5 = C24(I,J)
X6 = C25(I,J)
X7 = C37(I,J)
X8 = C38(I,J)
X1 = H7(I)
X2 = H33(I)
X3 = H34(I)
X4 = H35(I)
X5 = H36(I)
X6 = H37(I)
X7 = H22(I)
X8 = H23(I)
L1 = 0
YLAT(1)=X3
Upstream
Not Flared
X5 .GE. 99.0
.OR.
X5 .EQ. 0.0
No
20
Yes
XU = 0.0
XD = 0.0
L1 = 1
2

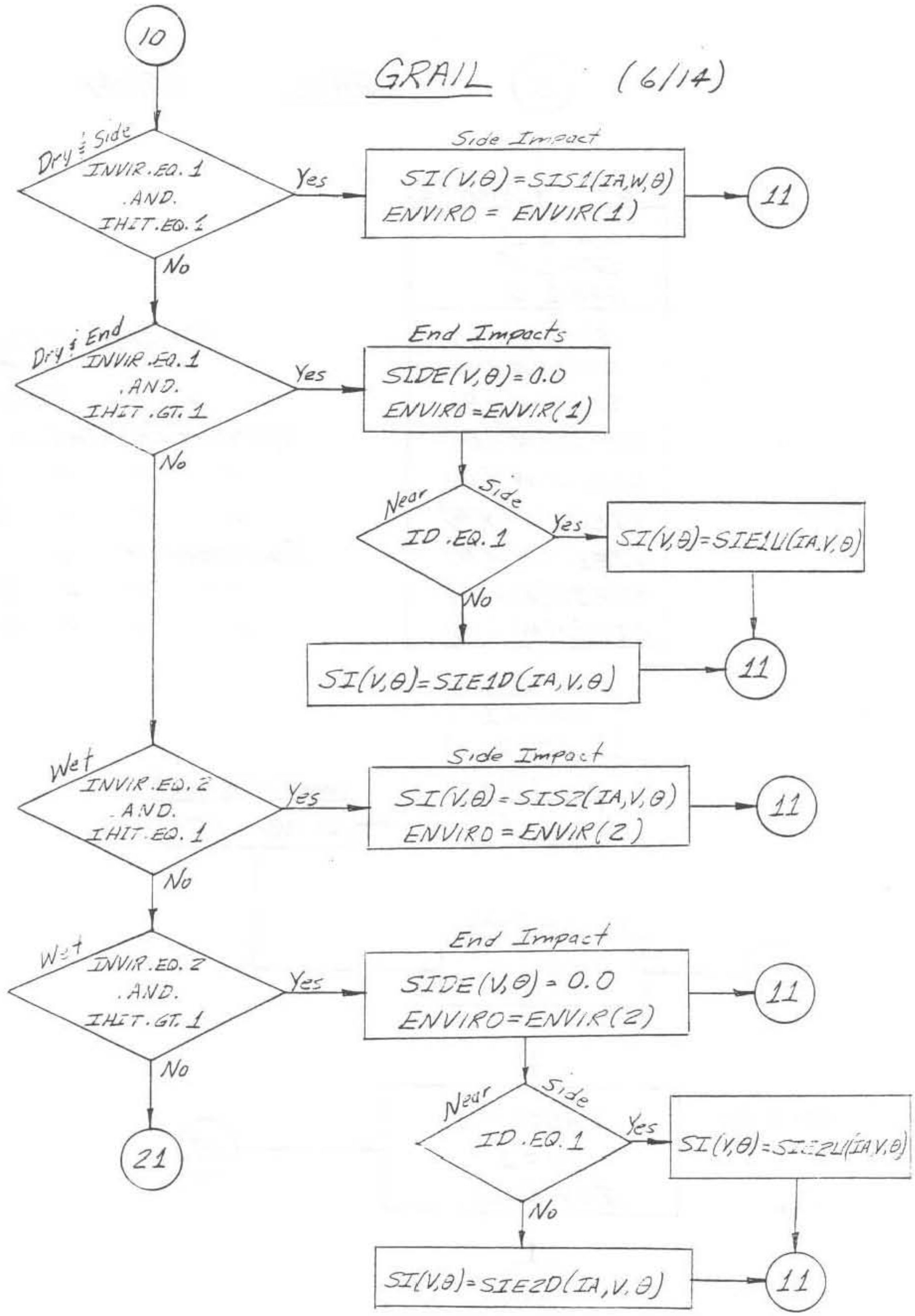

20
GRAIL
(2/14)
4 Hazard Envelopes
L1=L1+4
Upstream Flare Length
XU = X5 * (X2-X3)
Lateral Offset Distances Upstream
YLAT(2)= X3 +((1.0/6.0)*XU)/X5
YLAT(3)= X3 + ((3.0/6.0)*XU)/X5
YLAT(4) = X3 +((5.0/6.0)*XU)/X5
Downstream Not Flared
X6 .GE. 99.0
.OR.
X6 .EQ. 0.0
Yes
XD = 0.0
2
No
7 Haz. Envelopes
L1 =L1+3
Downstream Flare Length
XD = X6 *(X4-X3)
1


1
GRAIL (3/14)
Lateral Offset Distances Downstream
YLAT(5) = X3 +((1.0/6.0) * XD)/X6
YLAT(6) = X3+((3.0/6.0) * XD)/X6
YLAT(7) = X3+((5.0/6.0) * XD)/X6
2
4 lane Highway
H1(I).EQ. 1
No
Yes
Opposing traffic
IDIR = 2
4 lane Highway
H2(I).EQ. 1
.OR.
H2(I).EQ. 2
No
Yes
Near Side Traffic Only
IDIR = 1
Total Length and Tangent G.R. Lengths
XL = (ABS(X8-X7) * 5280.0
XT = XL - XU - XD
40

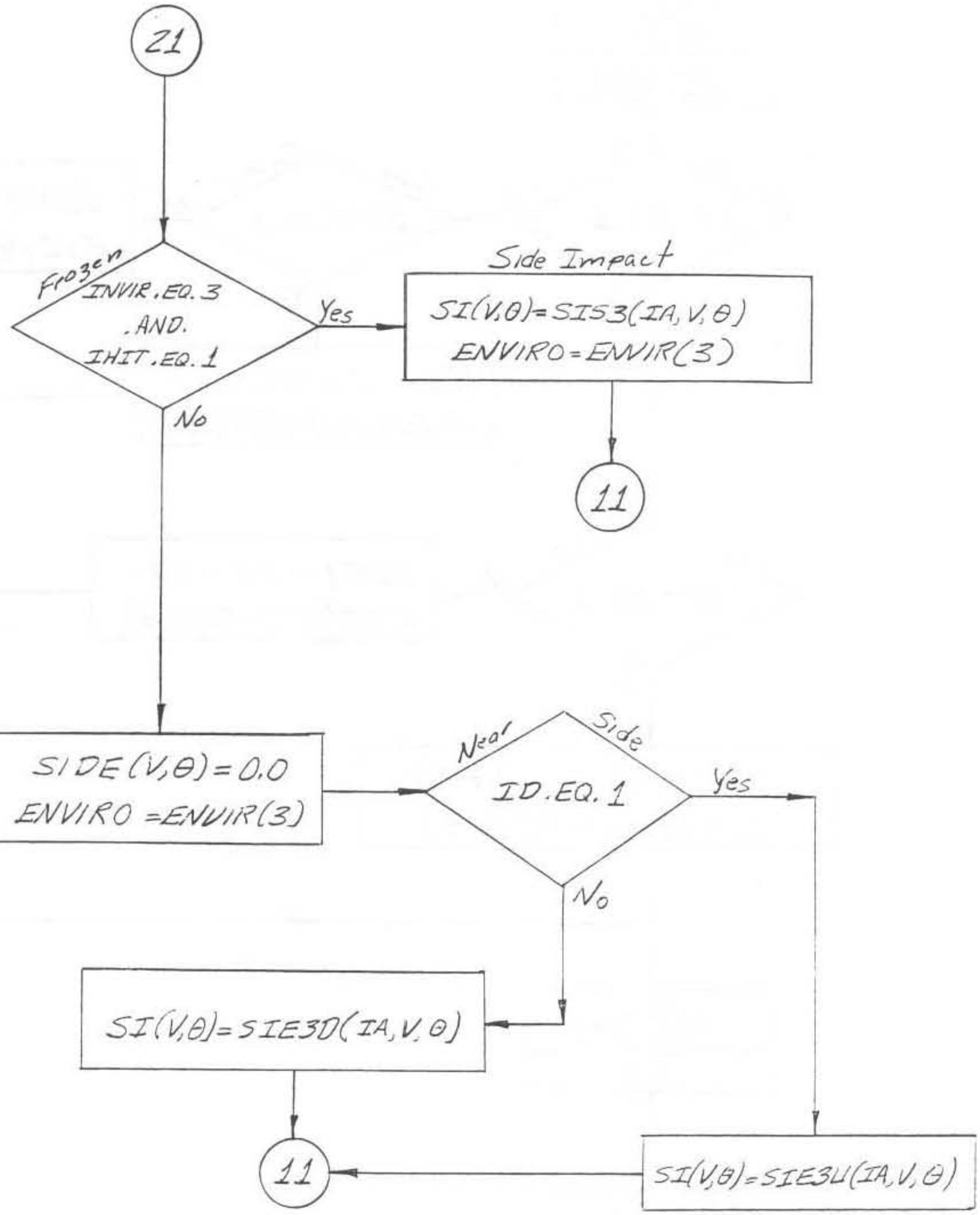

40
GRAIL
(4/14)
Protect Trees
H30(I).EQ.1
.and.
H18(I).EQ.2
Yes
No
CALL
GR2ADJ
Cable
H19(I).EQ. 2
.OR.
C19(I,J).EQ. 2
Yes
Call
GRAIL2
No
W-Beam
Wk. St. Posts
H19(I).EQ. 5
.OR.
C19(I,J).EQ. 5
Yes
CALL
GRAIL5
No
3
W-Beam
Str. Wood Posts
H19(I).EQ. 6
.OR.
C19(I,J).EQ. 6
Yes
CALL
GRAIL6
No
W-Beam
Str St Posts
H19(I).EQ. 7
.OR.
C19(I,J).EQ. 7
Yes
CALL
GRAIL7
Future GR
Designs

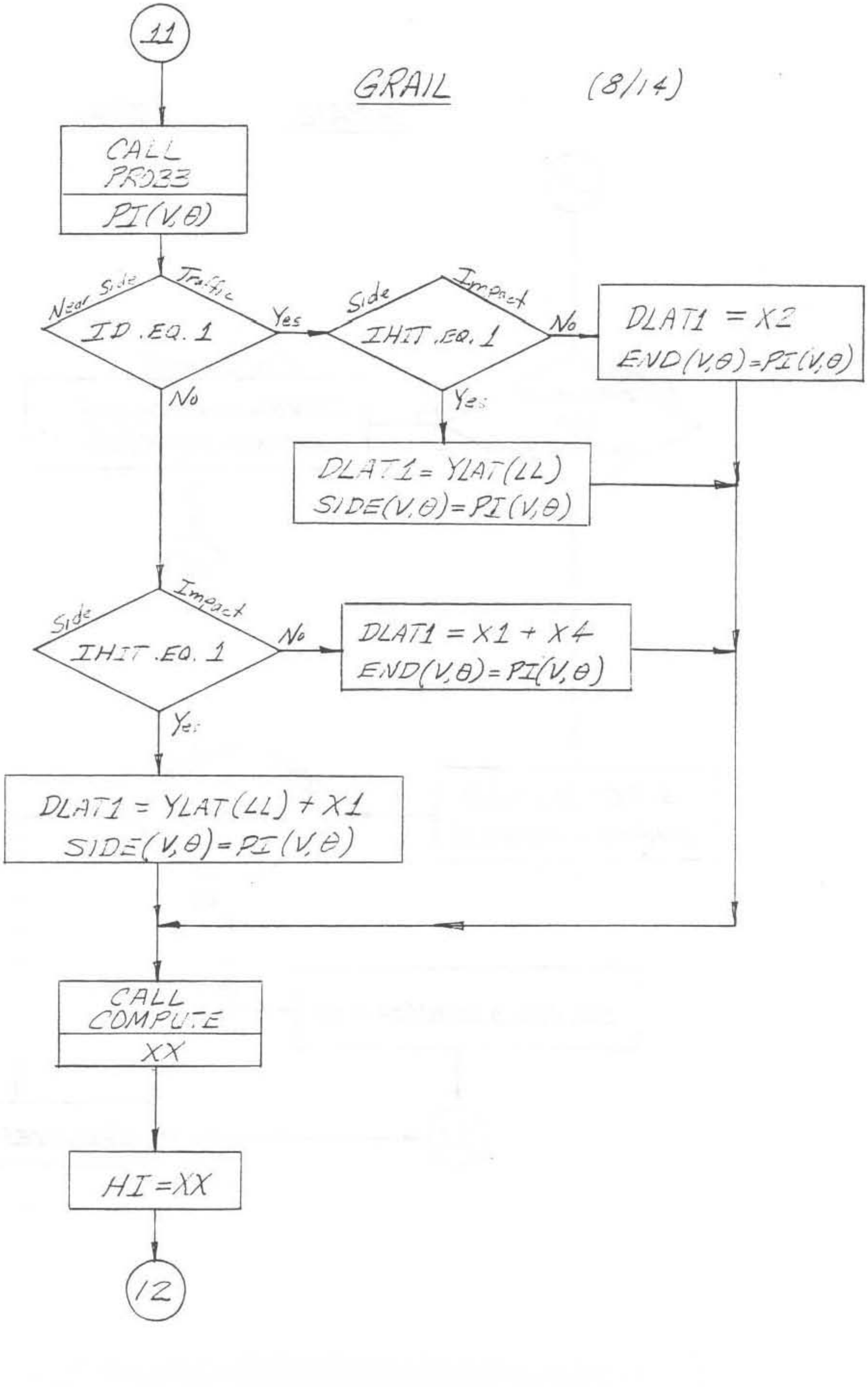


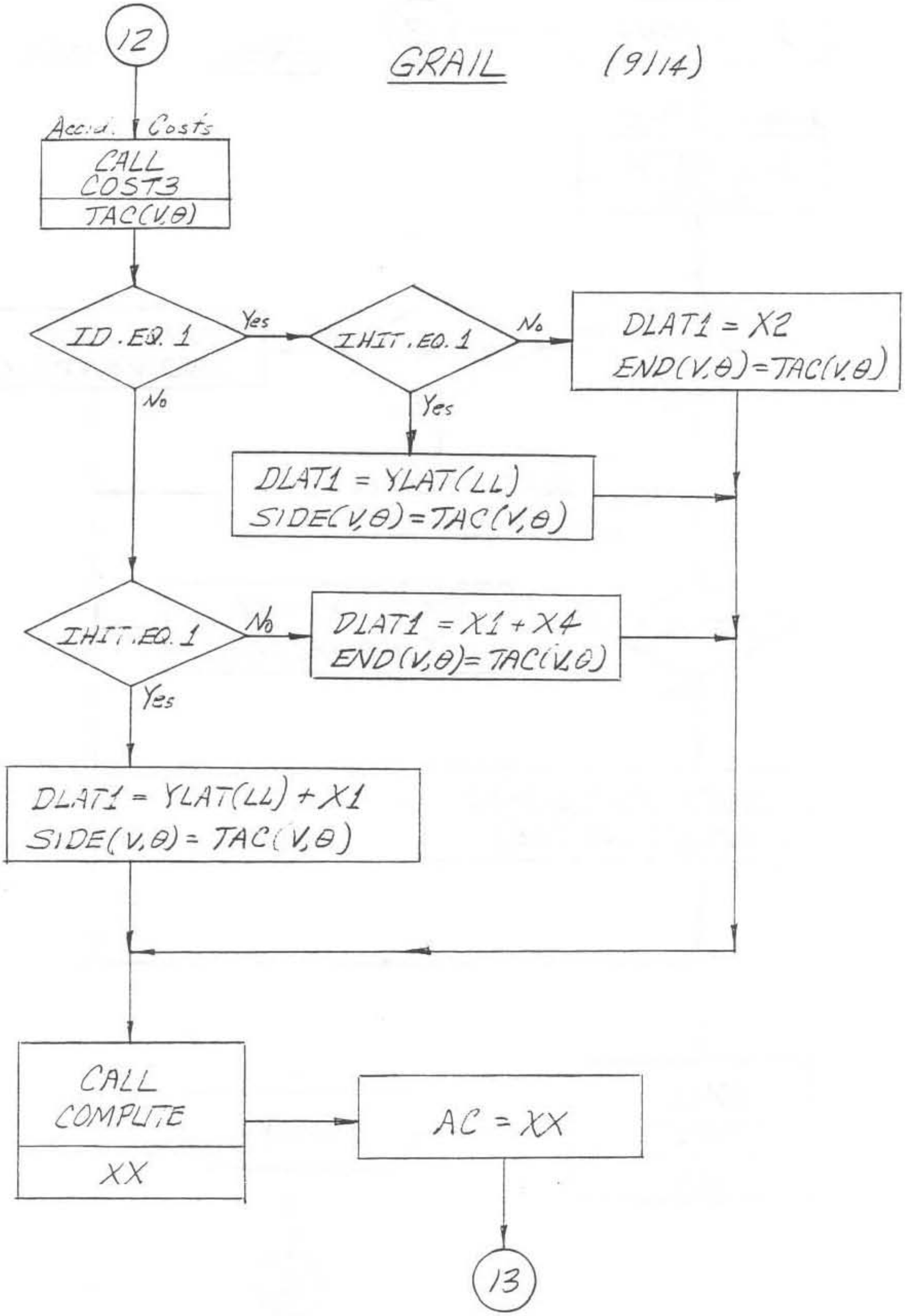
3
GRAIL (5/14)
GR Severities
GRAIL 2
GRAIL 5
GRAIL 6
SIS1(W,V,θ)
SIS2(W,V,θ)
SIS3(W,V,θ)
SIE1U(W,V,θ)
SIE2U(W,V,θ)
SIE3U(W,V,θ)
SIE1D(W,V,θ)
SIE2D(W,V,θ)
SIE3D(W,V,θ)
Side Impact (dry)
✓ ✓ (wet)
✓ ✓ (frozen)
Upstream End Impact (dry)
✓ ✓ ✓ (wet)
✓ ✓ ✓ (frozen)
Downstream ✓ ✓ (dry)
✓ ✓ ✓ (wet)
✓ ✓ ✓ (frozen)
Side Impacts
IHIT = 1
IH = 1
Side El. #1
LL = 1
Length of Element
DLONG = XT
Near Side Traffic
16
ID = 1
4500 lb. Car
Dry
IAUTO = 1
IA = 1
INVIR = 1
15
10

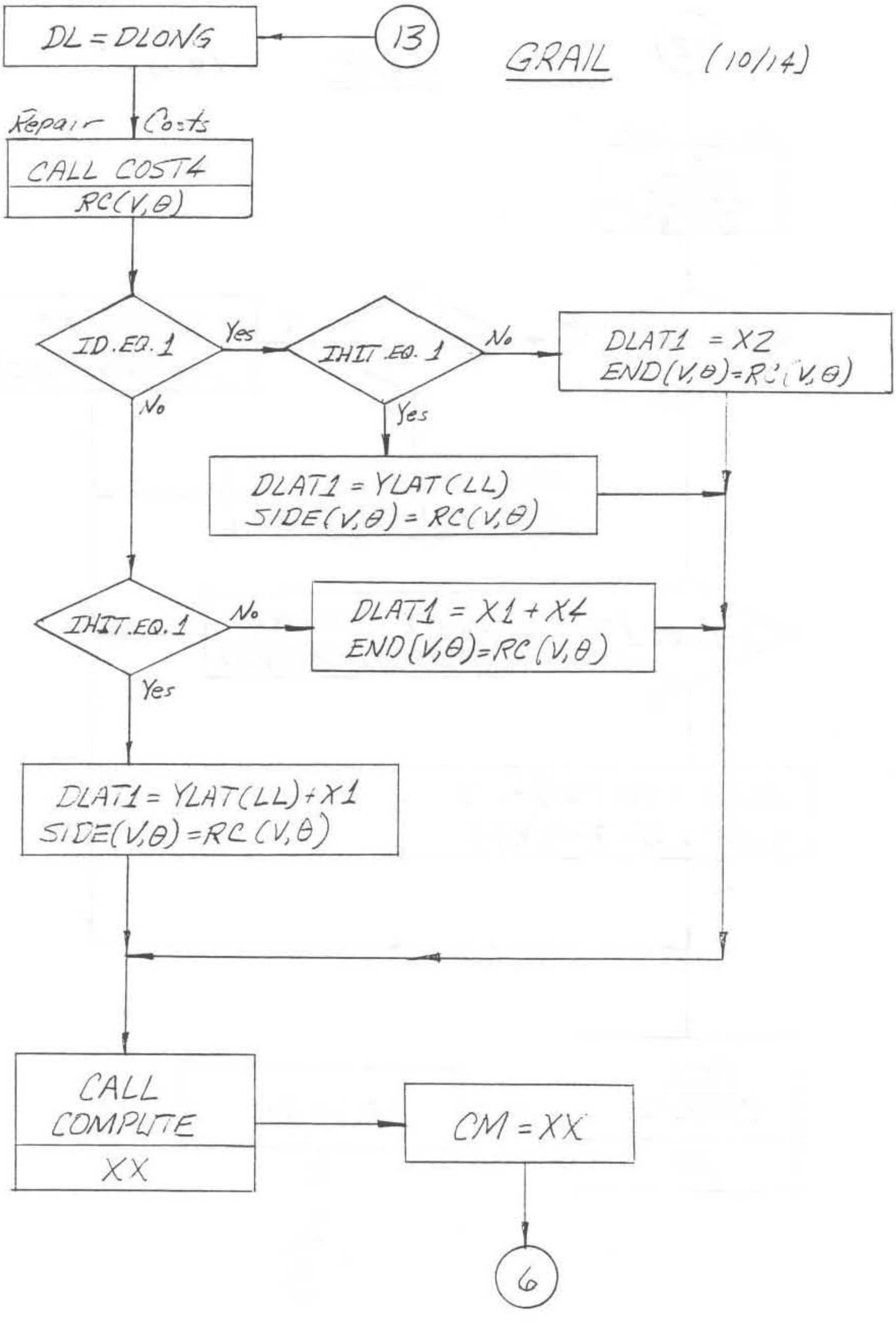

10
GRAIL (6/14)
Dry & Side
INVIR.EQ.1 .AND. IHIT.EQ.1
Yes
Side Impact
SI(V,θ)=SIS1(IA,W,θ)
ENVIRO = ENVIR(1)
11
No
Dry & End
INVIR.EQ.1 .AND. IHIT.GT.1
Yes
End Impacts
SIDE(V,θ)=0.0
ENVIRO=ENVIR(1)
Near Side
ID.EQ.1
Yes
SI(V,θ)=SIE1U(IA,V,θ)
No
SI(V,θ)=SIE1D(IA,V,θ)
11
No
Wet
INVIR.EQ.2 .AND. IHIT.EQ.1
Yes
Side Impact
SI(V,θ)=SIS2(IA,V,θ)
ENVIRO=ENVIR(2)
11
No
Wet
INVIR.EQ.2 .AND. IHIT.GT.1
Yes
End Impact
SIDE(V,θ) = 0.0
ENVIRO=ENVIR(2)
11
No
21
Near Side
ID.EQ.1
Yes
SI(V,θ)=SIE2U(IA,V,θ)
No
SI(V,θ)=SIE2D(IA,V,θ)
11

GRAIL (7/14)

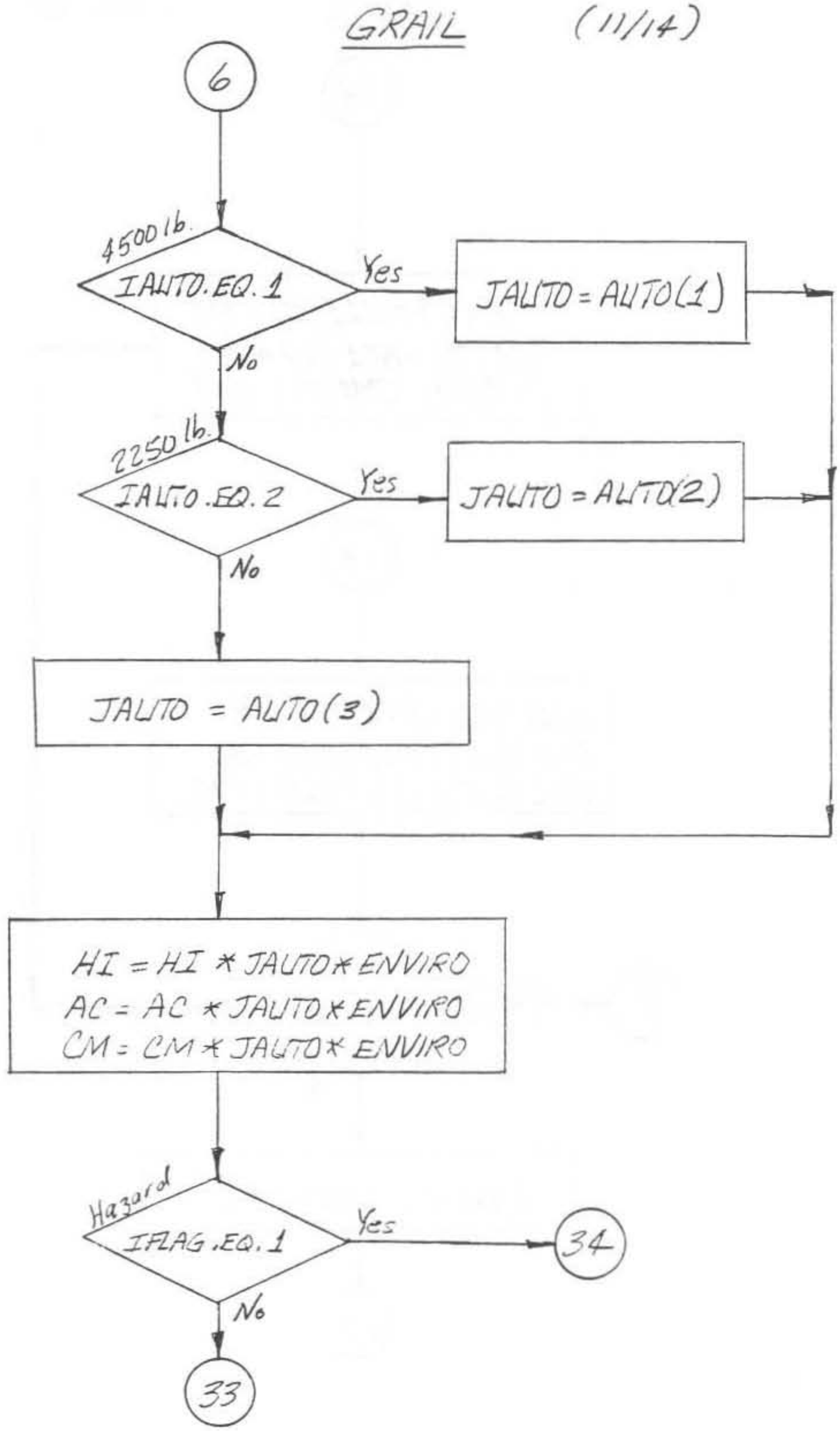

21
Frozen
INVIR.EQ.3
.AND.
IHIT.EQ.1
Yes
No
Side Impact
SI(V,θ)=SIS3(IA,V,θ)
ENVIRO=ENVIR(3)
11
SIDE(V,θ)=0.0
ENVIRO=ENVIR(3)
Near
Side
ID.EQ.1
Yes
No
SI(V,θ)=SIE3D(IA,V,θ)
11
SI(V,θ)=SIE3U(IA,V,θ)

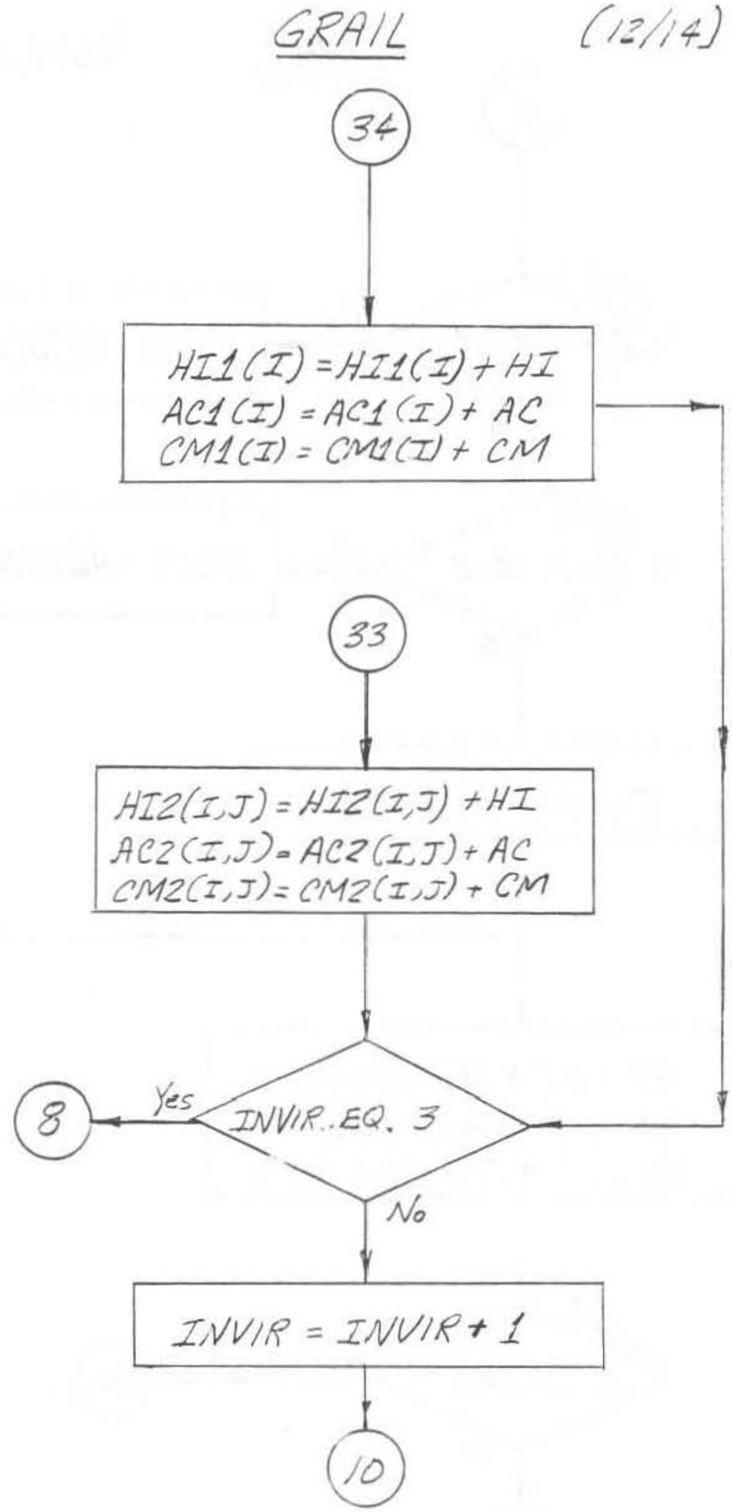

11
GRAIL (8/14)
CALL
PROB3
PI(V,θ)
Near Side Traffic
ID .EQ. 1
Yes
No
Side Impact
IHIT .EQ. 1
No
Yes
DLAT1 = X2
END(V,θ)=PI(V,θ)
DLAT1= YLAT(LL)
SIDE(V,θ)=PI(V,θ)
Side Impact
IHIT .EQ. 1
No
Yes
DLAT1 = X1 + X4
END(V,θ)=PI(V,θ)
DLAT1 = YLAT(LL) + X1
SIDE(V,θ)=PI(V,θ)
CALL
COMPUTE
XX
HI=XX
12

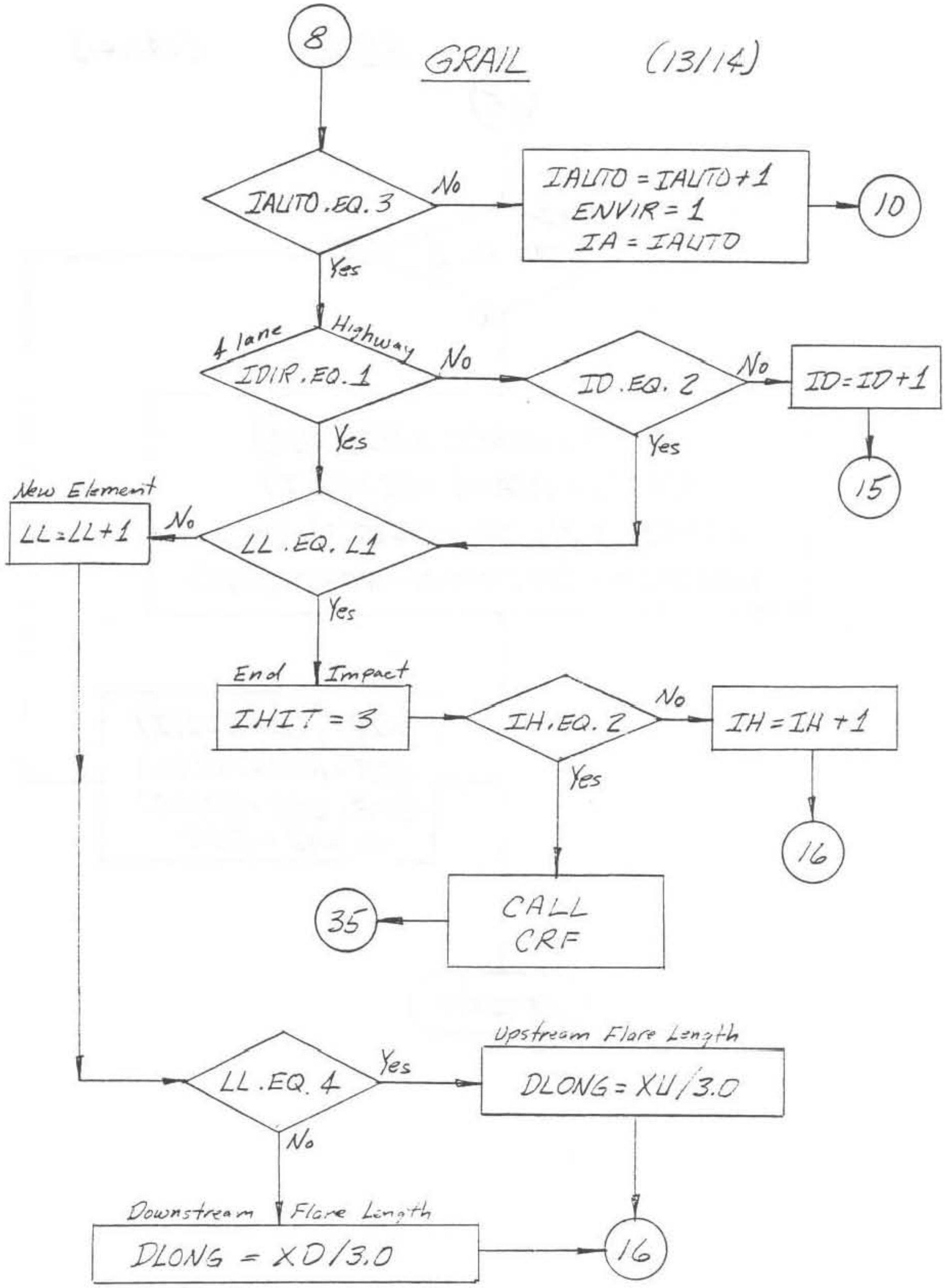

12
GRAIL (9114)
Accid. Costs
CALL COST3
TAC(V,θ)
ID.EQ.1
Yes
No
IHIT.EQ.1
No
Yes
DLAT1 = X2
END(V,θ)=TAC(V,θ)
DLAT1 = YLAT(LL)
SIDE(V,θ)=TAC(V,θ)
IHIT.EQ.1
No
Yes
DLAT1 = X1 + X4
END(V,θ)=TAC(V,θ)
DLAT1 = YLAT(LL) + X1
SIDE(V,θ) = TAC(V,θ)
CALL COMPUTE
XX
AC = XX
13

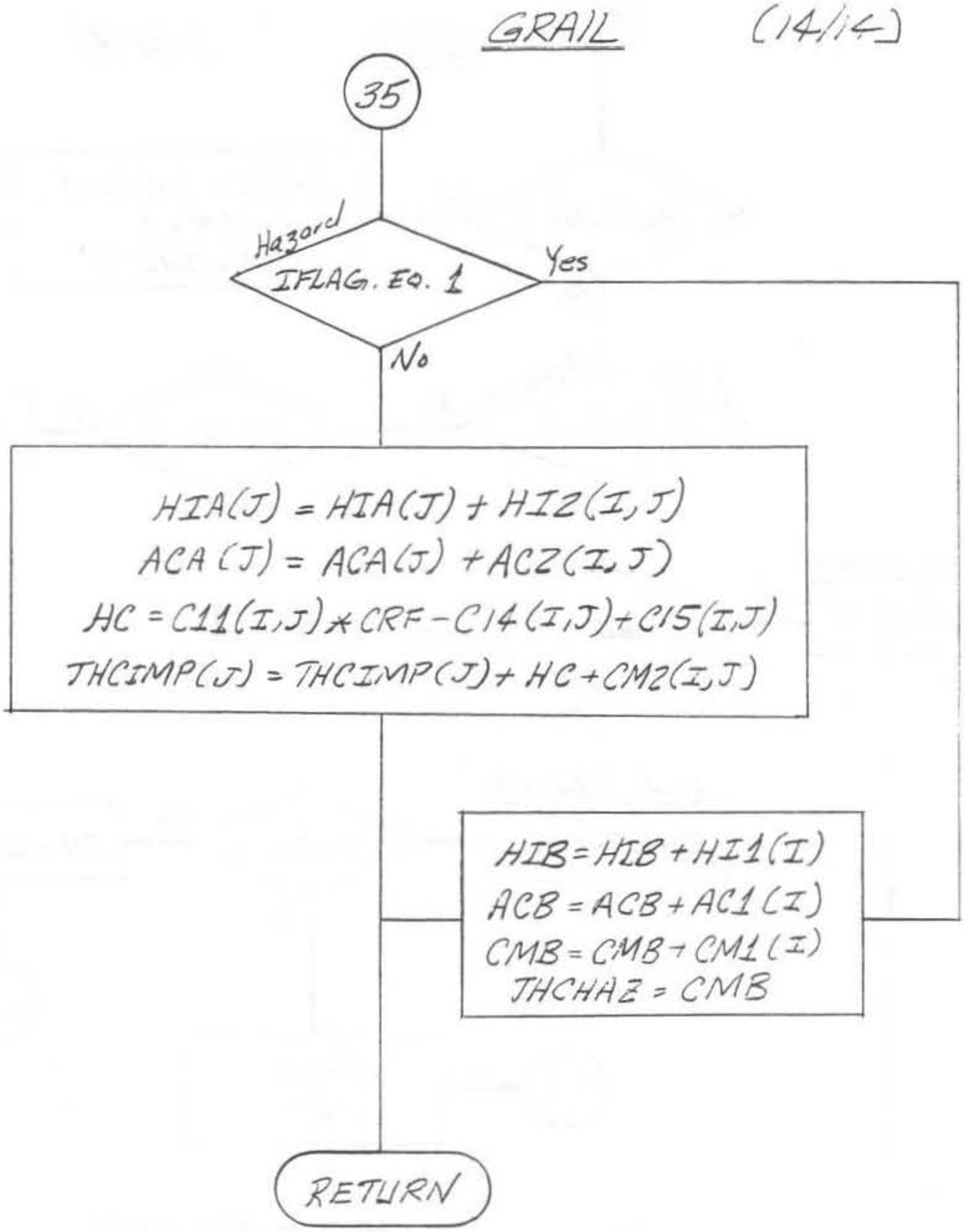


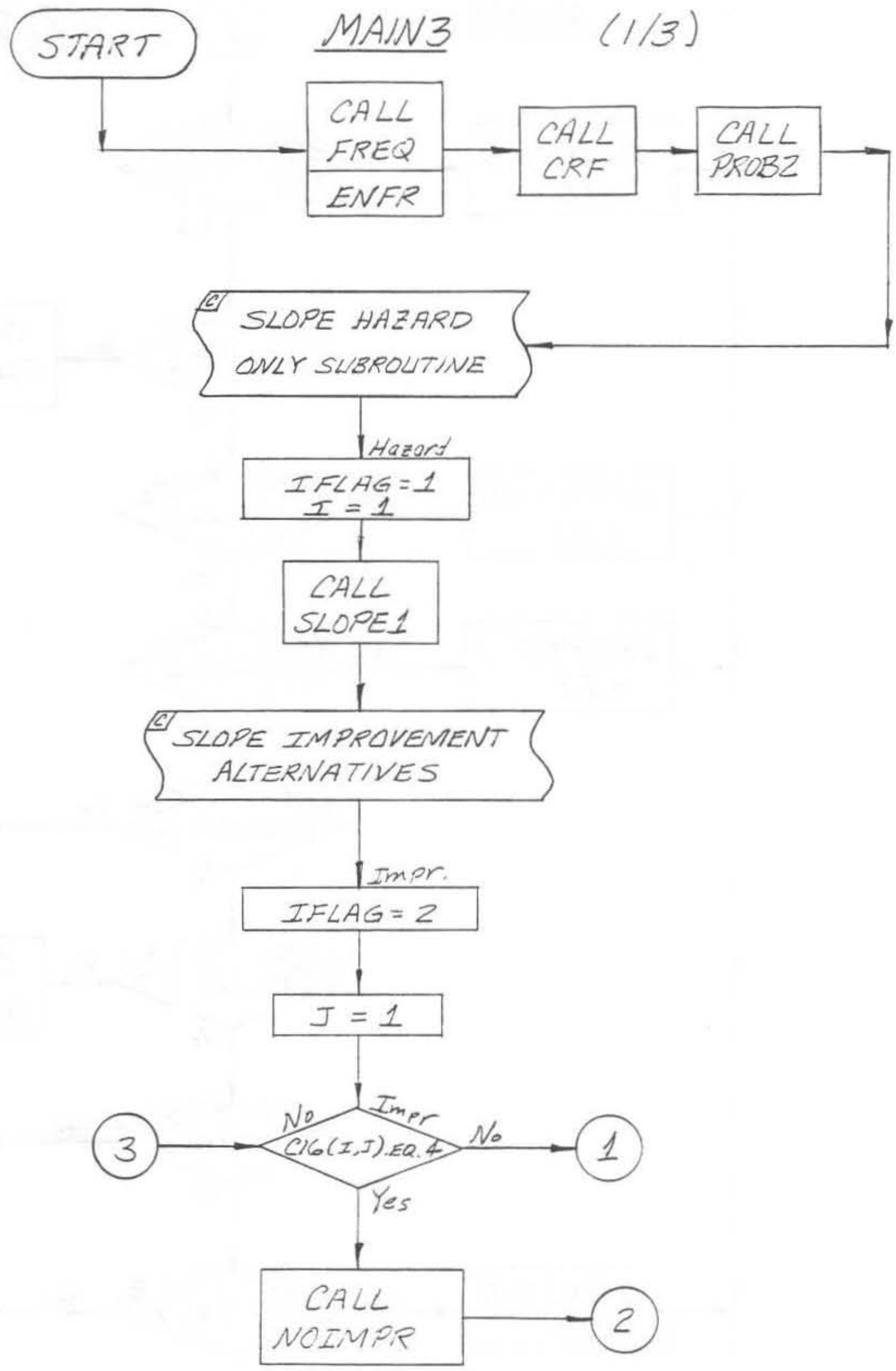
DL = DLONG
13
GRAIL (10/14)
Repair Costs
CALL COST4
RC(V,θ)
ID.EQ.1
Yes
IHIT.EQ.1
No
DLAT1 = X2
END(V,θ)=RC(V,θ)
No
Yes
DLAT1 = YLAT(LL)
SIDE(V,θ) = RC(V,θ)
IHIT.EQ.1
No
DLAT1 = X1 + X4
END(V,θ)=RC(V,θ)
Yes
DLAT1= YLAT(LL)+X1
SIDE(V,θ)=RC(V,θ)
CALL COMPUTE
XX
CM = XX
6

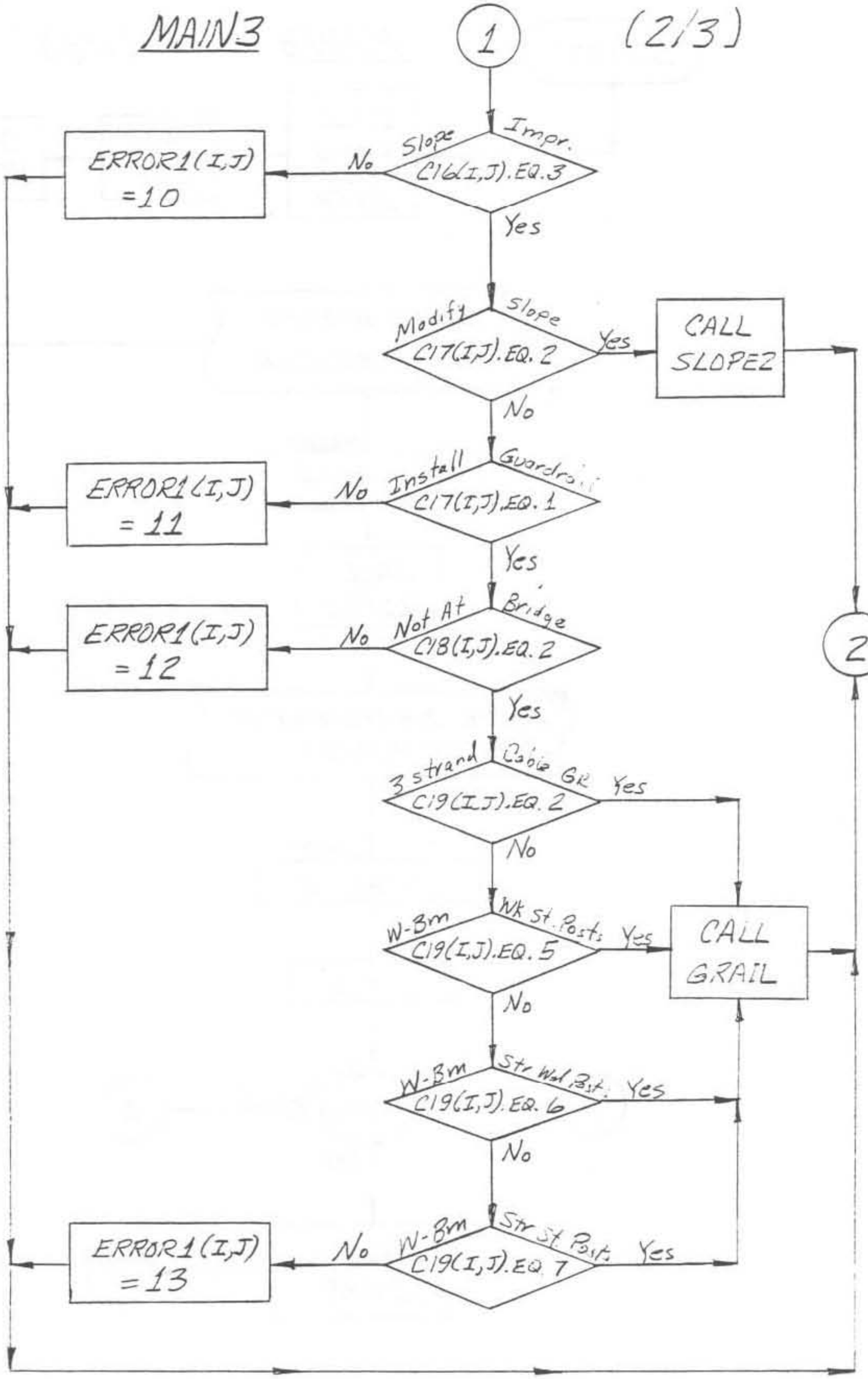

GRAIL (11/14)
6
4500 lb.
IAUTO.EQ.1
Yes
No
JAUTO = AUTO(1)
2250 lb.
IAUTO.EQ.2
Yes
No
JAUTO = AUTO(2)
JAUTO = AUTO(3)
HI = HI * JAUTO * ENVIRO
AC = AC * JAUTO * ENVIRO
CM = CM * JAUTO * ENVIRO
Hazard
IFLAG.EQ.1
Yes
No
34
33


GRAIL (12/14)
34
HI1(I) = HI1(I) + HI
AC1(I) = AC1(I) + AC
CM1(I) = CM1(I) + CM
33
HI2(I,J) = HI2(I,J) + HI
AC2(I,J) = AC2(I,J) + AC
CM2(I,J) = CM2(I,J) + CM
INVIR..EQ. 3
Yes
8
No
INVIR = INVIR + 1
10


8
GRAIL (13/14)
IAUTO.EQ.3
No
IAUTO = IAUTO + 1
ENVIR = 1
IA = IAUTO
10
Yes
4 lane Highway
IDIR.EQ.1
No
ID.EQ.2
No
ID=ID+1
15
Yes
Yes
New Element
LL=LL+1
No
LL.EQ.L1
Yes
End Impact
IHIT = 3
IH.EQ.2
No
IH = IH + 1
16
Yes
CALL
CRF
35
LL.EQ.4
Yes
Upstream Flare Length
DLONG = XU/3.0
No
Downstream Flare Length
DLONG = XD/3.0
16

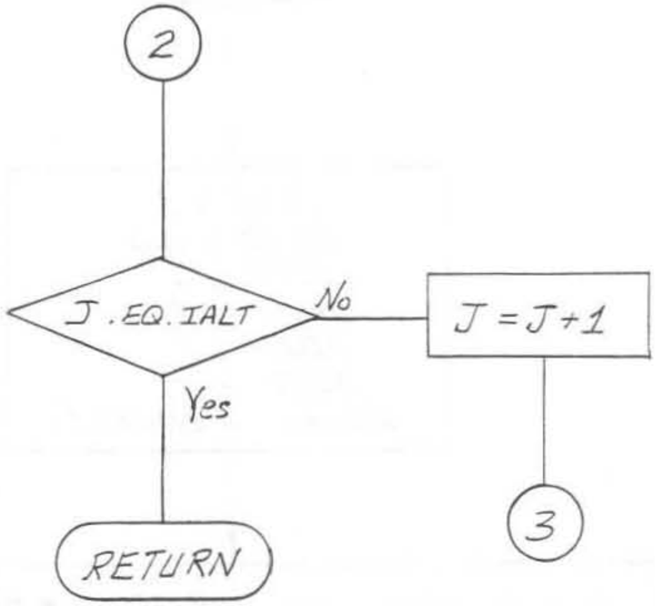

GRAIL (14/14)
35
Hazard
IFLAG. EQ. 1
Yes
No
HIA(J) = HIA(J) + HIZ(I,J)
ACA(J) = ACA(J) + ACZ(I,J)
HC = C11(I,J) * CRF - C14(I,J) + C15(I,J)
THCIMP(J) = THCIMP(J) + HC + CM2(I,J)
HIB = HIB + HI1(I)
ACB = ACB + AC1(I)
CMB = CMB + CM1(I)
THCHAZ = CMB
RETURN


MAIN3
(1/3)
START
CALL FREQ
ENFR
CALL CRF
CALL PROBZ
SLOPE HAZARD ONLY SUBROUTINE
Hazard
IFLAG=1
I = 1
CALL SLOPE1
SLOPE IMPROVEMENT ALTERNATIVES
Impr.
IFLAG=2
J = 1
Impr
C16(I,J).EQ.4
No
No
Yes
3
1
CALL NOIMPR
2

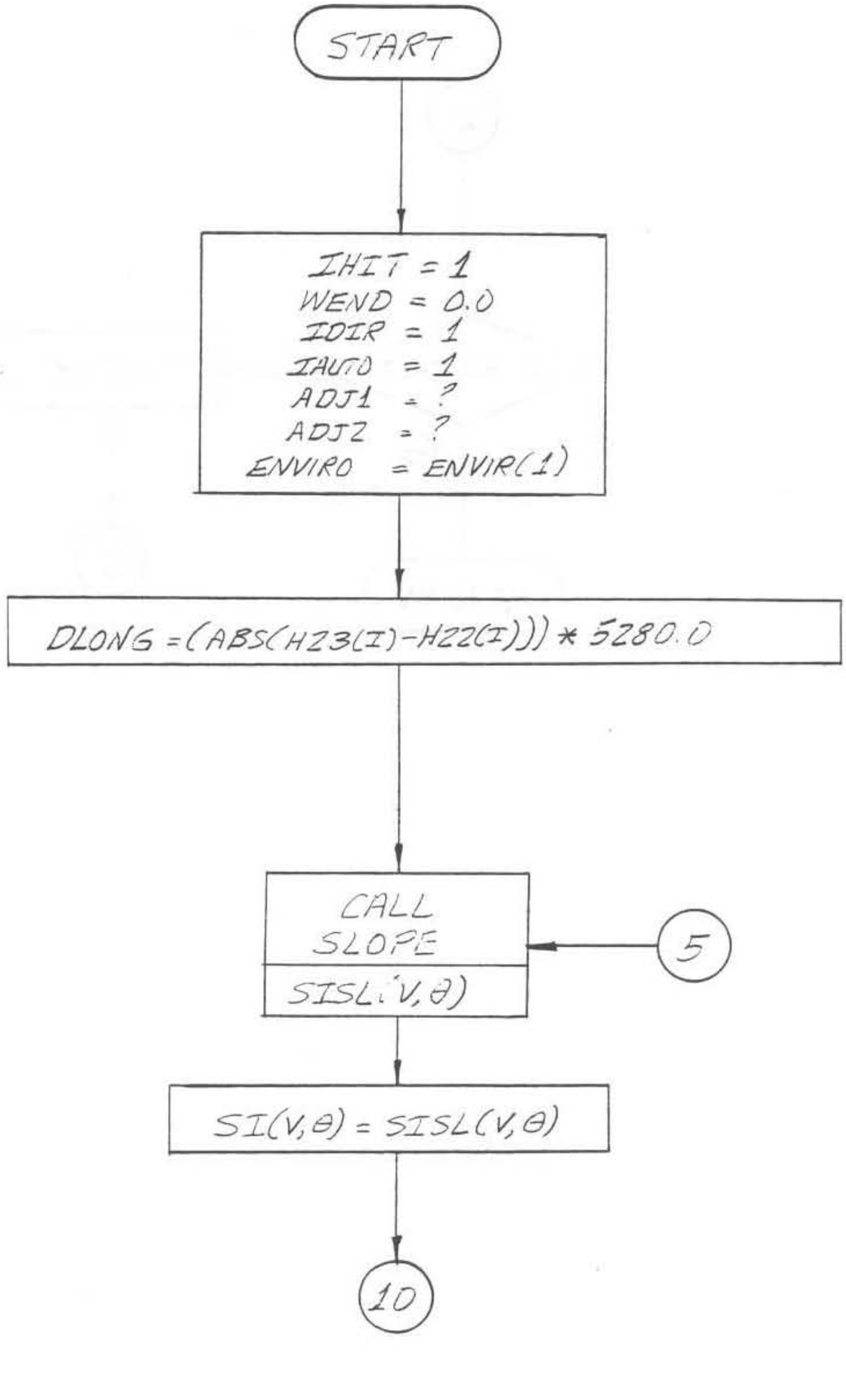


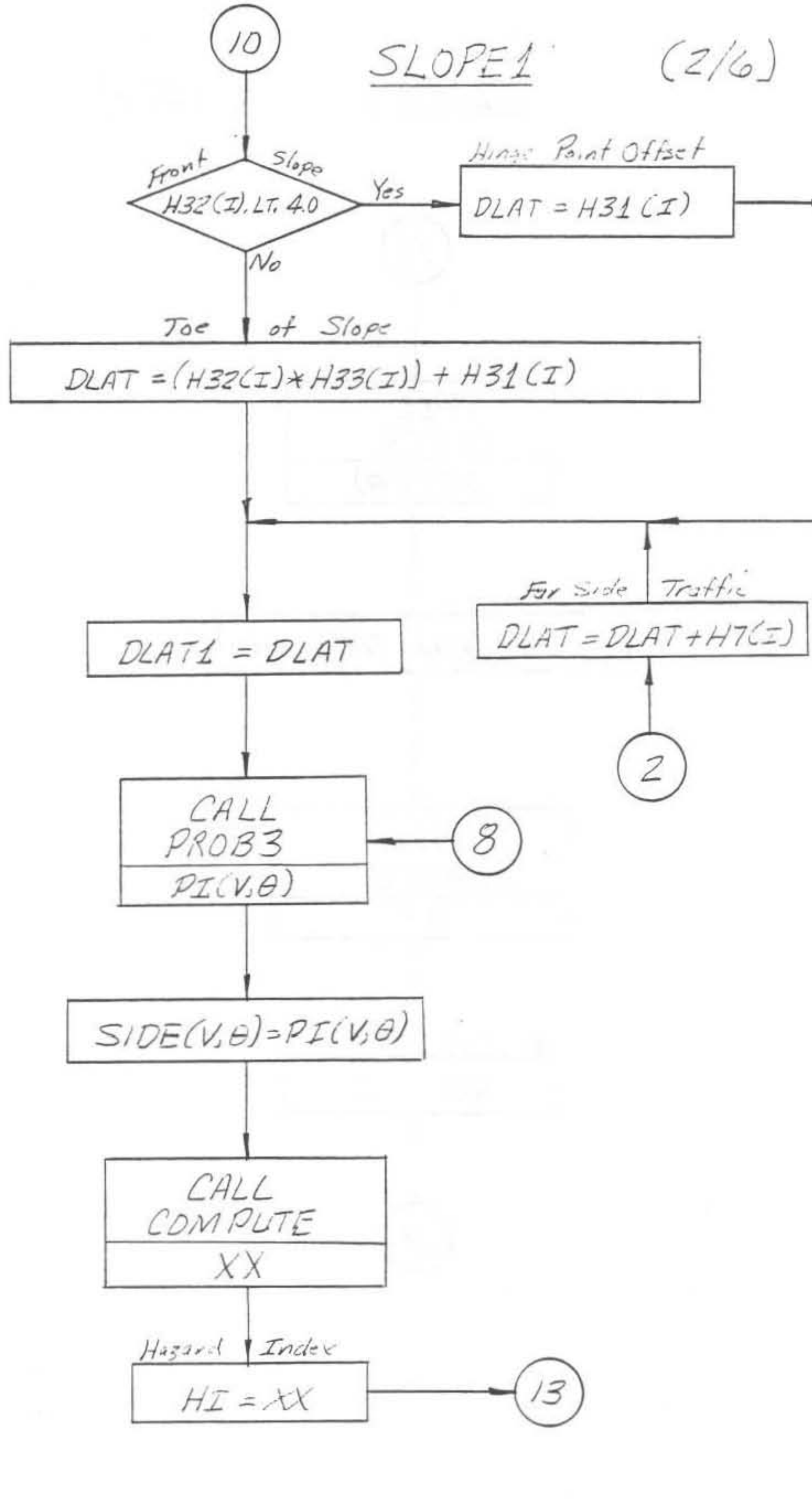
MAIN3
1
(2/3)
Slope Impr.
C16(I,J).EQ.3
No
ERROR1(I,J) =10
Yes
Modify Slope
C17(I,J).EQ.2
Yes
CALL SLOPE2
No
Install Guardrail
C17(I,J).EQ.1
No
ERROR1(I,J) = 11
Yes
Not At Bridge
C18(I,J).EQ.2
No
ERROR1(I,J) = 12
2
Yes
3 strand Cable GR
C19(I,J).EQ.2
Yes
No
W-Bm Wk St. Posts
C19(I,J).EQ.5
Yes
CALL GRAIL
No
W-Bm Str Wd Post
C19(I,J).EQ.6
Yes
No
W-Bm Str St. Post
C19(I,J).EQ.7
Yes
No
ERROR1(I,J) =13

MAIN3 (3/3)



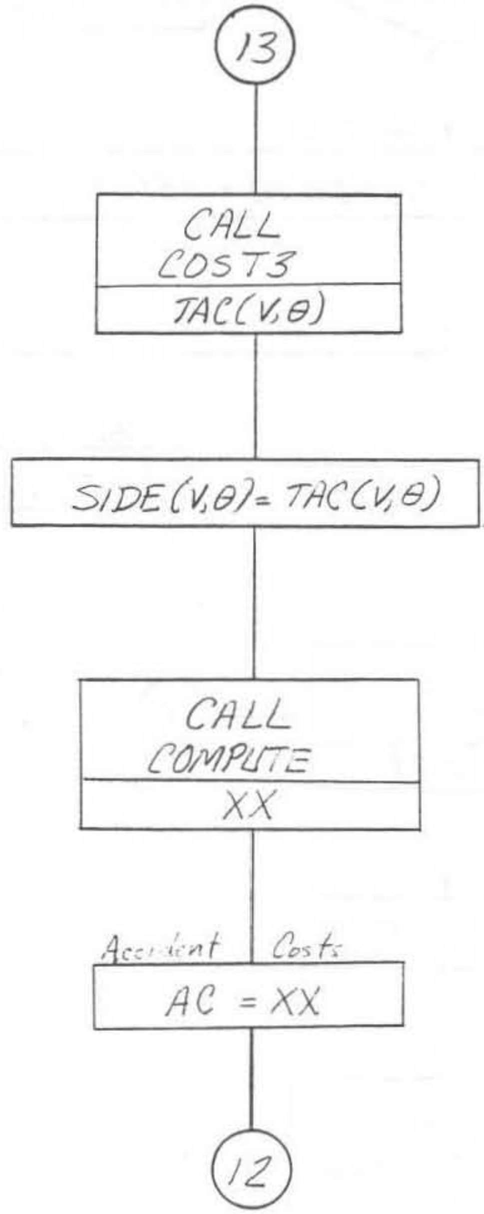
SLOPE1 (1/6)


START
IHIT = 1
WEND = 0.0
IDIR = 1
IAUTO = 1
ADJ1 = ?
ADJ2 = ?
ENVIRO = ENVIR(1)
DLONG = (ABS(H23(I)-H22(I))) * 5280.0
CALL
SLOPE
SISL(V,θ)
5
SI(V,θ) = SISL(V,θ)
10

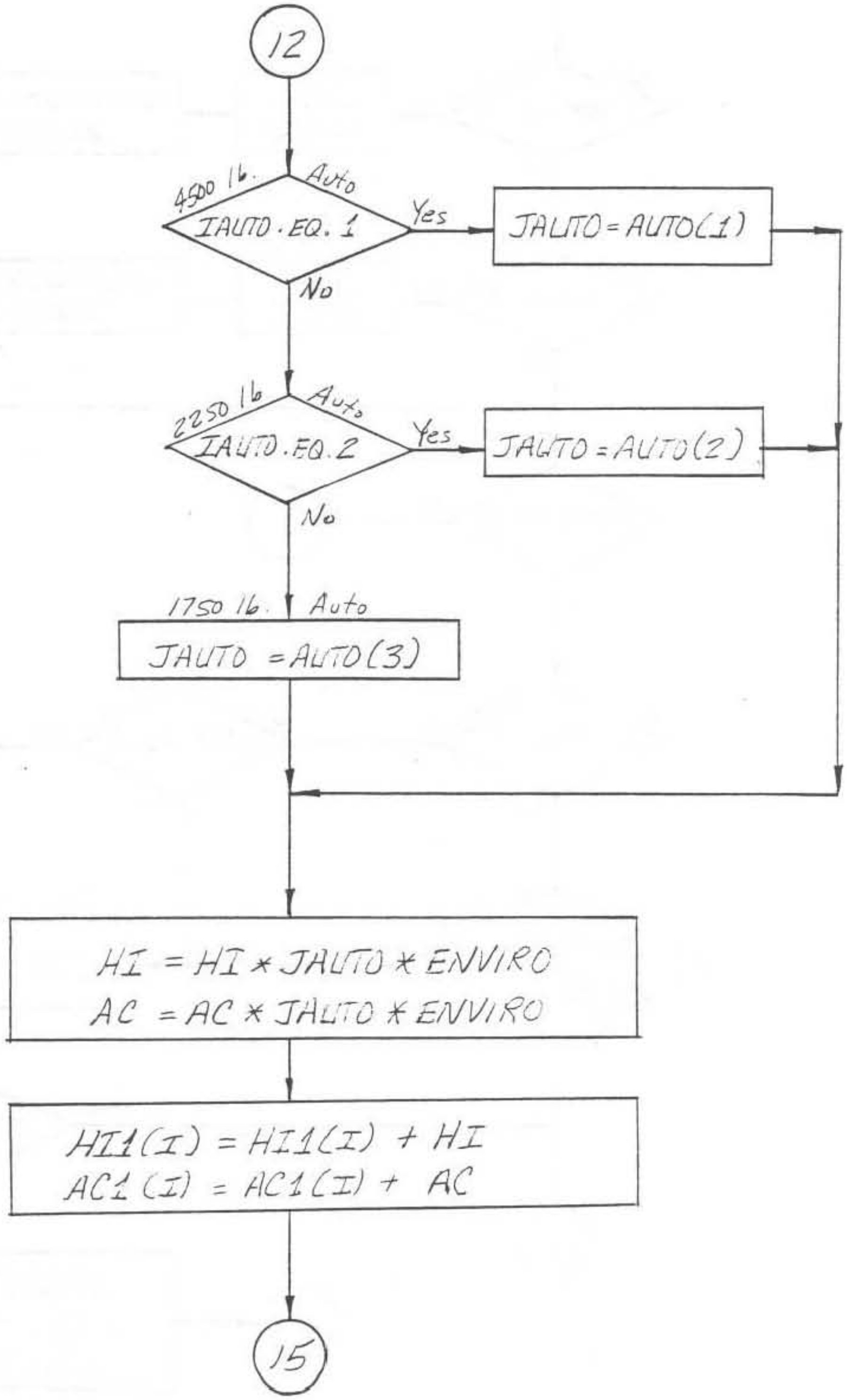


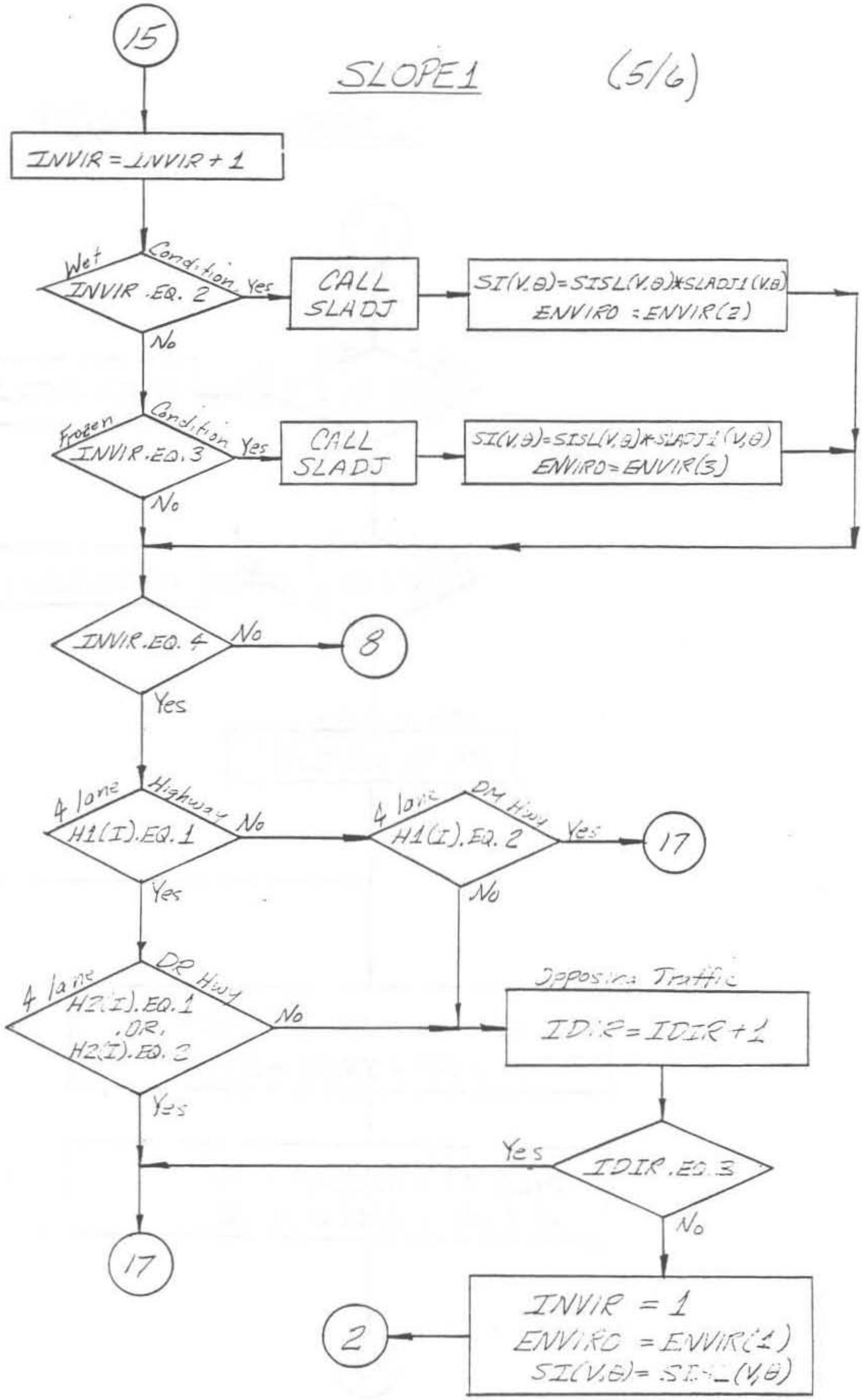
10
SLOPE1 (2/6)
Front Slope
H32(I).LT.4.0
Yes
Hinge Point Offset
DLAT = H31(I)
No
Toe of Slope
DLAT = (H32(I)*H33(I)) + H31(I)
For Side Traffic
DLAT = DLAT + H7(I)
2
DLAT1 = DLAT
CALL PROB3
PI(V,θ)
8
SIDE(V,θ) = PI(V,θ)
CALL COMPUTE
XX
Hazard Index
HI = XX
13

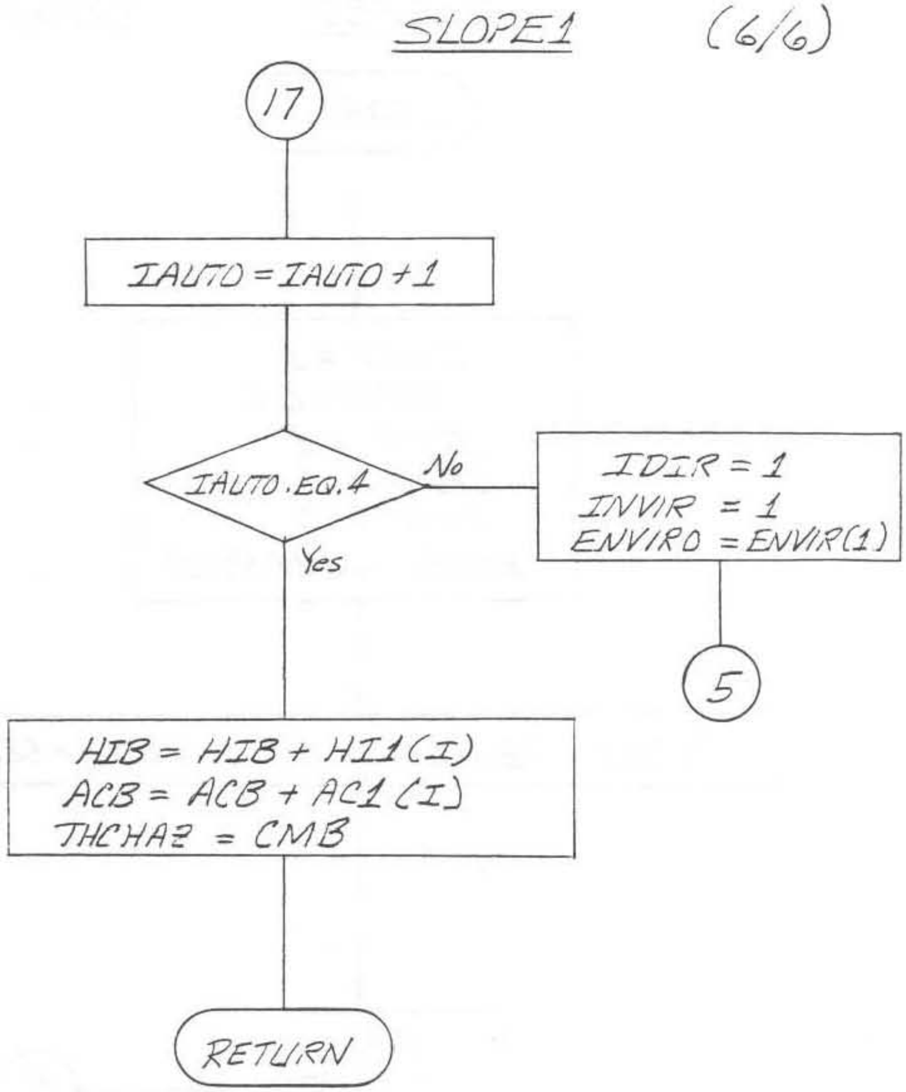
SLOPE1 (3/6)


13
CALL
COST3
TAC(V,θ)
SIDE(V,θ)= TAC(V,θ)
CALL
COMPUTE
XX
Accident Costs
AC = XX
12

SLOPE1 (4/6)

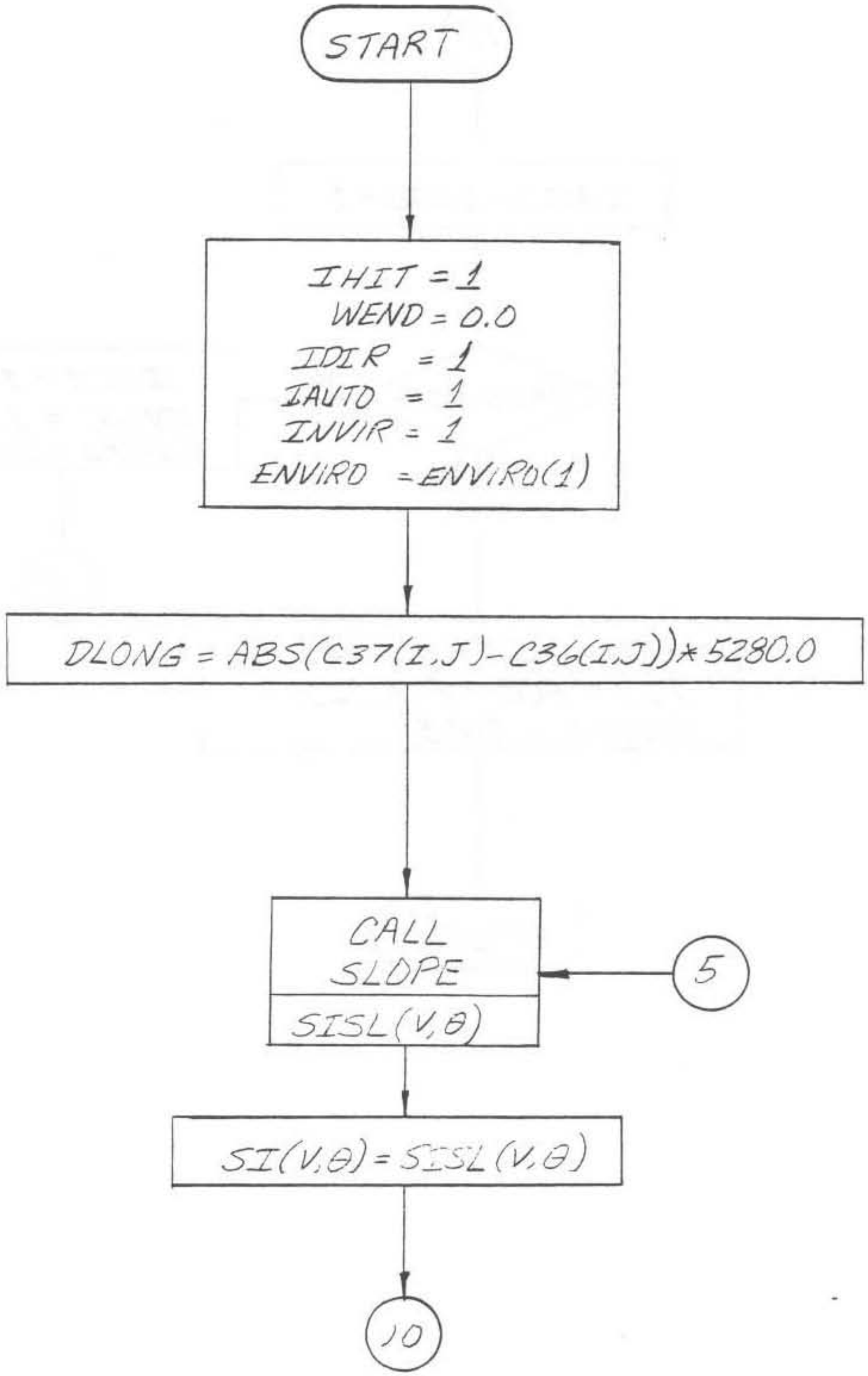

12
4500 lb. Auto
IAUTO.EQ.1
Yes
JAUTO = AUTO(1)
No
2250 lb Auto
IAUTO.EQ.2
Yes
JAUTO = AUTO(2)
No
1750 lb. Auto
JAUTO = AUTO(3)
HI = HI * JAUTO * ENVIRO
AC = AC * JAUTO * ENVIRO
HI1(I) = HI1(I) + HI
AC1(I) = AC1(I) + AC
15

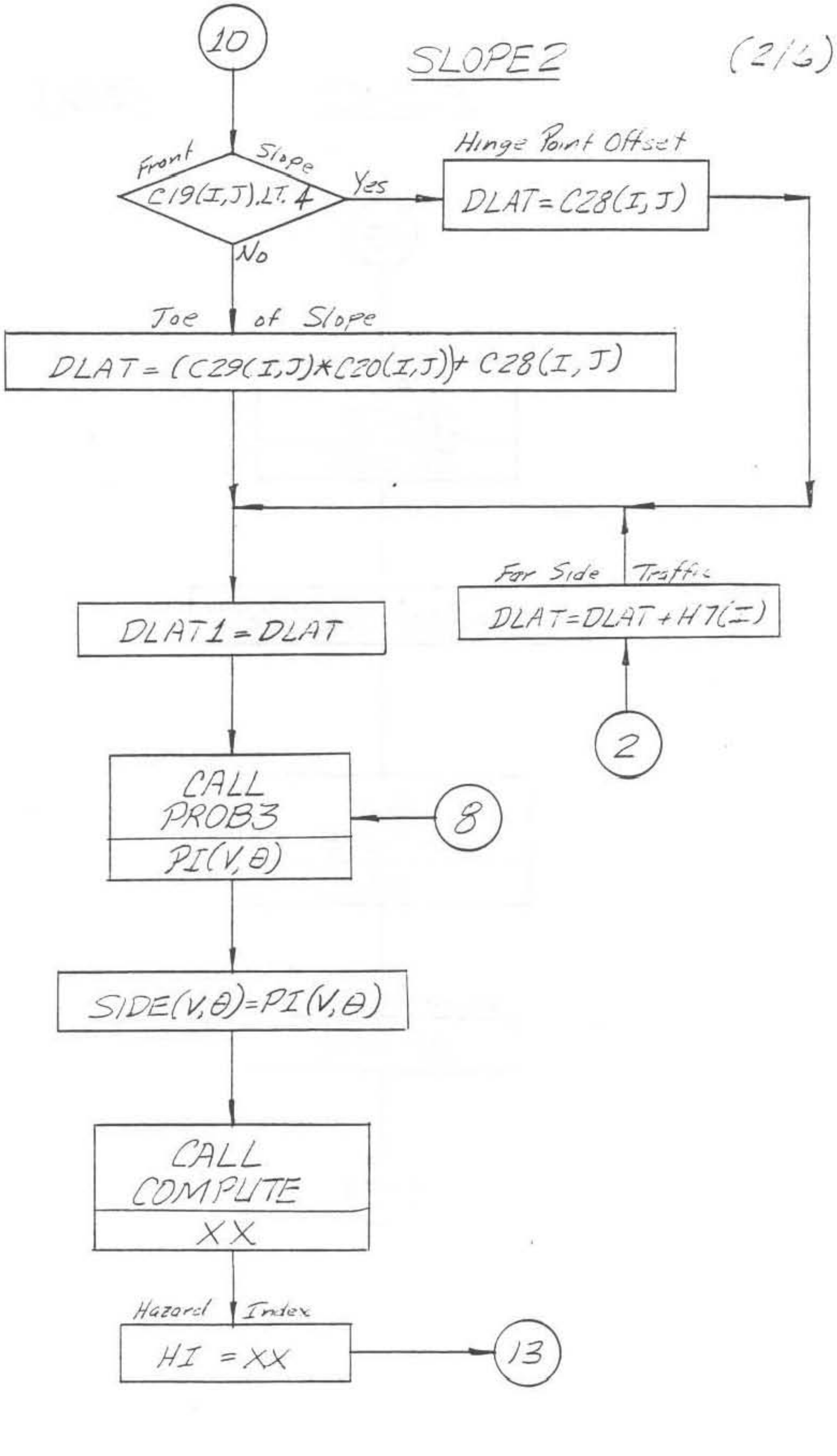

15
SLOPE1 (5/6)
INVIR = INVIR + 1
Wet Condition
INVIR .EQ. 2
Yes
No
CALL SLADJ
SI(V,θ)=SISL(V,θ)*SLADJ1(V,θ)
ENVIRO = ENVIR(2)
Frozen Condition
INVIR.EQ.3
Yes
No
CALL SLADJ
SI(V,θ)=SISL(V,θ)*SLADJ1(V,θ)
ENVIRO=ENVIR(3)
INVIR.EQ. 4
No
8
Yes
4 lane Highway
H1(I).EQ.1
No
Yes
4 lane DM Hwy
H1(I).EQ.2
Yes
17
No
4 lane DR Hwy
H2(I).EQ.1 .OR. H2(I).EQ.2
No
Yes
Opposing Traffic
IDIR=IDIR+1
Yes
IDIR.EQ.3
No
17
INVIR = 1
ENVIRO = ENVIR(1)
2



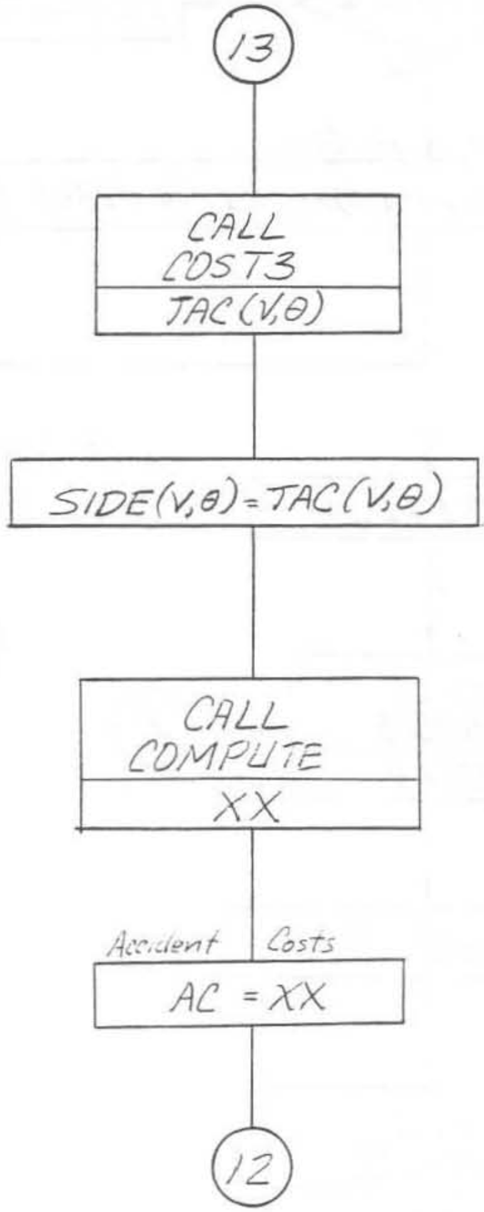
SLOPE1 (6/6)
17
IAUTO = IAUTO + 1
IAUTO.EQ.4
No
IDIR = 1
INVIR = 1
ENVIRO = ENVIR(1)
5
Yes
HIB = HIB + HI1(I)
ACB = ACB + AC1(I)
THCHAZ = CMB
RETURN

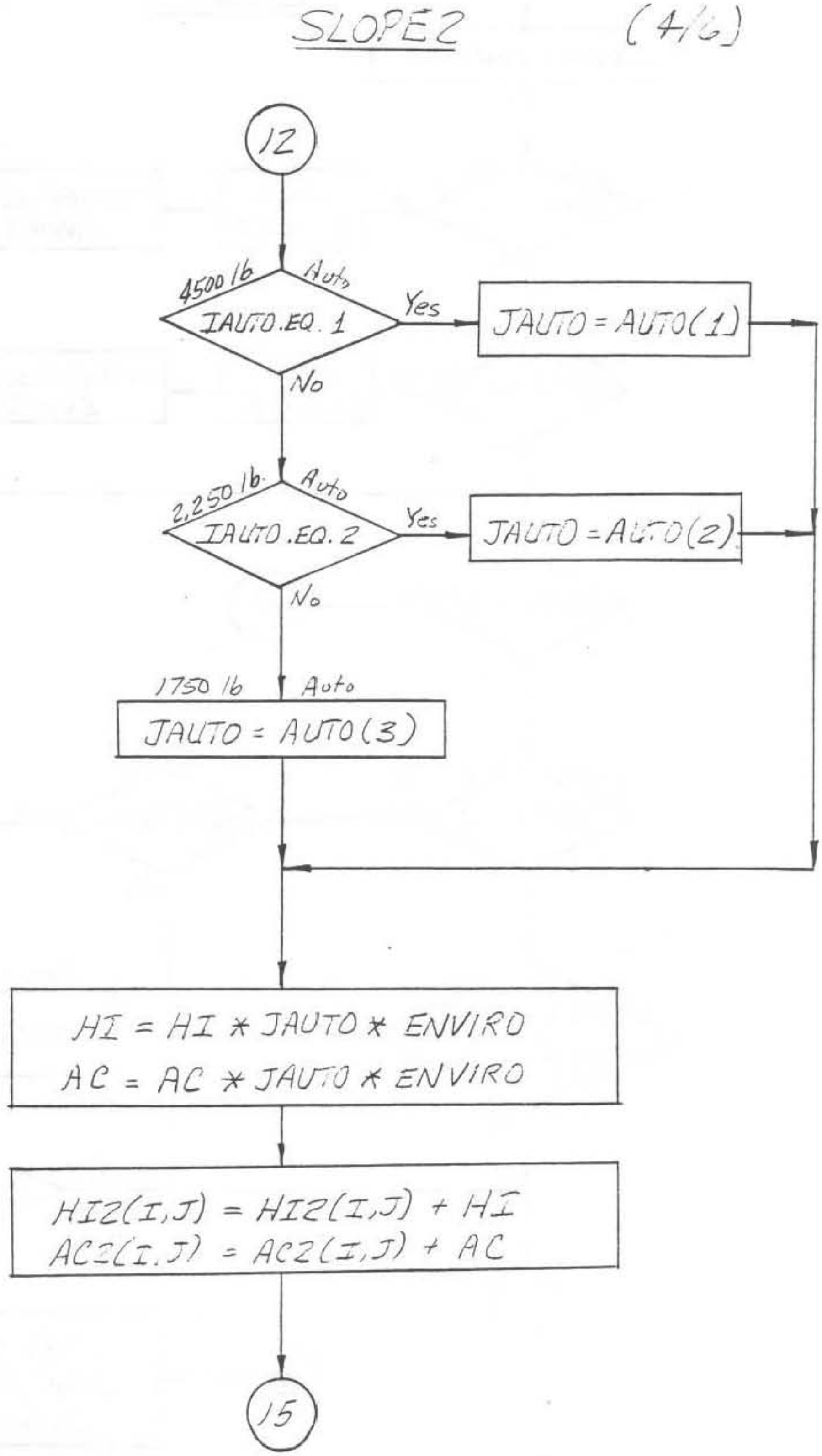
SLOPE2 (1/6)

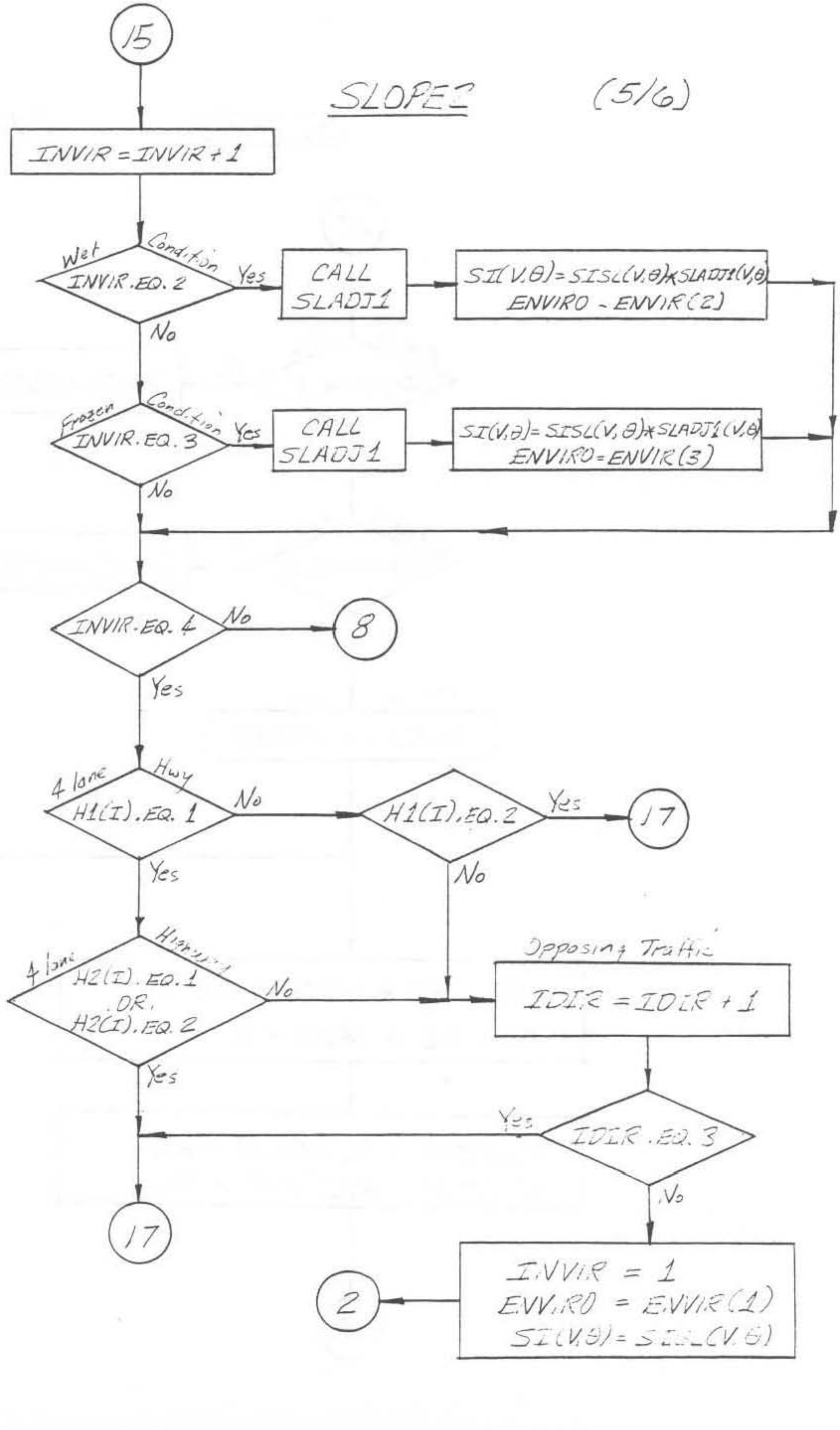

START
IHIT = 1
WEND = 0.0
IDIR = 1
IAUTO = 1
INVIR = 1
ENVIRO = ENVIRO(1)
DLONG = ABS(C37(I,J)-C36(I,J))*5280.0
CALL SLOPE
SISL(V,θ)
5
SI(V,θ) = SISL(V,θ)
10

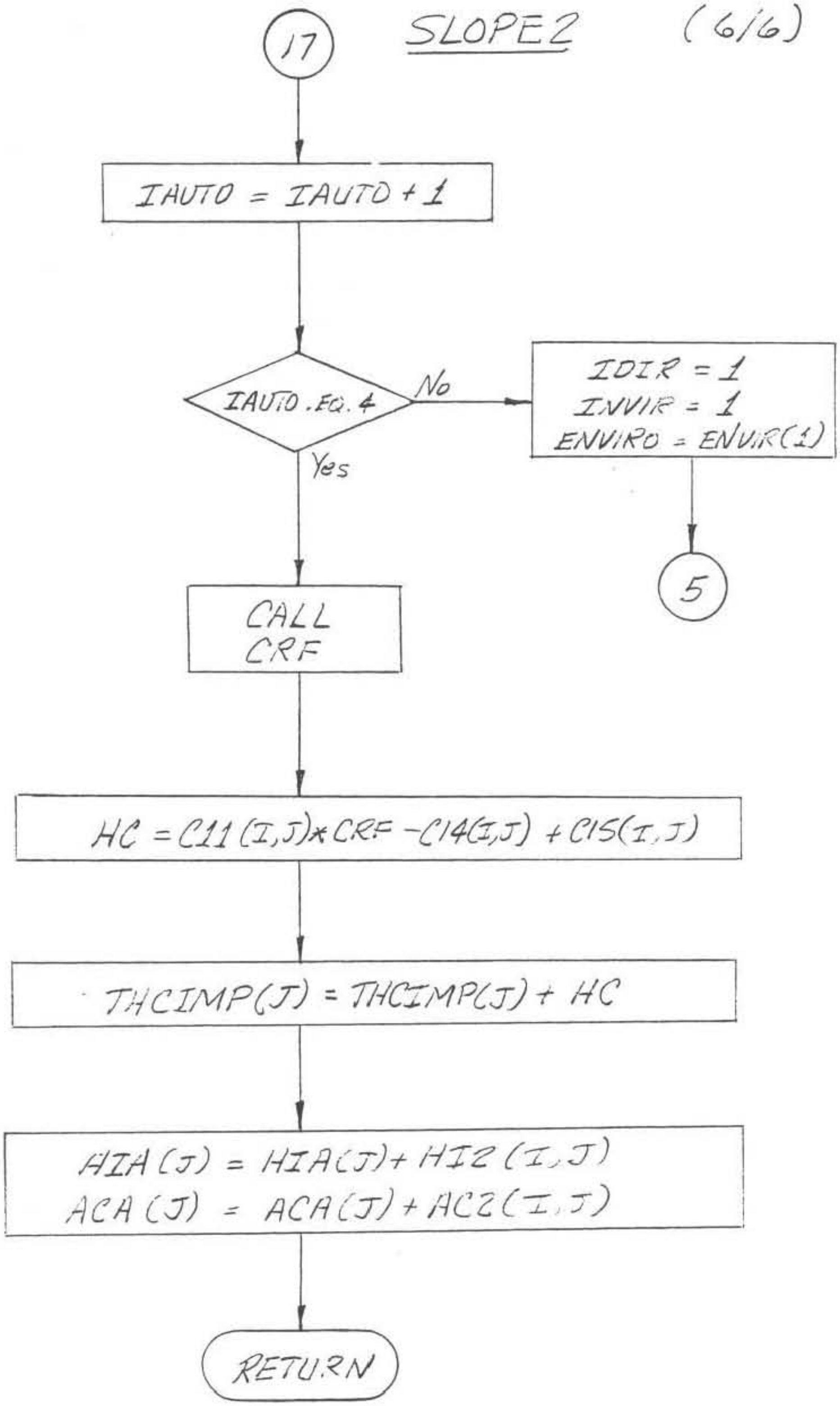

10
SLOPE2
(2/6)
Front Slope
C19(I,J).LT.4
Yes
No
Hinge Point Offset
DLAT=C28(I,J)
Toe of Slope
DLAT=(C29(I,J)*C20(I,J))+C28(I,J)
For Side Traffic
DLAT=DLAT+H7(I)
2
DLAT1=DLAT
CALL PROB3
PI(V,θ)
8
SIDE(V,θ)=PI(V,θ)
CALL COMPUTE
XX
Hazard Index
HI=XX
13

SLOPE2 (3/6)


13
CALL
COST3
TAC(V,θ)
SIDE(V,θ)=TAC(V,θ)
CALL
COMPUTE
XX
Accident Costs
AC = XX
12


SLOPE2 (4/6)
12
4500 lb Auto
IAUTO.EQ. 1
Yes
JAUTO = AUTO(1)
No
2,250 lb. Auto
IAUTO.EQ. 2
Yes
JAUTO = AUTO(2)
No
1750 lb Auto
JAUTO = AUTO(3)
HI = HI * JAUTO * ENVIRO
AC = AC * JAUTO * ENVIRO
HI2(I,J) = HI2(I,J) + HI
AC2(I,J) = AC2(I,J) + AC
15


15
SLOPE2 (5/6)
INVIR = INVIR + 1
Wet Condition
INVIR.EQ.2
Yes
No
CALL SLADJ1
SI(V,θ) = SISL(V,θ)*SLADJ1(V,θ)
ENVIRO = ENVIR(2)
Frozen Condition
INVIR.EQ.3
Yes
No
CALL SLADJ1
SI(V,θ) = SISL(V,θ)*SLADJ1(V,θ)
ENVIRO = ENVIR(3)
INVIR.EQ.4
No
8
Yes
4 lane Hwy
H1(I).EQ.1
No
H1(I).EQ.2
Yes
17
No
Yes
4 lane Highway
H2(I).EQ.1 .OR. H2(I).EQ.2
No
Yes
Opposing Traffic
IDIR = IDIR + 1
IDIR.EQ.3
Yes
No
17
INVIR = 1
ENVIRO = ENVIR(1)
SI(V,θ) = SISL(V,θ)
2


17
SLOPE2 (6/6)
IAUTO = IAUTO + 1
IAUTO .EQ. 4
No
IDIR = 1
INVIR = 1
ENVIRO = ENVIR(1)
5
Yes
CALL CRF
HC = C11(I,J)*CRF − C14(I,J) + C15(I,J)
THCIMP(J) = THCIMP(J) + HC
HIA(J) = HIA(J) + HI2(I,J)
ACA(J) = ACA(J) + AC2(I,J)
RETURN

A P P E N D I X

L. COMPUTER PROGRAM SOURCE LISTING

```
C***********************************************************************
C***********************************************************************
C*                GUARDRAIL UTILIZATION: A COST-EFFECTIVENESS
C*                      COMPUTER PROGRAM TO ANALYZE
C*          CABLE AND W-BEAM GUARDRAIL FOR USE ON FILL SLOPES
C*
C*
C*                    NEBRASKA DEPARTMENT OF ROADS
C*                                AND
C*                  UNIVERSITY OF NEBRASKA - LINCOLN
C*
C*                     HP&R  79-4  (AUGUST 1982)
C***********************************************************************
C***********************************************************************
C
C
C MAIN PROGRAM
C
C ********************************************************************
C
C
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(5), H7(5),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
      COMMON/CRF1/CR
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
      COMMON/SL1/ SLADJ1(5,5)
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *          SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *              SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
```

```
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *               NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
      REAL MB1, MB2, MB3, MB9, M34W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
C
C                 INITIALIZE PROGRAM CONTROL COUNTERS
C
      LINES = 0
      IPAGE = 0
      NTITLE= 0
      NCOUNT= 0
      NSTART= 0
C
C STATEMENT NO. 1000.......OUTER CONTROL LOOP BY HAZARD GROUPING
C
C
 1000 CONTINUE
C
C                   INITIAL PROGRAM GROUP VARIABLES
C
         HIB = 0.0
         CMB = 0.0
         ACB = 0.0
C
      DO 100 M=1,4
          CE(M) = 0.0
          BC(M) = 0.0
         HIA(M) = 0.0
         ACA(M) = 0.0
      THCIMP(M) = 0.0
         ICE(M) = 0
       ICOST(M) = 0
       NOTCE(M) = 0
  100 CONTINUE
C
      DO 101 L=1,6
      HI1(L) = 0.0
      AC1(L) = 0.0
      CM1(L) = 0.0
C
      DO 101 M=1,4
      HI2(L,M) = 0.0
      AC2(L,M) = 0.0
      CM2(L,M) = 0.0
      ERROR1(L,M) = 0
  101 CONTINUE
C
```

```
C
      CALL RESULT
C
C                 SUBROUTINE OUTPUT.....WRITES OUTPUT DATA BY GROUP
C
      CALL OUTPUT
C
      IF(IGR.EQ.2) GO TO 1010
C
      GO TO 1000
 1010 CONTINUE
C
      STOP
      END
C
C
C
C
C
C   ***********************************************************************
C   *
      SUBROUTINE GINFO
C   *
C   ***********************************************************************
C   *
C   *      SUBROUTINE READS GENERAL INFORMATION ON SOCIETIAL COSTS, ECONOMI
C   *    FACTORS, AUTOMOBILE SPLITS, AND ENVIROMENTAL CONDITIONS.
C   *
C   ***********************************************************************
C   ***********************************************************************
C
C
C
      DIMENSION POO(6), IAC(6), FA(6), YLAT(7)
C
      DIMENSION X(40)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4),C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *        SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *              SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
```

```
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
C
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50
C
C
C
C                             INITIALIZE VARIABLES
C
      G10 = 0.0
      G12 = 0.0
      G13 = 0.0
      G14 = 0.0
      G15 = 0.0
      G16 = 0.0
      G17 = 0.0
      G18 = 0.0
      G19 = 0.0
      G20 = 0.0
C
      READ(5,500)(X(L), L=1,40)
C
C
      G10 = X(1)
      G12 = X(3)
      G13 = 10.*X(5) + X(6)
      G14 = 10.*X(8) + X(9)
      G15 = 10.*X(11) + X(12)
      G16 = 10.*X(14) + X(15)
      G17 = 10.*X(17) + X(18) + 0.1*X(19) + 0.01*X(20) + 0.001*X(21)
      G18 = 1000000.*X(23) + 100000.*X(24) + 10000.*X(25) + 1000.*X(26)
     *      + 100.*X(27) + 10.*X(28) + X(29)
      G19 = 10000.*X(31) + 1000.*X(32) + 100.*X(33) + 10.*X(34)+X(35)
```

```
      G20 = 1000.*X(37) + 100.*X(38) + 10.*X(39) + X(40)
C
C
C    * * * * * * * * * * * FORMAT STATEMENT * * * * * * * * * * * * * * * *
C
  500 FORMAT(40F1.0)
C
      RETURN
      END
C
C    *********************************************************************
C    *
      SUBROUTINE GRCOST
C    *
C    *********************************************************************
C    *
C    *        SUBROUTINE READS GUARDRAIL COLLISION REPAIR COSTS
C    *
C    *********************************************************************
C    *********************************************************************
C
C
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
      DIMENSION X(80)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *        SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *             SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
```

```
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
C                                 INITIALIZE VARIABLES
C
        G1 = 0.0
        G2 = 0.0
        G3 = 0.0
        G9 = 0.0
       MB1 = 0.0
       MB2 = 0.0
       MB3 = 0.0
       MB9 = 0.0
      G41W = 0.0
      G42W = 0.0
      G41S = 0.0
      G42S = 0.0
      MB4W = 0.0
      MB4S = 0.0
C
C
       GRE1 = 0.0
       GRE2 = 0.0
       GRE3 = 0.0
       GRE4 = 0.0
       GRE5 = 0.0
       GET1 = 0.0
       GET3 = 0.0
      MBET1 = 0.0
      MBET2 = 0.0
C
C
      READ(5,500)(X(L), L=1,79)
C
C
       G1 = 10.*X(1) + X(2) + 0.1*X(3) + 0.01*X(4)
       G2 = 10.*X(6) + X(7) + 0.1*X(8) + 0.01*X(9)
       G3 = 10.*X(11) + X(12) + 0.1*X(13) + 0.01*X(14)
       G9 = 10.*X(16) + X(17) + 0.1*X(18) + 0.01*X(19)
      G41W= 10.*X(21) + X(22) + 0.1*X(23) + 0.01*X(24)
      G42W= 10.*X(26) + X(27) + 0.1*X(28) + 0.01*X(29)
      G41S= 10.*X(31) + X(32) + 0.1*X(33) + 0.01*X(34)
      G42S= 10.*X(36) + X(37) + 0.1*X(38) + 0.01*X(39)
```

```
      MB1 = 10.*X(41) + X(42) + 0.1*X(43) + 0.01*X(44)
      MB2 = 10.*X(46) + X(47) + 0.1*X(48) + 0.01*X(49)
      MB3 = 10.*X(51) + X(52) + 0.1*X(53) + 0.01*X(54)
      MB9 = 10.*X(56) + X(57) + 0.1*X(58) + 0.01*X(59)
      MB4W= 10.*X(61) + X(62) + 0.1*X(63) + 0.01*X(64)
      MB4S= 10.*X(66) + X(67) + 0.1*X(68) + 0.01*X(69)
C
C
      READ(5,502)( X(L), L=1,57)
C
      GRE1 = 100.*X(1) + 10.*X(2) + X(3) + 0.1*X(4) + 0.01*X(5)
      GRE2 = 100.*X(7) + 10.*X(8) + X(9) + 0.1*X(10) + 0.01*X(11)
      GRE3 = 100.*X(13) + 10.*X(14) + X(15) + 0.1*X(16) + 0.01*X(17)
      GRE4 = 100.*X(19) + 10.*X(20) + X(21) + 0.1*X(22) + 0.01*X(23)
      GRE5 = 100.*X(25) + 10.*X(26) + X(27) + 0.1*X(28) + 0.01*X(29)
      GET1 = 1000.*X(31) + 100.*X(32) + 10.*X(33) + X(34) + 0.1*X(35)
     *       + 0.01*X(36)
      GET2 = 1000.*X(38) + 100.*X(39) + 10.*X(40) + X(41) + 0.1*X(42)
     *       +0.01*X(43)
      MBET1= 1000.*X(45) + 100.*X(46) + 10.*X(47) + X(48) + 0.1*X(49)
     *       + 0.01*X(50)
      MBET2= 1000.*X(52) + 100.*X(53) + 10.*X(54) + X(55) + 0.1*X(56)
     *       + 0.01*X(57)
C
C * * * * * * * * * * FORMAT STATEMENTS * * * * * * * * * * * * * * * * * *
C
  500 FORMAT(79F1.0)
C
  502 FORMAT(57F1.0)
C
      RETURN
      END
C
C
C   ************************************************************************
C   *
      SUBROUTINE DATA
C   *
C   ************************************************************************
C   *
C   *          THIS SUBROUTINE STORES DATA FROM THE INVENTORY AND IMPROVEMEN
C   *      FORMS.  THE MAXIMUM NUMBER OF HAZARDS IS 6.  THE MAXIMUM NUMBER
C   *      IMPROVEMENTS IS 4.
C   ************************************************************************
C   ************************************************************************
C
C
C
      DIMENSION POO(6), IAC(6), FA(6), YLAT(7)
C
      DIMENSION X(78)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(5),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
```

```
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *        SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *            SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPO(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
C                      INITIALIZE ARRAYS
C
      DO 1 M=1,6
       H1(M)=0
       H2(M)=0
       H3(M)=0
       H4(M)=0
       H5(M)=0.0
       H6(M)=0.0
       H7(M)=0.0
       H8(M)=0.0
       H9(M)=0.0
      H10(M)=0.0
      H11(M)=0.0
      H12(M)=0.0
```

```
      H13(M)=0.0
      H14(M)=0
      H15(M)=0.0
      H16(M)=0
      H17(M)=0
      H18(M)=0
      H19(M)=0
      H20(M)=0
      H21(M)=0
      H22(M)=0.0
      H23(M)=0.0
      H30(M)=0
      H31(M)=0.0
      H32(M)=0.0
      H33(M)=0.0
      H34(M)=0.0
      H35(M)=0.0
      H36(M)=0.0
      H37(M)=0.0
      H38(M)=0.0
      H39(M)=0.0
      H40(M)=0.0
      H41(M)=0.0
      H42(M)=0
      H43(M)=0
      H44(M)=0
      H45(M)=0
      H46(M)=0
      H47(M)=0
      H48(M)=0
      H49(M)=0
      H50(M)=0
      H51(M)=0
C
C
C
      DO 1 N=1,4
        C1(M,N)=0
        C2(M,N)=0
        C3(M,N)=0.0
        C4(M,N)=0.0
        C5(M,N)=0.0
      C11(M,N)=0.0
      C12(M,N)=0.0
      C13(M,N)=0.0
      C14(M,N)=0.0
      C15(M,N)=0.0
      C16(M,N)=0
      C17(M,N)=0
      C18(M,N)=0
      C19(M,N)=0
      C20(M,N)=0.0
      C21(M,N)=0.0
      C22(M,N)=0.0
      C23(M,N)=0.0
      C24(M,N)=0.0
      C25(M,N)=0.0
      C26(M,N)=0.0
      C27(M,N)=0.0
      C28(M,N)=0.0
      C29(M,N)=0.0
      C30(M,N)=0
      C31(M,N)=0
      C32(M,N)=0
      C34(M,N)=0
      C35(M,N)=0
      C36(M,N)=0
      C37(M,N)=0.0
      C38(M,N)=0.0
      C39(M,N)=0
      C40(M,N)=0
      C41(M,N)=0
      C42(M,N)=0
      C50(M,N)=0
C
```

```
    1 CONTINUE
C
C
C     READ DATA FROM CARDS AND STORE IN CORRECT POSITIONS.  IGR KEEPS TRACK
C     INDIVIDUAL GROUPS.  ICARD LABELS CARD AS HAZARD OR IMPROVEMENT DATA.
C
C
      I=0
      J=0
C
  100 CONTINUE
      READ(5,500)(X(L),L=1,78),IGR,ICARD
C
      GO TO(200,205),ICARD
C
  200 CONTINUE
C
C                    THIS SECTION FILLS HAZARD ARRAYS
      I=I+1
C
       H1(I)=X(1)
       H2(I)=10.*X(2)+X(3)
       H3(I)=X(4)
       H4(I)=100.*X(5)+10.*X(6)+X(7)
       H5(I)=10.*X(8)+X(9)
       H6(I)=10000.*X(10)+1000.*X(11)+100.*X(12)+10.*X(13)+X(14)
       H7(I)=10.*X(15)+X(16)
       H8(I)=10.*X(17)+X(18)
       H9(I)=X(19)
      H10(I)=X(20)
      H11(I)=X(21)
      H12(I)=10.*X(22)+X(23)
      H13(I)=10.*X(24)+X(25)
      H14(I)=X(26)
      H15(I)=X(27)
      H16(I)=X(28)
      H17(I)=10.*X(29)+X(30)
      H18(I)=10.*X(31)+X(32)
      H19(I)=10.*X(33)+X(34)
      H20(I)=X(35)
      H21(I)=10.*X(36)+X(37)
      H22(I)=100.*X(38)+10.*X(39)+X(40)+0.1*X(41)+0.01*X(42)+0.001*X(43)
      H23(I)=100.*X(44)+10.*X(45)+X(46)+0.1*X(47)+0.01*X(48)+0.001*X(49)
      H30(I)=X(50)
      H50(I)=100.*X(1)+10.*X(2)+X(3)
      H51(I)=1000.*X(4)+100.*X(5)+10.*X(6)+X(7)
C
C
      IH30=H30(I)
C
      GO TO(2,3,4),IH30
C
C                          HAZARD IDENTIFICATION
C
C     IH30=1                      POINT HAZARD
C     IH30=2                      LONGITUDINAL HAZARD
C     IH30=3                      SLOPE HAZARD
C
C
    2 CONTINUE
      H31(I)=10.*X(51)+X(52)
      H32(I)=10.*X(53)+X(54)
      H33(I)=100.*X(55)+10.*X(56)+X(57)
      H34(I)=X(58)
      H35(I)=X(59)
      J=1
      GO TO 100
C
C
    3 CONTINUE
      H31(I)=10.*X(51)
      IF(H18(I).EQ.6.AND.H19(I).LE.9)GO TO 5
      J=1
      GO TO 100
C
```

```
    5 CONTINUE
      H49(I)=X(53)
      H33(I)=10.*X(54)+X(55)
      H34(I)=10.*X(56)+X(57)
      H35(I)=10.*X(58)+X(59)
      H36(I)=10.*X(60)+X(61)
      H37(I)=10.*X(62)+X(63)
      H38(I)=X(64)
      H39(I)=X(65)
      H40(I)=10.*X(66)+X(67)
      H41(I)=10.*X(68)+X(69)
      H42(I)=X(70)
      H43(I)=X(71)
      H44(I)=X(72)
      H45(I)=X(73)
      H46(I)=X(74)
      H47(I)=X(75)
      H48(I)=X(76)
      J=1
      GO TO 100
C
C
    4 CONTINUE
      H31(I)=10.*X(51)+X(52)
      H32(I)=X(53)
      H33(I)=10.*X(54)+X(55)
      H34(I)=10.*X(56)+X(57)
      H35(I)=X(58)
      H36(I)=10.*X(59)+X(60)
      H37(I)=10.*X(61)+X(62)
      H38(I)=X(63)
      H39(I)=10.*X(64)+X(65)
      H40(I)=10.*X(66)+X(67)
      J=1
      GO TO 100
C
C
  205 CONTINUE
C                     THIS SECTION FILLS IMPROVEMENT ARRAYS
C
       C1(I,J)=X(1)
       C2(I,J)=10.*X(2)+X(3)
       C3(I,J)=X(4)
       C4(I,J)=100.*X(5)+10.*X(6)+X(7)
C
       C5(I,J)=10.*X(9)+X(10)
      C11(I,J)=1000.*X(11)+100.*X(12)+10.*X(13)+X(14)+0.1*X(15)
      C11(I,J)=C11(I,J)*1000.0
      C12(I,J)=100.*X(16)+10.*X(17)+X(18)
      C12(I,J)=C12(I,J)*100.0
      C13(I,J)=100.*X(19)+10.*X(20)+X(21)
      C13(I,J)=C13(I,J)*100.0
      C14(I,J)=100.*X(22)+10.*X(23)+X(24)
      C14(I,J)=C14(I,J)*100.0
      C15(I,J)=100.*X(25)+10.*X(26)+X(27)
      C15(I,J)=C15(I,J)*100.0
      C16(I,J)=X(28)
      C17(I,J)=X(29)
      C37(I,J)=100.*X(57)+10.*X(58)+X(59)+0.1*X(60)+0.01*X(61)+
     *0.001*X(62)
      C38(I,J)=100.*X(63)+10.*X(64)+X(65)+0.1*X(66)+0.01*X(67)+
     *0.001*X(68)
      C40(I,J)=10.*X(73)+X(74)
      C41(I,J)=10.*X(75)+X(76)
      C42(I,J)=10.*X(77)+X(78)
      C50(I,J)=100.*X(1)+10.*X(2)+X(3)
      C51(I,J)=1000.*X(4)+100.*X(5)+10.*X(6)+X(7)
      IC16=C16(I,J)
      IC17=C17(I,J)
C
C
      GO TO(6,7,8,20),IC16
C
C                        IMPROVEMENT IDENTIFICATION
C
```

```
C       IC16=1                        POINT HAZARD IMPROVEMENT.
C       IC16=2                        LONGITUDINAL HAZARD IMPROVEMENT
C       IC16=3                        SLOPE HAZARD IMPROVEMENT
C       IC16=4                        NO IMPROVEMENT
C
      6 CONTINUE
        GO TO(9,10,11),IC17
C
C                        POINT HAZARD IMPROVEMENT IDENTIFICATION
C
C       IC17=1                        REDUCE SEVERITY
C       IC17=2                        INSTALL GUARDRAIL
C       IC17=3                        INSTALL CRASH CUSHION
C
      9 CONTINUE
        C18(I,J)=X(30)
        C19(I,J)=10.*X(31)+X(32)
        IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
        J=J+1
        GO TO 100
C
C
     10 CONTINUE
        C19(I,J)=10.*X(31)+X(32)
        GO TO 400
C
     11 CONTINUE
        C19(I,J)=10.*X(31)+X(32)
        IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
        J=J+1
        GO TO 100
C
C
      7 CONTINUE
        GO TO(12,13,14),IC17
C
C                   LONGITUDINAL HAZARD IMPROVEMENT IDENTIFICATION
C
C       IC17=1                       CURB IMPROVEMENT
C       IC17=2                       GUARDRAIL IMPROVEMENT
C       IC17=3                       BRIDGERAIL IMPROVEMENT
C
     12 CONTINUE
        C18(I,J)=X(30)
        IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
        J=J+1
        GO TO 100
C
C
     13 CONTINUE
        C18(I,J)=X(30)
        C19(I,J)=10.*X(31)+X(32)
        GO TO 400
C
     14 CONTINUE
        C18(I,J)=X(30)
        C19(I,J)=10.*X(31)+X(32)
        IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
        J=J+1
        GO TO 100
C
C
      8 CONTINUE
        GO TO(15,16),IC17
C
C                    SLOPE HAZARD IMPROVEMENT IDENTIFICATION
C
C       IC17=1                       INSTALL GUARDRAIL
C       IC17=2                       MODIFY SLOPE
C
     15 CONTINUE
        C18(I,J)=X(30)
        C19(I,J)=10.*X(31)+X(32)
        GO TO 400
C
```

```
C
   16 CONTINUE
      C28(I,J)=10.*X(30)+X(31)
      C29(I,J)=X(32)
      C20(I,J)=10.*X(33)+X(34)
      C21(I,J)=10.*X(35)+X(36)
      C22(I,J)=X(37)
      C23(I,J)=10.*X(38)+X(39)
      C24(I,J)=10.*X(40)+X(41)
      C25(I,J)=X(42)
      C26(I,J)=10.*X(43)+X(44)
      C27(I,J)=10.*X(45)+X(46)
      IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
      J=J+1
      GO TO 100
C
C
C
   20 CONTINUE
      IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
      J=J+1
      GO TO 100
C
C                    THIS SECTION COMPLETES BOX 6
C
  400 CONTINUE
      C39(I,J)=X(33)
      C21(I,J)=10.*X(34)+X(35)
      C22(I,J)=10.*X(36)+X(37)
      C23(I,J)=10.*X(38)+X(39)
      C24(I,J)=10.*X(40)+X(41)
      C25(I,J)=10.*X(42)+X(43)
      C26(I,J)=X(44)
      C27(I,J)=X(45)
      C28(I,J)=10.*X(46)+X(47)
      C29(I,J)=10.*X(48)+X(49)
      C30(I,J)=X(50)
      C31(I,J)=X(51)
      C32(I,J)=X(52)
      C33(I,J)=X(53)
      C34(I,J)=X(54)
      C35(I,J)=X(55)
      C36(I,J)=X(56)
C
C
C
      IF(IGR.EQ.1.OR.IGR.EQ.2)GO TO 300
      J=J+1
      GO TO 100
C
C
  300 CONTINUE
      IHAZ=I
      IALT=J
C
C
  500 FORMAT(78F1.0,2I1)
C
      RETURN
      END
C
C
C   ********************************************************************
C   *
      SUBROUTINE MAIN3
C   *
C   ********************************************************************
C   *
C   *          SUBROUTINE FOR SLOPE HAZARDS ONLY
C   *
C   ********************************************************************
C   ********************************************************************
C
C
C
```

```
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(5),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *        SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *            SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NOES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
```

```
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
C             CALCULATE ENCROACHMENT FREQUENCY FOR SLOPE
C
      CALL FREQ
C
C        CALCULATE HAZARD INDEX AND ACCIDENT COSTS FOR SLOPE HAZARD
C
      IFLAG=1
C
      I=1
      CALL SLOPE1
C
C  CALCULATE HAZARD INDEXES AND ACCIDENT COSTS FOR SLOPE HAZARD IMPROVEMEN
C
      IFLAG=2
C
      J=1
C                                    NO IMPROVEMENT
C
    1 CONTINUE
      IF(C16(I,J).EQ.4) GO TO 10
      GO TO 15
C
   10 CONTINUE
      CALL NOIMPR
      GO TO 200
C
   15 CONTINUE
      IF(C16(I,J).EQ.3) GO TO 20
      ERROR1(I,J) = 10
      GO TO 200
C
C                              IMPROVEMENT 1 - MODIFY SLOPE
C
   20 CONTINUE
      IF(C17(I,J).EQ.2) GO TO 30
      GO TO 40
   30 CONTINUE
      CALL SLOPE2
      GO TO 200
C
C                              IMPROVEMENT 2 - INSTALL GUARDRAIL
   40 IF(C17(I,J).EQ.1) GO TO 50
      ERROR1(I,J)=11
      GO TO 200
C
C                              NOT AT BRIDGE
   50 CONTINUE
      IF(C18(I,J).EQ.2) GO TO 60
      ERROR1(I,J)=12
      GO TO 200
C
C                              GUARDRAIL TYPE
C
C     C19(I,J)=2 ...3-STRAND CABLE WEAK POSTS
C     C19(I,J)=6 ...W-BEAM STRONG WOOD POSTS
C     C19(I,J)=7 ...W-BEAM STRONG STEEL POSTS
C     C19(I,J)=5 ...W-BEAM WEAK POSTS
   60 IF(C19(I,J).EQ.2.OR.C19(I,J).EQ.5.OR.C19(I,J).EQ.6.
     *OR.C19(I,J).EQ.7) GO TO 100
      ERROR1(I,J)=13
      GO TO 200
C
  100 CONTINUE
      CALL GRAIL
C
```

```
  200 CONTINUE
      IF(J.EQ.IALT) GO TO 250
      J = J+1
      GO TO 1
C
  250 CONTINUE
      RETURN
      END
C
C   *************************************************************************
C   *
      SUBROUTINE FREQ
C   *
C   *************************************************************************
C   *
C   *        SUBROUTINE CALCULATES ENCROACHMENT FREQUENCY FOR A GIVEN TYPE
C   *                         ROADWAY AND ADT
C   *
C   *************************************************************************
C   *************************************************************************
C
C
      DIMENSION PDG(6), IAC(6), FA(6), YLAT(7)
C
C
C
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *        SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *        SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
```

```
     *                    CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *                    AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
      INTEGER HWY
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
      ADT = H6(1)
      HWY = H50(1)
      ISIDE = H20(1)
C
C
      IF(HWY.EQ.101) ENFR = 0.000900 * ADT
      IF(HWY.EQ.102) ENFR = 0.000590 * ADT
      IF(HWY.EQ.103) ENFR = 0.000590 * ADT
      IF(HWY.EQ.104) ENFR = 0.000742 * ADT
      IF(HWY.EQ.105) ENFR = 0.000742 * ADT
      IF(HWY.EQ.106) ENFR = 0.000742 * ADT
      IF(HWY.EQ.107) ENFR = 0.001210 * ADT
      IF(HWY.EQ.210) ENFR = 0.000900 * ADT
      IF(HWY.EQ.220) ENFR = 0.000900 * ADT
      IF(HWY.EQ.230) ENFR = 0.000900 * ADT
      IF(HWY.EQ.240) ENFR = 0.000900 * ADT
      IF(HWY.EQ.250) ENFR = 0.001330 * ADT
      IF(HWY.EQ.260) ENFR = 0.001330 * ADT
C
      IF(HWY.GE.300) ENFR = 0.001210 * ADT
C
C
      IF(ISIDE.EQ.1.AND.HWY.LE.102) ENFR = ENFR*0.30
      IF(ISIDE.EQ.2.AND.HWY.LE.102) ENFR = ENFR*0.40
      IF(HWY .GT. 102) ENFR=ENFR*0.50
C
      RETURN
      END
C
C
C   ******************************************************************
C   *
      SUBROUTINE PROB1
C   *
C   ******************************************************************
C   *
C   *       SUBROUTINE CALCULATES LATERAL OFFSET PROBABILITIES
C   *
```

```
C     ***********************************************************************
C     ***********************************************************************
C
C
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(5),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *         SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *              SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
```

```
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
      X=DLAT
      DO 40 K=1,5
      OFSET(K)=0.0
   40 CONTINUE
      IF(X .GE. 0.0 .AND. X .LT. 5.0) GO TO 100
      IF(X .GE. 5.0 .AND. X .LT. 10.0) GO TO 101
      IF(X .GE. 10.0 .AND. X .LT. 15.0) GO TO 102
      IF(X .GE. 15.0 .AND. X .LT. 20.0) GO TO 103
      IF(X .GE. 20.0 .AND. X .LT. 25.0) GO TO 104
      IF(X .GE. 25.0 .AND. X .LT. 30.0) GO TO 105
      IF(X .GE. 30.0 .AND. X .LT. 35.0) GO TO 106
      IF(X .GE. 35.0 .AND. X .LT. 40.0) GO TO 107
      IF(X .GE. 40.0 .AND. X .LT. 120.0) GO TO 108
      IF(X .GE. 120.0) GO TO 109
      GO TO 1010
C
C
  100 OFSET(1)=-0.0174*X+1.0
      OFSET(2)=-0.0028*X+1.0
      OFSET(3)=1.0
      OFSET(4)=1.0
      OFSET(5)=1.0
      GO TO 1000
C
  101 OFSET(1)=-0.047*X+1.148
      OFSET(2)=-0.0224*X+1.098
      OFSET(3)=-0.016*X+1.08
      OFSET(4)=OFSET(3)
      OFSET(5)=-0.0084*X+1.042
      GO TO 1000
C
  102 OFSET(1)=-0.0242*X+0.92
      OFSET(2)=-0.017*X+1.044
      OFSET(3)=-0.016*X+1.08
      OFSET(4)=OFSET(3)
      OFSET(5)=-0.0084*X+1.042
      GO TO 1000
C
  103 OFSET(1)=-0.0174*X+0.818
      OFSET(2)=-0.0338*X+1.296
      OFSET(3)=-0.016*X+1.08
      OFSET(4)=OFSET(3)
      OFSET(5)=-0.0166*X+1.165
      GO TO 1000
C
  104 OFSET(1)=-0.0322*X+1.114
      OFSET(2)=-0.031*X+1.24
      OFSET(3)=-0.06*X+1.96
      OFSET(4)=OFSET(3)
      OFSET(5)=-0.0334*X+1.501
      GO TO 1000
C
  105 OFSET(1)=-0.0282*X+1.014
      OFSET(2)=-0.0254*X+1.10
      OFSET(3)=-0.024*X+1.06
      OFSET(4)=OFSET(3)
      OFSET(5)=-0.0582*X+2.121
      GO TO 1000
C
  106 OFSET(1)=-0.0094*X+0.45
```

```
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATCF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *        SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *                SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
      INTEGER HWY
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50
C
C
      GO TO (1,2),IFLAG
 1    HWY = H50(I)
      GO TO 3
 2    HWY = C50(I,J)
 3    CONTINUE
C
C RURAL INTERSTATE OR EXPRESSWAY OR MAJOR DIVIDED ARTERIAL (DR1,DR2)
C
      IF(HWY .EQ. 101 .OR. HWY .EQ. 102) GO TO 100
C
C     MAJOR RURAL ARTERIAL, SPECIAL STUDY (DR3)
      IF(HWY .EQ. 103) GO TO 300
C
C     RURAL 2 LANE HIGHWAY (DR4-DR7)
      IF(HWY .GE. 104 .AND. HWY .LE. 107) GO TO 400
C
C     URBAN INTERSTATE AND EXPRESSWAY (DM10,DM20,DM30,DM40)
C
      IF(HWY .EQ. 210 .OR. HWY .EQ. 220 .OR. HWY .EQ. 230 .OR.
```

```
      OFSET(2)=-0.0084*X+0.59
      OFSET(3)=-0.016*X+0.82
      OFSET(4)=OFSET(3)
      OFSET(5)=-0.0084*X+0.627
      GO TO 1000
C
  107 OFSET(1)=-0.0054*X+0.31
      OFSET(2)=-0.0056*X+0.492
      OFSET(3)=-0.004*X+0.40
      OFSET(4)=OFSET(3)
      OFSET(5)=0.333
      GO TO 1000
C
  108 OFSET(1)=-0.00118*X+0.141
      OFSET(2)=-0.00335*X+0.402
      OFSET(3)=-0.003*X+0.36
      OFSET(4)=OFSET(3)
      OFSET(5)=-0.00416*X+0.4995
      GO TO 1000
 109  OFSET(1)=0.001
      OFSET(2)=0.001
      OFSET(3)=0.002
      OFSET(4)=0.002
      OFSET(5)=0.003
 1000 CONTINUE
      DO 50 K=1,5
      IF(OFSET(K).LT.0.0)OFSET(K)=0.0
   50 CONTINUE
 1010 CONTINUE
C
      RETURN
      END
C
C
C   ******************************************************************
C   *
      SUBROUTINE PROB2
C   *
C   ******************************************************************
C   *
C   *  SUBROUTINE WHICH ASSIGNS IMPACT CONDITION PROBABILITIES
C   *  FOR A SPECIFIED ROADWAY DESIGN
C   *
C   ******************************************************************
C   ******************************************************************
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
```

```
     * HWY .EQ. 240) GO TO 200
C
C     RURAL LOW VOLUME HIGHWAYS (ROA1-ROA4, RC1-RC3, RL1-RL3)
C
      IF(HWY .GE. 301 .AND. HWY .LE. 304) GO TO 400
      IF(HWY .GE. 401 .AND. HWY .LE. 403) GO TO 400
      IF(HWY .GE. 501 .AND. HWY .LE. 503) GO TO 400
C
  100 CONTINUE
      IMP(1,1) = 0.001
      IMP(1,2) = 0.000
      IMP(1,3) = 0.000
      IMP(1,4) = 0.000
      IMP(1,5) = 0.000
      IMP(2,1) = 0.090
      IMP(2,2) = 0.038
      IMP(2,3) = 0.022
      IMP(2,4) = 0.015
      IMP(2,5) = 0.022
      IMP(3,1) = 0.335
      IMP(3,2) = 0.139
      IMP(3,3) = 0.084
      IMP(3,4) = 0.056
      IMP(3,5) = 0.084
      IMP(4,1) = 0.054
      IMP(4,2) = 0.023
      IMP(4,3) = 0.014
      IMP(4,4) = 0.009
      IMP(4,5) = 0.014
      IMP(5,1) = 0.000
      IMP(5,2) = 0.000
      IMP(5,3) = 0.000
      IMP(5,4) = 0.000
      IMP(5,5) = 0.000
      GO TO 1000
  200 CONTINUE
      IMP(1,1) = 0.010
      IMP(1,2) = 0.004
      IMP(1,3) = 0.003
      IMP(1,4) = 0.002
      IMP(1,5) = 0.003
      IMP(2,1) = 0.210
      IMP(2,2) = 0.088
      IMP(2,3) = 0.053
      IMP(2,4) = 0.035
      IMP(2,5) = 0.053
      IMP(3,1) = 0.243
      IMP(3,2) = 0.101
      IMP(3,3) = 0.061
      IMP(3,4) = 0.040
      IMP(3,5) = 0.060
      IMP(4,1) = 0.016
      IMP(4,2) = 0.007
      IMP(4,3) = 0.004
      IMP(4,4) = 0.003
      IMP(4,5) = 0.004
      IMP(5,1) = 0.000
      IMP(5,2) = 0.000
      IMP(5,3) = 0.000
      IMP(5,4) = 0.000
      IMP(5,5) = 0.000
      GO TO 1000
  300 CONTINUE
      IMP(1,1) = 0.016
      IMP(1,2) = 0.007
      IMP(1,3) = 0.004
      IMP(1,4) = 0.003
      IMP(1,5) = 0.004
      IMP(2,1) = 0.271
      IMP(2,2) = 0.113
      IMP(2,3) = 0.068
      IMP(2,4) = 0.045
      IMP(2,5) = 0.068
      IMP(3,1) = 0.188
      IMP(3,2) = 0.078
```

```
      IMP(3,3) = 0.047
      IMP(3,4) = 0.031
      IMP(3,5) = 0.047
      IMP(4,1) = 0.005
      IMP(4,2) = 0.002
      IMP(4,3) = 0.001
      IMP(4,4) = 0.001
      IMP(4,5) = 0.001
      IMP(5,1) = 0.000
      IMP(5,2) = 0.000
      IMP(5,3) = 0.000
      IMP(5,4) = 0.000
      IMP(5,5) = 0.000
      GO TO 1000
  400 CONTINUE
      IMP(1,1) = 0.006
      IMP(1,2) = 0.002
      IMP(1,3) = 0.001
      IMP(1,4) = 0.001
      IMP(1,5) = 0.002
      IMP(2,1) = 0.217
      IMP(2,2) = 0.090
      IMP(2,3) = 0.054
      IMP(2,4) = 0.036
      IMP(2,5) = 0.055
      IMP(3,1) = 0.249
      IMP(3,2) = 0.104
      IMP(3,3) = 0.062
      IMP(3,4) = 0.041
      IMP(3,5) = 0.062
      IMP(4,1) = 0.009
      IMP(4,2) = 0.004
      IMP(4,3) = 0.002
      IMP(4,4) = 0.001
      IMP(4,5) = 0.002
      IMP(5,1) = 0.000
      IMP(5,2) = 0.000
      IMP(5,3) = 0.000
      IMP(5,4) = 0.000
      IMP(5,5) = 0.000
C
C
 1000 CONTINUE
      RETURN
      END
C
C
C    ******************************************************************
C    *
      SUBROUTINE PROB3
C    *
C    ******************************************************************
C    *
C    *        SUBROUTINE CALCULATES PERSONAL INJURY PROBABLITIES
C    *
C    ******************************************************************
C    ******************************************************************
C
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
```

```
     *               C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *               C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *               C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *               C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *               C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *         SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *               SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *               MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *               GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *               CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *               AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *               NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *         H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *         C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
      DO 100 K=1,5
      DO 100 L=1,5
C
      IF(SI(K,L).GE.2.5)GO TO 10
      IF(SI(K,L).LT.0.2)GO TO 12
C
```

```
      PI(K,L) = 0.40*SI(K,L)
C     IF(SI(K,L) .LE. 1.5) PI(K,L)=0.20*SI(K,L)
C     IF(SI(K,L) .GT. 1.5) PI(K,L)=0.30+((SI(K,L)-1.5)*0.70)
      GO TO 13
C
   10 PI(K,L) = 1.00
      GO TO 13
C
   12 PI(K,L) = 0.08
   13 CONTINUE
  100 CONTINUE
C
      RETURN
      END
C
C
C   ***************************************************************************
C   *
      SUBROUTINE COMPUT
C   *
C   ***************************************************************************
C   *
C   * SUBRCUTINE CALCULATES HAZARD INDEX, ACCIDENT COSTS, AND MAINTENENCE C
C   *
C   ***************************************************************************
C   ***************************************************************************
C
C
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *               H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *               H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *               H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *               H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *               H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *               H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *               H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *               C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *               C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *               C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *               C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *               C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *               C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *               C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *          SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *            SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *               MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *               GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
```

```
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C                    CONSTANTS
C
      CC1=3.1416/180.0
      CC2= ENFR/5280.0
      WAUTO=6.0
      WBAR =1.0
C
C          OUTER CONTROL LOOP
C
C     IHIT=1 ..... SIDE TYPE VEHICLE IMPACTS
C     IHIT=2 ..... CORNER TYPE VEHICLE IMPACTS
C     IHIT=3 ..... END TYPE VHICLE IMPACTS
C
C               INITIALIZE VARIABLES
C
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
C
C
      DO 503 L=1,IHIT
      GO TO(10,11,12),L
C
   10 DLAT=DLAT1
      GO TO 13
C
   11 DLAT=DLAT1+WAUTO/2.0
      GO TO 13
C
   12 DLAT=DLAT1+WAUTO+WBAR/2.0
   13 CONTINUE
C
C
      CALL PROB1
      CALL PROB2
C
      DO 502 K=1,5
```

```
      GO TO(14,15,16,17,18),K
C
   14 ANG=5.0*CC1
      OFFSET=1.00*OFSET(1)
      GO TO 19
   15 ANG=10.0*CC1
      OFFSET=1.00*OFSET(2)
      GO TO 19
   16 ANG=15.0*CC1
      OFFSET=1.00*OFSET(3)
      GO TO 19
   17 ANG=20.0*CC1
      OFFSET=1.00*OFSET(4)
      GO TO 19
   18 ANG=25.0*CC1
      OFFSET=1.00*OFSET(5)
   19 CONTINUE
C
      SUM = 0.0
      DO 501 KK=1,5
      GO TO(20,21,21),L
C
   20 SUM=SUM+IMP(KK,K)*SIDE(KK,K)
      GO TO 22
   21 SUM=SUM+IMP(KK,K)*END(KK,K)
   22 CONTINUE
  501 CONTINUE
      GO TO(23,24,25),L
C
   23 SUM1=SUM1+OFFSET*SUM
      GO TO 26
   24 SUM2=SUM2+(1.0/SIN(ANG))*OFFSET*SUM
      GO TO 26
   25 SUM3=SUM3+(1.0/TAN(ANG))*OFFSET*SUM
   26 CONTINUE
  502 CONTINUE
  503 CONTINUE
C
      SUM1=SUM1*OLONG
      SUM2=SUM2*WAUTO
      SUM3=SUM3*WBAR
      XX=CC2*(SUM1+SUM2+SUM3)
C
      RETURN
      END
C
C
C **********************************************************************
C *
      SUBROUTINE COST3
C *
C **********************************************************************
C *
C *   SUBROUTINE COMPUTES PDO, INJURY, AND FATAL ACCIDENT COSTS FOR A
C *   SPECIFIED SEVERITY-INDEX
C *
C **********************************************************************
C
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
```

```
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *        SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *             SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
C
      GO TO (1,2), IFLAG
C
 1    CONTINUE
      IH30 = H30(I)
```

```
      GO TO (40,4,42), IH30
 4    CONTINUE
      ERROR1(I,J) = 30
      GO TO 50
 2    CONTINUE
      IC16 = C16(I,J)
      GO TO (6,7,8), IC16
 6    CONTINUE
      ERROR1(I,J) = 31
      GO TO 50
 7    CONTINUE
      IF(C17(I,J) .EQ. 1) GO TO 42
      IF(C17(I,J) .EQ. 2 .OR. C17(I,J) .EQ. 3) GO TO 41
 8    CONTINUE
      IF(C17(I,J) .EQ. 1) GO TO 41
      IF(C17(I,J) .EQ. 2) GO TO 42
 40   CONTINUE
C
C     POINT HAZARD ACCIDENT CLASSIFICATION
C
      PDO(1) = 90.0
      PDO(2) = 70.0
      PDO(3) = 50.0
      PDO(4) = 30.0
      PDO(5) = 20.0
      PDO(6) = 0.0
      IAC(1) = 10.0
      IAC(2) = 30.0
      IAC(3) = 50.0
      IAC(4) = 66.0
      IAC(5) = 72.0
      IAC(6) = 90.0
       FA(1) = 0.0
       FA(2) = 0.0
       FA(3) = 0.0
       FA(4) = 4.0
       FA(5) = 8.0
       FA(6) = 10.0
      GO TO 10
C
C
C
C
C     LONGITUDINAL HAZARD ACCIDENT CLASSIFICATION
C
 41   CONTINUE
      PDO(1) = 90.0
      PDO(2) = 70.0
      PDO(3) = 50.0
      PDO(4) = 30.0
      PDO(5) = 20.0
      PDO(6) = 0.0
      IAC(1) = 10.0
      IAC(2) = 30.0
      IAC(3) = 50.0
      IAC(4) = 70.0
      IAC(5) = 78.0
      IAC(6) = 96.0
       FA(1) = 0.0
       FA(2) = 0.0
       FA(3) = 0.0
       FA(4) = 0.0
       FA(5) = 2.0
       FA(6) = 4.0
      GO TO 10
C
C
C
C      SLOPE HAZARD ACCIDENT CLASSIFICATION
C
 42   CONTINUE
      PDO(1) = 90.0
      PDO(2) = 70.0
      PDO(3) = 50.0
      PDO(4) = 30.0
```

```
      PDO(5) = 20.0
      PDO(6) = 0.0
      IAC(1) = 10.0
      IAC(2) = 30.0
      IAC(3) = 48.0
      IAC(4) = 66.0
      IAC(5) = 74.0
      IAC(6) = 92.0
       FA(1) = 0.0
       FA(2) = 0.0
       FA(3) = 2.0
       FA(4) = 4.0
       FA(5) = 6.0
       FA(6) = 8.0
 10   CONTINUE
C
C
      DO 12 L=1,6
      PDO(L) = PDO(L)*0.01
      IAC(L) = IAC(L)*0.01
       FA(L) = FA(L)*0.01
   12 CONTINUE
C
C
      DO 20 L=1,5
      DO 20 K=1,5
      S = PI(L,K)
      IF(S .GE. 0.00 .AND. S .LT. 0.10) GO TO 21
      IF(S .GE. 0.10 .AND. S .LT. 0.30) GO TO 22
      IF(S .GE. 0.30 .AND. S .LT. 0.50) GO TO 23
      IF(S .GE. 0.50 .AND. S .LT. 0.70) GO TO 24
      IF(S .GE. 0.70 .AND. S .LT. 0.80) GO TO 25
      IF(S .GE. 0.80 .AND. S .LT. 1.00) GO TO 26
      IF(S .GE. 1.00) GO TO 27
C
C
 21   CONTINUE
      A1 = 0.0
      A2 = PDO(1)*G20 + IAC(1)*G19 + FA(1)*G18
      S1 = 0.00
      S2 = 0.10
      GO TO 30
C
 22   CONTINUE
       A1 = PDO(1)*G20 + IAC(1)*G19 + FA(1)*G18
       A2 = PDO(2)*G20 + IAC(2)*G19 + FA(2)*G18
       S1 = 0.10
       S2 = 0.30
      GO TO 30
C
 23   CONTINUE
       A1 = PDO(2)*G20 + IAC(2)*G19 + FA(2)*G18
       A2 = PDO(3)*G20 + IAC(3)*G19 + FA(3)*G18
       S1 = 0.30
       S2 = 0.50
      GO TO 30
C
 24   CONTINUE
       A1 = PDO(3)*G20 + IAC(3)*G19 + FA(3)*G18
       A2 = PDO(4)*G20 + IAC(4)*G19 + FA(4)*G18
       S1 = 0.50
       S2 = 0.70
      GO TO 30
C
 25   CONTINUE
       A1 = PDO(4)*G20 + IAC(4)*G19 + FA(4)*G18
       A2 = PDO(5)*G20 + IAC(5)*G19 + FA(5)*G18
       S1 = 0.70
       S2 = 0.90
      GO TO 30
C
 26   CONTINUE
       A1 = PDO(5)*G20 + IAC(5)*G19 + FA(5)*G18
       A2 = PDO(6)*G20 + IAC(6)*G19 + FA(6)*G18
       S1 = 0.90
```

```
      S2 = 1.00
      GO TO 30
C
 27    CONTINUE
       TAC(L,K) = PDO(6)*G20 + IAC(6)*G19 + FA(6)*G18
       GO TO 29
C
 30   CONTINUE
      B1 = A2 - A1
      B2 = S2 - S1
       B = B1/B2
C
C
C
C
      TAC(L,K) = A2 - (B*(S2 - S))
 29   CONTINUE
 20   CONTINUE
 50   CONTINUE
      RETURN
      END
C
C
C   ****************************************************************************
C   *
      SUBROUTINE COST4
C   *
C   ****************************************************************************
C   *
C   *  THIS SUBROUTINE COMPUTES GUARDRAIL COLLISION MAINTENANCE COSTS (RC(V
C   *
C   ****************************************************************************
C   ****************************************************************************
C
C
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *               H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *               H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *               H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *               H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *               H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *               H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *               H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *               C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *               C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *               C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *               C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *               C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *               C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *               C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *         SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *            SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
```

```
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
C
      GO TO (1,2), IFLAG
 1    CONTINUE
      ICODE = H19(I)
      POSTS = H41(I)
      ISIDE = H20(I)
      IF(ID .EQ. 1) IEND = H46(I)
      IF(ID .EQ. 2) IEND = H47(I)
      GO TO 3
 2    CONTINUE
      ICODE = C19(I,J)
      POSTS = C29(I,J)
      ISIDE = H20(I)
      IF(ID .EQ. 1) IEND = C34(I,J)
      IF(ID .EQ. 2) IEND = C35(I,J)
C
C     ICODE  ......... GUARDRAIL DESCRIPTOR CODE
C     POSTS  ......... POST SPACING (FT)
C     ISIDE = 1 ...... ROADSIDE GUARDRAIL
C     ISIDE = 2 ...... MEDIAN GUARDRAIL
C     IAUTO = 1,2,3 .. 4450, 2250, 1700 LB. AUTOMOBILE RESPECTIVELY
C     IHIT  = 1 ...... SIDE TYPE IMPACT
C     IHIT  = 3 ...... END TYPE IMPACT
C       ID  = 1 ...... NEAR SIDE TRAFFIC
C       ID  = 2 ...... FAR SIDE TRAFFIC
C
C
C
C
```

```
 3      CONTINUE
        GO TO (50,11,50,50,14,14,14,50,50,50), ICODE
 11     CONTINUE
C
C       CABLE GUARDRAIL (3 STRANDS ON ONE SIDE OF POST)
C
        DO 28 L = 1,5
        DO 28 K = 1,5
        S = SI(L,K)
        GO TO (20,26,26), IHIT
 20     CONTINUE
        GO TO (21,22,23), IAUTO
 21     CONTINUE
        DP = 11.62*S
        GO TO 24
 22     CONTINUE
        IF(S .LE. 0.94) DP = 2.60* S
        IF(S .GT. 0.94) DP = -4.42 + (7.31*S)
        GO TO 24
 23     CONTINUE
        IF(S .LE. 0.94) DP = 2.60*S
        IF(S .GT. 0.94) DP = -4.46 + (7.30*S)
 24     CONTINUE
        DL = 16.0 * DP
        IF(DL .GT. DLONG) DL = DLONG
        RC(L,K) = G1 * DL
        GO TO 27
 26     CONTINUE
        IF(S .GE. 0.0 .AND. S .LT. 0.5) A=0.50
        IF(S .GE. 0.5 .AND. S .LT. 1.0) A=0.60
        IF(S .GE. 1.0 .AND. S .LT. 1.5) A=0.70
        IF(S .GE. 1.5 .AND. S .LT. 2.0) A=0.80
        IF(S .GE. 2.0 .AND. S .LT. 2.5) A=0.90
        IF(S .GE. 2.5)                  A=1.00
        IF(IAUTO .EQ. 2) A=(2250.0/4500.0)*A
        IF(IAUTO .EQ. 3) A=(1700.0/4500.0)*A
        RC(L,K) = GRE3 * A
 27     CONTINUE
 28     CONTINUE
        GO TO 52
 14     CONTINUE
C
C
C
C
C       W-BEAM GUARDRAIL
C
        DO 40 L=1,5
        DO 40 K=1,5
        S = SI(L,K)
        GO TO (30,31,31), IHIT
 30     CONTINUE
        GO TO (33,34,35), IAUTO
 33     CONTINUE
        IF(ICODE .EQ. 5 .AND. POSTS .EQ. 6.0)  DL=73.0*S
        IF(ICODE .EQ. 5 .AND. POSTS .EQ. 12.0) DL=91.0*S
        IF(ICODE .EQ. 6 .AND. POSTS .EQ. 6.0)  DL=39.0*S
        IF(ICODE .EQ. 6 .AND. POSTS .EQ. 12.0) DL=49.0*S
        IF(ICODE .EQ. 7 .AND. POSTS .EQ. 6.0)  DL=42.0*S
        IF(ICODE .EQ. 7 .AND. POSTS .EQ. 12.0) DL=53.0*S
        GO TO 36
 34     CONTINUE
        IF(ICODE .EQ. 5 .AND. POSTS .EQ. 6.0)  DL=36.0*S
        IF(ICODE .EQ. 5 .AND. POSTS .EQ. 12.0) DL=45.0*S
        IF(ICODE .EQ. 6 .AND. POSTS .EQ. 6.0)  DL=22.0*S
        IF(ICODE .EQ. 6 .AND. POSTS .EQ. 12.0) DL=28.0*S
        IF(ICODE .EQ. 7 .AND. POSTS .EQ. 6.0)  DL=24.0*S
        IF(ICODE .EQ. 7 .AND. POSTS .EQ. 12.0) DL=30.0*S
        GO TO 36
 35     CONTINUE
        IF(ICODE .EQ. 5 .AND. POSTS .EQ. 6.0)  DL=27.0*S
        IF(ICODE .EQ. 5 .AND. POSTS .EQ. 12.0) DL=34.0*S
        IF(ICODE .EQ. 6 .AND. POSTS .EQ. 6.0)  DL=17.0*S
        IF(ICODE .EQ. 6 .AND. POSTS .EQ. 12.0) DL=21.0*S
        IF(ICODE .EQ. 7 .AND. POSTS .EQ. 6.0)  DL=18.0*S
```

```
      IF(ICODE .EQ. 7 .AND. POSTS .EQ. 12.0) DL=23.0*S
 36   CONTINUE
      IF(DL .GT. DLONG) DL=DLONG
      IF(ICODE .EQ. 5 .AND. POSTS .EQ. 6.0)  CPLF=G2*(2.00)
      IF(ICODE .EQ. 5 .AND. POSTS .EQ. 12.0) CPLF=G2
      IF(ICODE .EQ. 6 .AND. POSTS .EQ. 6.0)  CPLF=G41W
      IF(ICODE .EQ. 6 .AND. POSTS .EQ. 12.0) CPLF=G41W*(0.40)
      IF(ICODE .EQ. 7 .AND. POSTS .EQ. 6.0)  CPLF=G41S
      IF(ICODE .EQ. 7 .AND. POSTS .EQ. 12.0) CPLF=G41S*(0.40)
      RC(L,K) = CPLF*DL
      GO TO 37
C
C
C
C
C
 31   CONTINUE
      IF(S .GE. 0.0 .AND. S .LT. 0.5) A=0.50
      IF(S .GE. 0.5 .AND. S .LT. 1.0) A=0.60
      IF(S .GE. 1.0 .AND. S .LT. 1.5) A=0.70
      IF(S .GE. 1.5 .AND. S .LT. 2.0) A=0.80
      IF(S .GE. 2.0 .AND. S .LT. 2.5) A=0.90
      IF(S .GE. 2.5)                  A=1.00
      IF(IAUTO .EQ. 2) A=(2250.0/4450.0)*A
      IF(IAUTO .EQ. 3) A=(1700.0/4450.0)*A
      IF(IEND .EQ. 1) CR = GRE2
      IF(IEND .EQ. 2) CR = GRE1
      IF(IEND .EQ. 3) CR = GRE5
      IF(IEND .EQ. 4) CR = GRE4
      IF(IEND .EQ. 5) CR = GET1
      IF(IEND .EQ. 6) CR=GET2
      IF(IEND .EQ. 7) CR=MBET1
      IF(IEND .EQ. 8) CR=MBET2
      RC(L,K) = CR*A
 37   CONTINUE
 40   CONTINUE
      GO TO 52
 50   CONTINUE
C ----------------------------------------------------------------------
C -   FUTURE EXPANSIUN OF SUBROUTINE
C ----------------------------------------------------------------------
 52   CONTINUE
      RETURN
      END
C *********************************************************************
C *
      SUBROUTINE CRF
C *
C *********************************************************************
C *
C *   THIS SUBROUTINE CALCULATES THE ECONOMIC CAPITAL RECOVERY FACTOR
C *
C *********************************************************************
C
C
C
      DIMENSION PDQ(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(5),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
```

```
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
      COMMON/CRF1/ CR
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
      COMMON/SL1/ SLADJ1(5,5)
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *         SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *              SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
C     INT = INTEREST RATE
C     LIFE = LIFE OF PROJECT (YEARS)
C
      INT = G17/100.0
      LIFE = G16
      A = (1.0 + INT)**LIFE
      CR  = (INT*A)/(A-1)
      RETURN
      END
```

```
C
C     **********************************************************************
C     *
      SUBROUTINE SLOPE1
C     *
C     **********************************************************************
C     *
C     *     SLOPE HAZARD SUBROUTINE
C     *
C     **********************************************************************
C     **********************************************************************
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
      COMMON/SL1/ SLADJ1(5,5)
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *        SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *               SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
```

```
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
C                    INITIALIZE VARIABLES
       IHIT=1
       WEND=0.0
       IDIR=1
      IAUTO=1
      INVIR=1
      ENVIRO=ENVIR(1)
C
C
C
C                DETERMINE LENGTH OF HAZARD
C
      DLONG=ABS(H23(I) - H22(I)) * 5280.0
C
C
C       CALCULATE SEVERITY INDEXES FOR SLOPE HAZARD
C
    5 CONTINUE
      CALL SLOPE
C
C                    STORE SISL VALUES
C
      DO 10 M=1,5
      DO 10 N=1,5
      SI(M,N)=SISL(M,N)
   10 CONTINUE
C
C    DETERMINE LATERAL OFFSET DISTANCE OF SLOPE HAZARD.  IF SLOPE IS 6:1, C
C    IS MEASURED TO BOTTOM OF DITCH.  IF SLOPE IS 4:1 DLAT IS THE AVERAGE E
C    THE DITCH BOTTOM AND HINGE POINT OF SLOPE.  IF SLOPE IS 3:1 OR LESS DL
C    MEASURED TOHINGE POINT OF SLOPE.
C
      DH32 = H32(I)
      IF(DH32.LT.4.0)GO TO 15
      DLAT=(H32(I)*H33(I))+H31(I)
      IF(DH32.EQ.4.0) DLAT=(DLAT+H31(I))/2.0
      GO TO 2
C
   15 CONTINUE
      DLAT=H31(I)
    2 CONTINUE
      DLAT1 = DLAT
C
C
C                 CALCULATE INJURY PROBALILITIES
    8 CONTINUE
      CALL PROB3
C
      DO 25 M=1,5
      DO 25 N=1,5
      SIDE(M,N) = PI(M,N)
   25 CONTINUE
C
```

```
C               CALCULATE HAZARD INDEX FOR SLOPE
      CALL COMPUT
      HI = XX
C
C                 CALCULATE INJURY ACCIDENT COSTS
C
      CALL COST3
C
      DO 30 M=1,5
      DO 30 N=1,5
      SIDE(M,N) = TAC(M,N)
   30 CONTINUE
C
C                 CALCULATE AVERAGE ACCIDENT COSTS
C
      CALL COMPUT
      AC = XX
C
C
      GO TO(40,50,60),IAUTO
C
C                 IAUTO IS A COUNTER FOR AUTO SIZE
C     IAUTO = 1                  4500 LB
C     IAUTO = 2                  2250 LB
C     IAUTO = 3                  1750 LB
C
   40 CONTINUE
      JAUTO = AUTO(1)
      GO TO 70
C
   50 CONTINUE
      JAUTO = AUTO(2)
      GO TO 70
C
   60 CONTINUE
      JAUTO = AUTO(3)
C
   70 CONTINUE
C
C               ENVIRO IS AN ENVIROMENTAL PROBABILITY FACTOR
C
      HI = HI*JAUTO*ENVIRO
      AC = AC*JAUTO*ENVIRO
C
C
      HI1(I) = HI1(I)+HI
      AC1(I) = AC1(I)+AC
C
C
      INVIR = INVIR+1
C
C                INVIR IS A COUNTER FOR THE ENVIROMENTAL CONDITIONS
C     INVIR = 1          DRY CONDITION
C     INVIR = 2          WET CONDITION
C     INVIR = 3          FROZEN CONDITION
C    SLADJ1(M,N) IS THE ADJUSTMENT FACTOR FOR THE WET AND FROZEN CONDITIONS
C
      GO TO(80,80,90,100),INVIR
   80 CONTINUE
      CALL SLADJ
      DO 85 M=1,5
      DO 85 N=1,5
      SI(M,N) = SISL(M,N)*SLADJ1(M,N)
   85 CONTINUE
      ENVIRO = ENVIR(2)
      GO TO 8
   90 CONTINUE
      CALL SLADJ
      DO 95 M=1,5
      DO 95 N=1,5
      SI(M,N) = SISL(M,N)*SLADJ1(M,N)
   95 CONTINUE
      ENVIRO = ENVIR(3)
      GO TO 8
C
```

```
  100 CONTINUE
C
C   CHECK WHETHER ROAD IS 4-LANE DIVIDED HIGHWAY.  IF NOT, UNCOMING TRAFFIC
C   OPPOSITE LANE IS CONSIDERED.
C
C
      IF(H1(I).EQ.1)GO TO 110
      IF(H1(I).EQ.2)GO TO 130
      GO TO 120
C
  110 CONTINUE
      IF(H2(I).EQ.1.OR.H2(I).EQ.2)GO TO 130
  120 CONTINUE
      IDIR = IDIR+1
      IF(IDIR.EQ.3)GO TO 130
C
      INVIR = 1
      ENVIRO = ENVIR(1)
      DO 125 M=1,5
      DO 125 N=1,5
      SI(M,N) = SISL(M,N)
  125 CONTINUE
C
      DLAT = DLAT+H7(I)
      GO TO 2
C
C
  130 CONTINUE
      IAUTO = IAUTO+1
      IF(IAUTO.EQ.4)GO TO 200
      IDIR = 1
      INVIR= 1
      ENVIRO = ENVIR(1)
      GO TO 5
C
C
  200 CONTINUE
C
C
      THCHAZ = CMB
      HIB = HIB + HI1(I)
      ACB = ACB + AC1(I)
C
      RETURN
      END
C
C
C   ******************************************************************
C   *
      SUBROUTINE SLOPE2
C   *
C   ******************************************************************
C   *
C   *      SLOPE IMPROVEMENT SUBROUTINE
C   *
C   ******************************************************************
C   ******************************************************************
C
C
      DIMENSION POO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
```

```
     *                C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *                C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *                C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *                C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *                C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
      COMMON/CRF1/ CR
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
      COMMON/SL1/ SLADJ1(5,5)
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *          SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *                SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
       IHIT=1
       WEND=0.0
       IDIR=1
      IAUTO=1
      INVIR=1
      ENVIRO=ENVIR(1)
```

```
C
C
C              DETERMINE LENGTH OF IMPROVEMENT
C
      DLONG=ABS(C38(I,J)-C37(I,J))*5280.0
C
C
C      CALCULATE SEVERITY INDEXES FOR SLOPE IMPROVEMENT
C
    5 CONTINUE
      CALL SLOPE
C
C                        STORE SISL VALUES
C
      DO 10 M=1,5
      DO 10 N=1,5
      SI(M,N)=SISL(M,N)
   10 CONTINUE
C   DETERMINE LATERAL OFFSET DISTANCE OF SLOPE HAZARD.  IF SLOPE IS 6:1 DL
C   MEASURED TO BOTTOM OF DITCH.  IF SLOPE IS 4:1 DLAT IS THE AVERAGE BETW
C   THE BOTTOM OF DITCH AND THE HINGE POINT.  IF SLOPE IS 3:1 OR LESS DLAT
C   MEASURED TOHINGE POINT OF SLOPE.
C
      DC19 = C29(I,J)
      IF(DC19.LT.4.0)GO TO 15
      DLAT =(C29(I,J)*C20(I,J))+C28(I,J)
      IF(DC19.EQ.4.0) DLAT=(DLAT+C28(I,J))/2.0
      GO TO 2
C
   15 CONTINUE
      DLAT=C28(I,J)
    2 CONTINUE
      DLAT1 = DLAT
C
C
C                 CALCULATE INJURY PROBALILITIES
    8 CONTINUE
      CALL PROB3
C
      DO 25 M=1,5
      DO 25 N=1,5
      SIDE(M,N) = PI(M,N)
   25 CONTINUE
C
C               CALCULATE HAZARD INDEX FOR SLOPE
      CALL COMPUT
      HI = XX
C
C                 CALCULATE INJURY ACCIDENT COSTS
C
      CALL COST3
C
      DO 30 M=1,5
      DO 30 N=1,5
      SIDE(M,N) = TAC(M,N)
   30 CONTINUE
C
C                 CALCULATE AVERAGE ACCIDENT COSTS
C
      CALL COMPUT
      AC = XX
C
C
      GO TO(40,50,60),IAUTO
C
C
C                 IAUTO IS A COUNTER FOR AUTO SIZE
C     IAUTO = 1             4500 LB
C     IAUTO = 2             2250 LB
C     IAUTO = 3             1750 LB
C
   40 CONTINUE
      JAUTO = AUTO(1)
      GO TO 70
C
   50 CONTINUE
      JAUTO = AUTO(2)
```

```
      GO TO 70
C
   60 CONTINUE
      JAUTO = AUTO(3)
C
   70 CONTINUE
C
C              ENVIRO IS AN ENVIROMENTAL PROBABILITY FACTOR
C
      HI = HI*JAUTO*ENVIRO
      AC = AC*JAUTO*ENVIRO
C
C
      HI2(I,J)=HI2(I,J)+HI
      AC2(I,J)=AC2(I,J)+AC
C
C
C
      INVIR = INVIR+1
C
C               INVIR IS A COUNTER FOR THE ENVIROMENTAL CONDITIONS
C     INVIR = 1        DRY CONDITION
C     INVIR = 2        WET CONDITION
C     INVIR = 3        FROZEN CONDITION
C      SLADJ1(V,T) IS THE ADJUSTMENT FACTOR FOR THE WET AND FROZEN CONDITI
C
      GO TO(80,80,90,100),INVIR
   80 CONTINUE
      CALL SLADJ
      DO 85 M=1,5
      DO 85 N=1,5
      SI(M,N) = SISL(M,N)*SLADJ1(M,N)
   85 CONTINUE
      ENVIRO = ENVIR(2)
      GO TO 8
C
C
   90 CONTINUE
C
      CALL SLADJ
      DO 95 M=1,5
      DO 95 N=1,5
      SI(M,N) = SISL(M,N)*SLADJ1(M,N)
   95 CONTINUE
      ENVIRO = ENVIR(3)
      GO TO 8
C
C
  100 CONTINUE
C
C   CHECK WHETHER ROAD IS 4-LANE DIVIDED HIGHWAY.  IF NOT, ONCOMING TRAFFIC
C   OPPOSITE LANE IS CONSIDERED.
C
      IF(H1(I).EQ.1)GO TO 110
      IF(H1(I).EQ.2)GO TO 130
      GO TO 120
C
  110 CONTINUE
      IF(H2(I).EQ.1.OR.H2(I).EQ.2)GO TO 130
  120 CONTINUE
      IDIR = IDIR+1
      IF(IDIR.EQ.3)GO TO 130
C
      INVIR = 1
      ENVIRO = ENVIR(1)
      DO 125 M=1,5
      DO 125 N=1,5
      SI(M,N) = SISL(M,N)
  125 CONTINUE
C
      DLAT = DLAT+H7(I)
      GO TO 2
C
C
  130 CONTINUE
```

```
      IAUTO = IAUTO+1
      IF(IAUTO.EQ.4)GO TO 200
      IDIR = 1
      INVIR= 1
      ENVIRO = ENVIR(1)
      GO TO 5
C
  200 CONTINUE
C
      CALL CRF
      HC = C11(I,J)*CR - C14(I,J) + C15(I,J)
      THCIMP(J) = THCIMP(J) + HC
C
C
      HIA(J) = HIA(J) + HI2(I,J)
      ACA(J) = ACA(J) + AC2(I,J)
C
      RETURN
      END
C
C
C
C     ************************************************************************
C     *
      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     *  H32--FRONTSLOPE--2,3,4,6 TO 1 ONLY.  H36--BACKSLOPE--0,2,4 TO 1 UNLY
C     *  H33--FILL HEIGHT--50 FEET OR LESS.  H34--DITCH WIDTH--FROM 0 TO 12 F
C     *  UPDATED VERSION HAS ADJUSTMENT FACTORS FOR 4500, 2250, AND 1700 LB.
C     *  WHICH ARE INITIATED BY THE COUNTER IAUTO = 1, 2, 3 RESPECTIVELY.
C     *
C     ************************************************************************
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
      DIMENSION SPEED(5), ANGLE(5)
      DIMENSION SIADJ(5,5)
C
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
```

```
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *            SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *            SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NOES(100), NSPO(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
      DATA SPEED(1)/40.0/,SPEED(2)/50.0/,SPEED(3)/60.0/,SPEED(4)/70.0/,
     *SPEED(5)/80.0/
C
      DATA ANGLE(1)/5.0/,ANGLE(2)/10./,ANGLE(3)/15./,ANGLE(4)/20./,
     *ANGLE(5)/25./
C
C
9999  CONTINUE
      IF(IFLAG .EQ. 1) GO TO 501
      IF(IFLAG .EQ. 2) GO TO 502
      CONTINUE
 501  ITEMP1 = H32(I)
      ITEMP2 = H33(I)
      ITEMP3 = H34(I)
      ITEMP4 = H36(I)
      GO TO 503
 502  ITEMP1 = C29(I,J)
      ITEMP2 = C20(I,J)
      ITEMP3 = C21(I,J)
      ITEMP4 = C23(I,J)
 503  CONTINUE
C
C
      DO 1001 K=1,5
```

```
      DO 1002 L=1,5
C
      VEL=SPEED(K)
      ANG=ANGLE(L)
C
      GO TO (1,2,3,4,1,6),ITEMP1
C
 1    GO TO 1003
C
C
 2    IF(ITEMP4 .EQ. 0) GO TO 7
      IF(ITEMP4 .EQ. 4) GO TO 8
      IF(ITEMP4 .EQ. 2) GO TO 9
      GO TO 1004
C
 3    IF(ITEMP4 .EQ. 0) GO TO 10
      IF(ITEMP4 .EQ. 4) GO TO 11
      IF(ITEMP4 .EQ. 2) GO TO 12
      GO TO 1004
 4    IF(ITEMP4 .EQ. 0) GO TO 13
      IF(ITEMP4 .EQ. 4) GO TO 14
      IF(ITEMP4 .EQ. 2) GO TO 15
      GO TO 1004
 6    IF(ITEMP4 .EQ. 0) GO TO 16
      IF(ITEMP4 .EQ. 4) GO TO 17
      IF(ITEMP4 .EQ. 2) GO TO 18
      GO TO 1004
C
C
C
 7    IF(ITEMP2 .GT. 15) GO TO 200
      IF(ANG .LT. 22.5) GO TO 100
      SISL(K,L)=0.010*VEL+0.900
      GO TO 1000
 100  IF(ANG .LT. 17.5) GO TO 101
      SISL(K,L)=0.028*VEL-0.400
      GO TO 1000
 101  IF(ANG .LT. 12.5) GO TO 102
      SISL(K,L)=0.045*VEL-1.633
      GO TO 1000
 102  IF(ANG .LE. 7.5) GO TO 103
      SISL(K,L)=0.015*VEL-0.190
      GO TO 1000
 103  IF(ANG .LT. 0.0) GO TO 104
      SISL(K,L)=0.000*VEL+0.533
      GO TO 1000
 104  CONTINUE
C
C
 200  IF(ITEMP2 .GT. 25) GO TO 201
      IF(ANG .LT. 22.5) GO TO 105
      SISL(K,L)=0.075*VEL-2.433
      GO TO 1000
 105  IF(ANG .LT. 17.5) GO TO 106
      SISL(K,L)=0.0485*VEL-1.365
      GO TO 1000
 106  IF(ANG .LT. 12.5) GO TO 107
      SISL(K,L)=0.020*VEL-0.200
      GO TO 1000
 107  IF(ANG .LE. 7.5) GO TO 108
      SISL(K,L)=0.0095*VEL+0.405
      GO TO 1000
 108  IF(ANG .LT. 0.0) GO TO 109
      SISL(K,L)=0.005*VEL+0.667
      GO TO 1000
 109  CONTINUE
C
C
 201  IF(ITEMP2 .GT. 40) GO TO 202
      IF(ANG .LT. 22.5) GO TO 110
      SISL(K,L)=0.020*VEL+0.033
      GO TO 1000
 110  IF(ANG .LT. 17.5) GO TO 111
      SISL(K,L)=0.0095*VEL+0.543
      GO TO 1000
```

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 111   IF(ANG .LT. 12.5) GO TO 112
       SISL(K,L)=0.000*VEL+1.000
       GO TO 1000
 112   IF(ANG .LE. 7.5) GO TO 113
       SISL(K,L)=0.000*VEL+1.170
       GO TO 1000
 113   IF(ANG .LT. 0.0) GO TO 114
       SISL(K,L)=0.000*VEL+1.267
       GO TO 1000
 114   CONTINUE
C
C
 202   GO TO 1005
C
C
C
 8     IF(ITEMP2 .GT. 15) GO TO 203
       IF(ANG .LT. 22.5) GO TO 115
       SISL(K,L)=-0.0194*VEL+4.0456
       GO TO 1000
 115   IF(ANG .LT. 17.5) GO TO 116
       SISL(K,L)=0.0029*VEL+1.9126
       GO TO 1000
 116   IF(ANG .LT. 12.5) GO TO 117
       SISL(K,L)=0.0243*VEL-0.1942
       GO TO 1000
 117   IF(ANG .LE. 7.5) GO TO 118
       SISL(K,L)=0.0165*VEL-0.0485
       GO TO 1000
 118   IF(ANG .LT. 0.0) GO TO 119
       SISL(K,L)=0.0097*VEL+0.0000
       GO TO 1000
 119   CONTINUE
C
C
 203   IF(ITEMP2 .GT. 25) GO TO 204
       IF (ANG .LT. 22.5) GO TO 120
       SISL(K,L)=0.1117*VEL-3.4631
       GO TO 1000
 120   IF(ANG .LT. 17.5) GO TO 121
       SISL(K,L)=0.0738*VEL-2.2524
       GO TO 1000
 121   IF(ANG .LT. 12.5) GO TO 122
       SISL(K,L)=0.0485*VEL-1.4563
       GO TO 1000
 122   IF(ANG .LE. 7.5) GO TO 123
       SISL(K,L)=0.0233*VEL-0.2330
       GO TO 1000
 123   IF(ANG .LT. 0.0) GO TO 124
       SISL(K,L)=0.0049*VEL+0.6476
       GO TO 1000
 124   CONTINUE
C
C
 204   IF(ITEMP2 .GT. 40) GO TO 205
       IF(ANG .LT. 22.5) GO TO 125
       SISL(K,L)=0.0680*VEL-1.6505
       GO TO 1000
 125   IF(ANG .LT. 17.5) GO TO 126
       SISL(K,L)=0.0325*VEL+0.3078
       GO TO 1000
 126   IF(ANG .LT. 12.5) GO TO 127
       SISL(K,L)=0.0097*VEL+1.5534
       GO TO 1000
 127   IF(ANG .LE. 7.5) GO TO 128
       SISL(K,L)=0.0068*VEL+1.1553
       GO TO 1000
 128   IF(ANG .LT. 0.0) GO TO 129
       SISL(K,L)=0.0049*VEL+0.9058
       GO TO 1000
 129   CONTINUE
C
C
 205   GO TO 1005
C
```

```
C
C
  9     IF(ITEMP2 .GT. 15) GO TO 206
        IF(ANG .LT. 22.5) GO TO 130
        SISL(K,L)=-0.020*VEL+4.167
        GO TO 1000
  130   IF(ANG .LT. 17.5) GO TO 131
        SISL(K,L)=0.003*VEL+1.970
        GO TO 1000
  131   IF(ANG .LT. 12.5) GO TO 132
        SISL(K,L)=0.025*VEL-0.200
        GO TO 1000
  132   IF(ANG .LE. 7.5) GO TO 133
        SISL(K,L)=0.0170*VEL-0.050
        GO TO 1000
  133   IF(ANG .LT. 0.0) GO TO 134
        SISL(K,L)=0.010*VEL+0.000
        GO TO 1000
  134   CONTINUE
C
C
  206   IF(ITEMP2 .GT. 25) GO TO 207
        IF(ANG .LT. 22.5) GO TO 135
        SISL(K,L)=0.115*VEL-3.567
        GO TO 1000
  135   IF(ANG .LT. 17.5) GO TO 136
        SISL(K,L)=0.076*VEL-2.320
        GO TO 1000
  136   IF(ANG .LT. 12.5) GO TO 137
        SISL(K,L)=0.050*VEL-1.500
        GO TO 1000
  137   IF(ANG .LE. 7.5) GO TO 138
        SISL(K,L)=0.024*VEL-0.240
        GO TO 1000
  138   IF(ANG .LT. 0.0) GO TO 139
        SISL(K,L)=0.005*VEL+0.667
        GO TO 1000
  139   CONTINUE
C
C
  207   IF(ITEMP2 .GT. 40) GO TO 208
        IF(ANG .LT. 22.5) GO TO 140
        SISL(K,L)=0.070*VEL-1.700
        GO TO 1000
  140   IF(ANG .LT. 17.5) GO TO 141
        SISL(K,L)=0.0335*VEL+0.317
        GO TO 1000
  141   IF(ANG .LT. 12.5) GO TO 142
        SISL(K,L)=0.010*VEL+1.600
        GO TO 1000
  142   IF(ANG .LE. 7.5) GO TO 143
        SISL(K,L)=0.007*VEL+1.190
        GO TO 1000
  143   IF(ANG .LT. 0.0) GO TO 144
        SISL(K,L)=0.005*VEL+0.933
        GO TO 1000
  144   CONTINUE
C
C
  208   GO TO 1005
C
C
C
  10    IF(ITEMP2 .GT. 15) GO TO 209
        IF(ANG .LT. 22.5) GO TO 145
        SISL(K,L)=0.050*VEL-2.133
        GO TO 1000
  145   IF(ANG .LT. 17.5) GO TO 146
        SISL(K,L)=0.026*VEL-0.897
        GO TO 1000
  146   IF(ANG .LT. 12.5) GO TO 147
        SISL(K,L)=0.000*VEL+0.467
        GO TO 1000
  147   IF(ANG .LE. 7.5) GO TO 148
        SISL(K,L)=0.000*VEL+0.370
```

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      GO TO 1000
148   IF(ANG .LT. 0.0) GO TO 149
      SISL(K,L)=0.000*VEL+0.300
      GO TO 1000
149   CONTINUE
C
C
209   IF(ITEMP2 .GT. 25) GO TO 210
      IF(ANG .LT. 22.5) GO TO 150
      SISL(K,L)=0.015*VEL-0.100
      GO TO 1000
150   IF(ANG .LT. 17.5) GO TO 151
      SISL(K,L)=0.010*VEL+0.700
      GO TO 1000
151   IF(ANG .LT. 12.5) GO TO 152
      SISL(K,L)=0.005*VEL-0.233
      GO TO 1000
152   IF(ANG .LE. 7.5) GO TO 153
      SISL(K,L)=0.003*VEL+0.373
      GO TO 1000
153   IF(ANG .LT. 0.0) GO TO 154
      SISL(K,L)=0.000*VEL+0.567
      GO TO 1000
154   CONTINUE
C
C
210   IF(ITEMP2 .GT. 40) GO TO 211
      IF(ANG .LT. 22.5) GO TO 155
      SISL(K,L)=0.015*VEL-0.067
      GO TO 1000
155   IF(ANG .LT. 17.5) GO TO 156
      SISL(K,L)=0.006*VEL+0.457
      GO TO 1000
156   IF(ANG .LT. 12.5) GO TO 157
      SISL(K,L)=-0.005*VEL+1.033
      GO TO 1000
157   IF(ANG .LE. 7.5) GO TO 158
      SISL(K,L)=-0.005*VEL+0.967
      GO TO 1000
158   IF(ANG .LT. 0.0) GO TO 159
      SISL(K,L)=-0.005*VEL+0.933
      GO TO 1000
159   CONTINUE
C
C
211   GO TO 1005
C
C
C
11    IF(ITEMP2 .GT. 15) GO TO 212
      IF(ANG .LT. 22.5) GO TO 160
      SISL(K,L)=0.060*VEL-2.400
      GO TO 1000
160   IF(ANG .LT. 17.5) GO TO 161
      SISL(K,L)=0.0305*VEL-1.000
      GO TO 1000
161   IF(ANG .LT. 12.5) GO TO 162
      SISL(K,L)=0.020*VEL-0.533
      GO TO 1000
162   IF(ANG .LE. 7.5) GO TO 163
      SISL(K,L)=0.009*VEL-0.027
      GO TO 1000
163   IF(ANG .LT. 0.0) GO TO 164
      SISL(K,L)=0.005*VEL+0.133
      GO TO 1000
164   CONTINUE
C
C
212   IF(ITEMP2 .GT. 25) GO TO 213
      IF(ANG .LT. 22.5) GO TO 165
      SISL(K,L)=0.030*VEL-0.600
      GO TO 1000
165   IF(ANG .LT. 17.5) GO TO 166
      SISL(K,L)=0.0235*VEL-0.407
      GO TO 1000
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 166   IF(ANG .LT. 12.5) GO TO 167
       SISL(K,L)=0.020*VEL-0.367
       GO TO 1000
 167   IF(ANG .LE. 7.5) GO TO 168
       SISL(K,L)=0.0025*VEL+0.697
       GO TO 1000
 168   IF(ANG .LT. 0.0) GO TO 169
       SISL(K,L)=-0.005*VEL+1.167
       GO TO 1000
 169   CONTINUE
C
C
 213   IF(ITEMP2 .GT. 40) GO TO 214
       IF(ANG .LT. 22.5) GO TO 170
       SISL(K,L)=0.025*VEL-0.033
       GO TO 1000
 170   IF(ANG .LT. 17.5) GO TO 171
       SISL(K,L)=0.0205*VEL+0.056
       GO TO 1000
 171   IF(ANG .LT. 12.5) GO TO 172
       SISL(K,L)=0.020*VEL-0.133
       GO TO 1000
 172   IF(ANG .LE. 7.5) GO TO 173
       SISL(K,L)=0.012*VEL+0.460
       GO TO 1000
 173   IF(ANG .LT. 0.0) GO TO 174
       SISL(K,L)=0.010*VEL+0.667
       GO TO 1000
 174   CONTINUE
C
C
 214   GO TO 1005
C
C
C
 12    IF(ITEMP2 .GT. 15) GO TO 215
       IF(ANG .LT. 22.5) GO TO 175
       SISL(K,L)=0.1020*VEL-4.080
       GO TO 1000
 175   IF(ANG .LT. 17.5) GO TO 176
       SISL(K,L)=0.0519*VEL-1.700
       GO TO 1000
 176   IF(ANG .LT. 12.5) GO TO 177
       SISL(K,L)=0.0340*VEL-0.9061
       GO TO 1000
 177   IF(ANG .LE. 7.5) GO TO 178
       SISL(K,L)=0.0153*VEL-0.0459
       GO TO 1000
 178   IF(ANG .LT. 0.0) GO TO 179
       SISL(K,L)=0.0085*VEL+0.2261
       GO TO 1000
 179   CONTINUE
C
C
 215   IF(ITEMP2 .GT. 25) GO TO 216
       IF(ANG .LT. 22.5) GO TO 180
       SISL(K,L)=0.0510*VEL-1.020
       GO TO 1000
 180   IF(ANG .LT. 17.5) GO TO 181
       SISL(K,L)=0.040*VEL-0.6919
       GO TO 1000
 181   IF(ANG .LT. 12.5) GO TO 182
       SISL(K,L)=0.0340*VEL-0.6239
       GO TO 1000
 182   IF(ANG .LE. 7.5) GO TO 183
       SISL(K,L)=0.0043*VEL+1.1849
       GO TO 1000
 183   IF(ANG .LT. 0.0) GO TO 184
       SISL(K,L)=-0.0085*VEL+1.9839
       GO TO 1000
 184   CONTINUE
C
C
 216   IF(ITEMP2 .GT. 40) GO TO 217
       IF(ANG .LT. 22.5)GO TO 185
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      SISL(K,L)=0.0425*VEL-0.0561
      GO TO 1000
  185 IF(ANG .LT. 17.5) GO TO 186
      SISL(K,L)=0.0349*VEL+0.0952
      GO TO 1000
  186 IF(ANG .LT. 12.5) GO TO 187
      SISL(K,L)=0.0340*VEL-0.2261
      GO TO 1000
  187 IF(ANG .LE. 7.5) GO TO 188
      SISL(K,L)=0.0204*VEL+0.7820
      GO TO 1000
  188 IF (ANG .LT. 0.0) GO TO 189
      SISL(K,L)=0.0170*VEL+1.1339
      GO TO 1000
  189 CONTINUE
C
C
  217 GO TO 1005
C
C
C
  13  IF(ITEMP2 .GT.15) GO TO 218
      IF(ANG .LT. 22.5) GO TO 190
      SISL(K,L)=0.010*VEL-0.067
      GO TO 1000
  190 IF(ANG .LT. 17.5) GO TO 191
      SISL(K,L)=0.0075*VEL-0.007
      GO TO 1000
  191 IF(ANG .LT. 12.5) GO TO 192
      SISL(K,L)=0.005*VEL+0.067
      GO TO 1000
  192 IF(ANG .LE. 7.5) GO TO 193
      SISL(K,L)=0.0025*VEL+0.193
      GO TO 1000
  193 IF(ANG .LT. 0.0) GO TO 194
      SISL(K,L)=0.0015*VEL+0.233
      GO TO 1000
  194 CONTINUE
C
C
  218 IF(ITEMP2 .GT. 25) GO TO 219
      IF(ANG .LT. 22.5) GO TO 195
      SISL(K,L)=0.010*VEL+0.067
      GO TO 1000
  195 IF(ANG .LT. 17.5) GO TO 196
      SISL(K,L)=0.0055*VEL+0.243
      GO TO 1000
  196 IF(ANG .LT. 12.5) GO TO 197
      SISL(K,L)=0.005*VEL+0.167
      GO TO 1000
  197 IF(ANG .LE. 7.5) GO TO 198
      SISL(K,L)=0.0045*VEL+0.133
      GO TO 1000
  198 IF(ANG .LT. 0.0) GO TO 199
      SISL(K,L)=0.005*VEL+0.067
      GO TO 1000
  199 CONTINUE
C
C
  219 IF(ITEMP2 .GT. 40) GO TO 220
      IF(ANG .LT. 22.5) GO TO 300
      SISL(K,L)=0.000*VEL+0.767
      GO TO 1000
  300 IF(ANG .LT. 17.5) GO TO 301
      SISL(K,L)=0.000*VEL+0.680
      GO TO 1000
  301 IF(ANG .LT. 12.5) GO TO 302
      SISL(K,L)=0.000*VEL+0.600
      GO TO 1000
  302 IF(ANG .LE. 7.5) GO TO 303
      SISL(K,L)=0.0025*VEL+0.340
      GO TO 1000
  303 IF(ANG .LT. 0.0) GO TO 304
      SISL(K,L)=0.005*VEL+0.133
      GO TO 1000
```

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 304   CONTINUE
C
C
 220   GO TO 1005
C
C
C
 14    IF(ITEMP2  .GT. 15) GO TO 221
       IF(ANG .LT. 22.5) GO TO 305
       SISL(K,L)=0.010*VEL+0.367
       GO TO 1000
 305   IF(ANG .LT. 17.5) GO TO 306
       SISL(K,L)=0.0065*VEL+0.407
       GO TO 1000
 306   IF(ANG .LT. 12.5)  GO TO 307
       SISL(K,L)=0.005*VEL+0.333
       GO TO 1000
 307   IF(ANG .LE. 7.5) GO TO 308
       SISL(K,L)=0.0075*VEL+0.087
       GO TO 1000
 308   IF(ANG .LT. 0.0) GO TO 309
       SISL(K,L)=0.010*VEL-0.167
       GO TO 1000
 309   CONTINUE
C
C
 221   IF(ITEMP2 .GT. 25) GO TO 222
       IF(ANG .LT. 22.5) GO TO 310
       SISL(K,L)=0.015*VEL+0.167
       GO TO 1000
 310   IF(ANG .LT. 17.5) GO TO 311
       SISL(K,L)=0.0115*VEL+0.303
       GO TO 1000
 311   IF(ANG .LT. 12.5) GO TO 312
       SISL(K,L)=0.010*VEL+0.333
       GO TO 1000
 312   IF(ANG .LE. 7.5) GO TO 313
       SISL(K,L)=-0.003*VEL+0.890
       GO TO 1000
 313   IF(ANG .LT. 0.0) GO TO 314
       SISL(K,L)=-0.005*VEL+0.833
       GO TO 1000
 314   CONTINUE
C
C
 222   IF(ITEMP2 .GT. 40) GO TO 223
       IF(ANG .LT. 22.5) GO TO 315
       SISL(K,L)=0.006*VEL+0.860
       GO TO 1000
 315   IF(ANG .LT. 17.5) GO TO 316
       SISL(K,L)=0.0005*VEL+1.133
       GO TO 1000
 316   IF(ANG .LT. 12.5) GO TO 317
       SISL(K,L)=-0.004*VEL+1.360
       GO TO 1000
 317   IF(ANG .LE. 7.5) GO TO 318
       SISL(K,L)=-0.0065*VEL+1.423
       GO TO 1000
 318   IF(ANG .LT. 0.0) GO TO 319
       SISL(K,L)=-0.008*VEL+1.447
       GO TO 1000
 319   CONTINUE
C
C
 223   GO TO 1005
C
C
C
 15    IF(ITEMP2 .GT.15) GO TO 224
       IF(ANG .LT. 22.5) GO TO 320
       SISL(K,L)=0.0170*VEL+0.6239
       GO TO 1000
 320   IF(ANG .LT. 17.5) GO TO 321
       SISL(K,L)=0.0111*VEL+0.6919
       GO TO 1000
```

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 321    IF(ANG .LT. 12.5) GO TO 322
        SISL(K,L)=0.0085*VEL+0.5661
        GO TO 1000
 322    IF(ANG .LE. 7.5) GO TO 323
        SISL(K,L)=0.0128*VEL+0.1479
        GO TO 1000
 323    IF(ANG .LT. 0.0) GO TO 324
        SISL(K,L)=0.0170*VEL-0.2839
        GO TO 1000
 324    CONTINUE
C
C
 224    IF(ITEMP2 .GT. 25) GO TO 225
        IF(ANG .LT. 22.5) GO TO 325
        SISL(K,L)=0.0255*VEL+0.2839
        GO TO 1000
 325    IF(ANG .LT. 17.5) GO TO 326
        SISL(K,L)=0.0196*VEL+0.5151
        GO TO 1000
 326    IF(ANG .LT. 12.5) GO TO 327
        SISL(K,L)=0.0170*VEL+0.5661
        GO TO 1000
 327    IF(ANG .LE. 7.5) GO TO 328
        SISL(K,L)=-0.0051*VEL+1.5130
        GO TO 1000
 328    IF(ANG .LT. 0.0) GO TO 329
        SISL(K,L)=-0.0085*VEL+1.4161
        GO TO 1000
 329    CONTINUE
C
C
 225    IF(ITEMP2 .GT. 40) GO TO 226
        IF(ANG .LT. 22.5) GO TO 330
        SISL(K,L)=0.0102*VEL+1.4620
        GO TO 1000
 330    IF(ANG .LT. 17.5) GO TO 331
        SISL(K,L)=0.0009*VEL+1.9261
        GO TO 1000
 331    IF(ANG .LT. 12.5) GO TO 332
        SISL(K,L)=-0.0068*VEL+2.3120
        GO TO 1000
 332    IF(ANG .LE. 7.5) GO TO 333
        SISL(K,L)=-0.0111*VEL+2.4191
        GO TO 1000
 333    IF(ANG .LT. 0.0) GO TO 334
        SISL(K,L)=-0.0136*VEL+2.4599
        GO TO 1000
 334    CONTINUE
C
C
 226    GO TO 1005
C
C
C
 16     IF(ITEMP2 .GT. 15) GO TO 227
        IF(ANG .LT. 22.5) GO TO 335
        SISL(K,L)=0.015*VEL-0.567
        GO TO 1000
 335    IF(ANG .LT. 17.5) GO TO 336
        SISL(K,L)=0.009*VEL-0.250
        GO TO 1000
 336    IF(ANG .LT. 12.5) GO TO 337
        SISL(K,L)=0.005*VEL-0.067
        GO TO 1000
 337    IF(ANG .LE. 7.5) GO TO 338
        SISL(K,L)=-0.001*VEL+0.260
        GO TO 1000
 338    IF(ANG .LT. 0.0) GO TO 339
        SISL(K,L)=-0.005*VEL+0.467
        GO TO 1000
 339    CONTINUE
C
C
 227    IF(ITEMP2 .GT. 25) GO TO 228
        IF(ANG .LT. 22.5) GO TO 340
```

```
      SISL(K,L)=0.015*VEL-0.567
      GO TO 1000
 340  IF(ANG .LT. 17.5) GO TO 341
      SISL(K,L)=0.009*VEL-0.250
      GO TO 1000
 341  IF(ANG .LT. 12.5) GO TO 342
      SISL(K,L)=0.005*VEL-0.067
      GO TO 1000
 342  IF (ANG .LE. 7.5) GO TO 343
      SISL(K,L)=-0.001*VEL+0.260
      GO TO 1000
 343  IF(ANG .LT. 0.0) GO TO 344
      SISL(K,L)=-0.005*VEL+0.467
      GO TO 1000
 344  CONTINUE
C
C
 228  IF(ITEMP2 .GT. 40) GO TO 229
      IF(ANG .LT. 22.5) GO TO 345
      SISL(K,L)=0.015*VEL-0.567
      GO TO 1000
 345  IF(ANG .LT. 17.5) GO TO 346
      SISL(K,L)=0.009*VEL-0.250
      GO TO 1000
 346  IF(ANG .LT. 12.5) GO TO 347
      SISL(K,L)=0.005*VEL-0.067
      GO TO 1000
 347  IF(ANG .LE. 7.5) GO TO 348
      SISL(K,L)=-0.001*VEL+0.260
      GO TO 1000
 348  IF(ANG .LT. 0.0) GO TO 349
      SISL(K,L)=-0.005*VEL+0.467
      GO TO 1000
 349  CONTINUE
C
C
 229  GO TO 1005
C
C
C
 17   IF(ITEMP2 .GT. 15) GO TO 230
      IF(ANG .LT. 22.5) GO TO 350
      SISL(K,L)=0.020*VEL-0.367
      GO TO 1000
 350  IF(ANG .LT. 17.5) GO TO 351
      SISL(K,L)=0.0125*VEL-0.037
      GO TO 1000
 351  IF(ANG .LT. 12.5) GO TO 352
      SISL(K,L)=0.005*VEL+0.300
      GO TO 1000
 352  IF(ANG .LE. 7.5) GO TO 353
      SISL(K,L)=-0.001*VEL+0.560
      GO TO 1000
 353  IF(ANG .LT. 0.0) GO TO 354
      SISL(K,L)=-0.005*VEL+0.767
      GO TO 1000
 354  CONTINUE
C
C
 230  IF(ITEMP2 .GT. 25) GO TO 231
      IF(ANG .LT. 22.5) GO TO 355
      SISL(K,L)=0.020*VEL-0.367
      GO TO 1000
 355  IF(ANG .LT. 17.5) GO TO 356
      SISL(K,L)=0.0125*VEL-0.037
      GO TO 1000
 356  IF(ANG .LT. 12.5) GO TO 357
      SISL(K,L)=0.005*VEL+0.300
      GO TO 1000
 357  IF(ANG .LE. 7.5) GO TO 358
      SISL(K,L)=-0.001*VEL+0.560
      GO TO 1000
 358  IF(ANG .LT. 0.0) GO TO 359
      SISL(K,L)=-0.005*VEL+0.767
      GO TO 1000
```

```
 359   CONTINUE
C
C
 231   IF(ITEMP2 .GT. 40) GO TO 232
       IF (ANG .LT. 22.5) GO TO 360
       SISL(K,L)=0.020*VEL-0.367
       GO TO 1000
 360   IF(ANG .LT. 17.5) GO TO 361
       SISL(K,L)=0.0125*VEL-0.037
       GO TO 1000
 361   IF(ANG .LT. 12.5) GO TO 362
       SISL(K,L)=0.005*VEL+0.300
       GO TO 1000
 362   IF(ANG .LE. 7.5) GO TO 363
       SISL(K,L)=-0.001*VEL+0.560
       GO TO 1000
 363   IF(ANG .LT. 0.0) GO TO 364
       SISL(K,L)=-0.005*VEL+0.767
       GO TO 1000
 364   CONTINUE
C
C
 232   GO TO 1005
C
C
C
 18    IF(ITEMP2 .GT. 15) GO TO 233
       IF(ANG .LT. 22.5) GO TO 365
       SISL(K,L)=0.0340*VEL-0.6239
       GO TO 1000
 365   IF(ANG .LT. 17.5) GO TO 366
       SISL(K,L)=0.0213*VEL-0.0629
       GO TO 1000
 366   IF(ANG .LT. 12.5) GO TO 367
       SISL(K,L)=0.0085*VEL+0.5100
       GO TO 1000
 367   IF(ANG .LE. 7.5) GO TO 368
       SISL(K,L)=-0.0017*VEL+0.9520
       GO TO 1000
 368   IF(ANG .LT. 0.0) GO TO 369
       SISL(K,L)=-0.0085*VEL+1.3039
       GO TO 1000
 369   CONTINUE
C
C
 233   IF(ITEMP2 .GT. 25) GO TO 234
       IF (ANG .LT. 22.5) GO TO 370
       SISL(K,L)=0.0340*VEL-0.6239
       GO TO 1000
 370   IF(ANG .LT. 17.5) GO TO 371
       SISL(K,L)=0.0213*VEL-0.0629
       GO TO 1000
 371   IF(ANG .LT. 12.5) GO TO 372
       SISL(K,L)=0.0085*VEL+0.5100
       GO TO 1000
 372   IF(ANG .LE. 7.5) GO TO 373
       SISL(K,L)=-0.0017*VEL+0.9520
       GO TO 1000
 373   IF(ANG .LT. 0.0) GO TO 374
       SISL(K,L)=-0.0085*VEL+1.3039
       GO TO 1000
 374   CONTINUE
C
C
 234   IF(ITEMP2 .GT. 40) GO TO  235
       IF(ANG .LT. 22.5) GO TO 375
       SISL(K,L)=0.0340*VEL-0.6239
       GO TO 1000
 375   IF(ANG .LT. 17.5) GO TO 376
       SISL(K,L)=0.0213*VEL-0.0629
       GO TO 1000
 376   IF(ANG .LT. 12.5) GO TO 377
       SISL(K,L)=0.0085*VEL+0.5100
       GO TO 1000
 377   IF(ANG .LE. 7.5) GO TO 378
```

```
      SISL(K,L)=-0.0017*VEL+0.9520
      GO TO 1000
 378  IF(ANG .LT. 0.0) GO TO 379
      SISL(K,L)=-0.0085*VEL+1.3039
      GO TO 1000
 379  CONTINUE
C
C
 235  GO TO 1005
C
 1000 CONTINUE
C
C
C ****** SI ADJUSTMENT FACTORS FOR DITCH WIDTHS ******
C
C
      IF(ITEMP3 .GE. 8.AND. ITEMP4.NE. 0) GO TO 400
      IF(ITEMP3 .LT. 8 .AND. ITEMP3 .GT. 4.AND. ITEMP4.NE. 0) GO TO 401
      IF(ITEMP3 .LE. 4.AND. ITEMP4.NE. 0) GO TO 402
      GO TO 4000
C
C
 400  SISL(K,L)=SISL(K,L)*0.70
      GO TO 4000
 401  SISL(K,L)=SISL(K,L)*0.81
      GO TO 4000
 402  SISL(K,L)=SISL(K,L)*1.00
C
C ****** SI ADJUSTMENT FACTORS FOR WATER IN DITCH ******
C
C
 4000 IF(IFLAG .EQ. 1 .AND. H35(I) .EQ. 2.) GO TO 800
      IF(IFLAG .EQ. 1) GO TO 810
      IF(IFLAG .EQ. 2 .AND. C22(I,J) .EQ. 2.) GO TO 800
      GO TO 810
 800  SISL(K,L) = SISL(K,L)*1.05
      GO TO 811
 810  IF(IFLAG .EQ. 1 .AND. H35(I) .EQ. 3.) GO TO 801
      IF(IFLAG .EQ. 1) GO TO 811
      IF(IFLAG .EQ. 2 .AND. C22(I,J) .EQ. 3.) GO TO 801
      GO TO 811
 801  SISL(K,L) = SISL(K,L)*1.10
 811  CONTINUE
C
C
C ****** SI ADJUSTMENT FACTORS FOR VEHICLE TYPES ******
C
      GO TO (41,40,40),IAUTO
C
 40   GO TO (50,51,52,53,50,54),ITEMP1
 50   GO TO 1003
 51   GO TO (71,72,73,74,75),L
 52   GO TO (76,77,78,79,80),L
 53   GO TO (81,82,83,84,85),L
 54   GO TO (86,87,88,89,90),L
C
 71   SIADJ(K,L) = -0.010*VEL+1.413
      GO TO 60
 72   SIADJ(K,L) = -0.010*VEL+1.413
      GO TO 60
 73   SIADJ(K,L) = 0.0165*VEL-0.027
      GO TO 60
 74   SIADJ(K,L) = -0.0175*VEL+2.007
      GO TO 60
 75   SIADJ(K,L) = 0.030*VEL-0.500
      GO TO 60
C
 76   SIADJ(K,L) = 0.000*VEL+0.683
      GO TO 60
 77   SIADJ(K,L) = 0.000*VEL+0.683
      GO TO 60
 78   SIADJ(K,L) = 0.018*VEL-0.223
      GO TO 60
 79   SIADJ(K,L) = 0.009*VEL+0.587
      GO TO 60
```

```
 80     SIADJ(K,L)'= 0.025*VEL-0.350
        GO TO 60
C
 81     SIADJ(K,L) = 0.008*VEL+0.497
        GO TO 60
 82     SIADJ(K,L) = 0.008*VEL+0.497
        GO TO 60
 83     SIADJ(K,L) = 0.010*VEL-0.360
        GO TO 60
 84     SIADJ(K,L) = 0.003*VEL+0.647
        GO TO 60
 85     SIADJ(K,L) = 0.022*VEL-0.250
        GO TO 60
C
 86     SIADJ(K,L) = 0.008*VEL+0.497
        GO TO 60
 87     SIADJ(K,L) = 0.008*VEL+0.497
        GO TO 60
 88     SIADJ(K,L) = 0.010*VEL-0.360
        GO TO 60
 89     SIADJ(K,L) = 0.003*VEL+0.647
        GO TO 60
 90     SIADJ(K,L) = 0.022*VEL-0.250
        GO TO 60
C
C
 60     CONTINUE
C
        SISL(K,L) = SISL(K,L)*SIADJ(K,L)
C
 41     CONTINUE
C
C ****** SI ADJUSTMENT FACTORS FOR ROUGH SLOPES ******
C
        IF(IFLAG .EQ. 1 .AND. H38(I) .EQ. 2.) GO TO 901
        IF(IFLAG .EQ. 1) GO TO 905
        IF(IFLAG .EQ. 2 .AND. C25(I,J) .EQ. 2.) GO TO 901
        GO TO 905
 901    IF(SISL(K,L) .GE. 0.30) GO TO 905
        SISL(K,L) = 0.30
 905    CONTINUE
C
C ****** SET MINIMUM SI VALUE TO 0.20 ******
 403    IF(SISL(K,L) .GE. 0.2) GO TO 405
 404    SISL(K,L)=0.200
 405    CONTINUE
C
C
 1002 CONTINUE
C
 1001 CONTINUE
        GO TO 1006
 1003 IF(IFLAG .EQ. 2) GO TO 1200
        ERROR1(I,1) = 20
        GO TO 1006
 1200 ERROR1(I,J) = 20
        GO TO 1006
 1004 IF(IFLAG .EQ. 2) GO TO 1201
        ERROR1(I,1) = 21
        GO TO 1006
 1201 ERROR1(I,J) = 21
        GO TO 1006
 1005 IF(IFLAG .EQ. 2) GO TO 1202
        ERROR1(I,1) = 22
        GO TO 1006
 1202 ERROR1(I,J) = 22
 1006 CONTINUE
 9998 RETURN
        END
C
C
C   *****************************************************************
C   *
        SUBROUTINE SLADJ
C   *
```

```
C    *********************************************************************
C    *
C    *        ENVIRGMENTAL SLOPE ADJUSTMENT FACTORS
C    *
C    *********************************************************************
C    *********************************************************************
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4);
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
      COMMON/CRF1/ CR
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
      COMMON/SL1/ SLADJ1(5,5)
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *        SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *              SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
```

```
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
      GO TO(3,2,1), INVIR
C
    1 CONTINUE
C
C                         FROZEN CONDITION
C
      SLADJ1(1,1) = 1.00
      SLADJ1(1,2) = 1.00
      SLADJ1(1,3) = 1.00
      SLADJ1(1,4) = 1.05
      SLADJ1(1,5) = 1.05
      SLADJ1(2,1) = 1.00
      SLADJ1(2,2) = 1.00
      SLADJ1(2,3) = 1.05
      SLADJ1(2,4) = 1.05
      SLADJ1(2,5) = 1.10
      SLADJ1(3,1) = 1.00
      SLADJ1(3,2) = 1.05
      SLADJ1(3,3) = 1.05
      SLADJ1(3,4) = 1.10
      SLADJ1(3,5) = 1.10
      SLADJ1(4,1) = 1.05
      SLADJ1(4,2) = 1.05
      SLADJ1(4,3) = 1.10
      SLADJ1(4,4) = 1.10
      SLADJ1(4,5) = 1.10
      SLADJ1(5,1) = 1.05
      SLADJ1(5,2) = 1.10
      SLADJ1(5,3) = 1.10
      SLADJ1(5,4) = 1.10
      SLADJ1(5,5) = 1.15
C
      GO TO 5
C
C
C
    2 CONTINUE
C
C                            WET CONDITION
C
      SLADJ1(1,1) = 1.00
      SLADJ1(1,2) = 1.00
      SLADJ1(1,3) = 1.00
      SLADJ1(1,4) = 1.00
      SLADJ1(1,5) = 0.95
      SLADJ1(2,1) = 1.00
      SLADJ1(2,2) = 1.00
      SLADJ1(2,3) = 1.00
      SLADJ1(2,4) = 0.95
      SLADJ1(2,5) = 0.95
      SLADJ1(3,1) = 1.00
      SLADJ1(3,2) = 1.00
      SLADJ1(3,3) = 0.95
      SLADJ1(3,4) = 0.95
      SLADJ1(3,5) = 0.95
      SLADJ1(4,1) = 1.00
      SLADJ1(4,2) = 0.95
```

```
      SLADJ1(4,3) = 0.95
      SLADJ1(4,4) = 0.95
      SLADJ1(4,5) = 0.90
      SLADJ1(5,1) = 0.95
      SLADJ1(5,2) = 0.95
      SLADJ1(5,3) = 0.95
      SLADJ1(5,4) = 0.90
      SLADJ1(5,5) = 0.90
      GO TO 5
C
    3 CONTINUE
C
      DO 100 L = 1,5
      DO 100 K = 1,5
      SLADJ1(L,K) = 1.00
  100 CONTINUE
    5 CONTINUE
C
      RETURN
      END
C
C
C   ************************************************************************
C   *
      SUBROUTINE GRAIL
C   *
C   ************************************************************************
C   *
C   *      THIS SUBROUTINE IS THE MAIN GUARDRAIL SUBROUTINE AND LINKS ALL OF
C   *       OTHER SUBROUTINES TOGETHER
C   *
C   ************************************************************************
C   ************************************************************************
C
C
C
      DIMENSION PDO(6),IAC(6),FA(6),YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
      COMMON/CRF1/ CR
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
      COMMON/SL1/ SLADJ1(5,5)
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *          SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *              SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
```

```
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *               MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *               GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *               CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *               AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *               NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *         H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *         C35, C36, C39, C40, C41, C42, C50
C
      DO 800 K=1,3
      DO 800 L=1,5
      DO 800 M=1,5
      SIS1(K,L,M)=0.0
      SIS2(K,L,M)=0.0
      SIS3(K,L,M)=0.0
      SI1(K,L,M)=0.0
      SI2(K,L,M)=0.0
      SI3(K,L,M)=0.0
      SIE1U(K,L,M)=0.0
      SIE2U(K,L,M)=0.0
      SIE3U(K,L,M)=0.0
      SIE1D(K,L,M)=0.0
      SIE2D(K,L,M)=0.0
      SIE3D(K,L,M)=0.0
  800 CONTINUE
C
      GO TO(1,2), IFLAG
C
    1 CONTINUE
      X1 = H7(I)
      X2 = H33(I)
      X3 = H34(I)
      X4 = H35(I)
      X5 = H36(I)
      X6 = H37(I)
      X7 = H22(I)
      X8 = H23(I)
      GO TO 5
C
```

```
    2 CONTINUE
      X1 = H7(I)
      X2 = C21(I,J)
      X3 = C22(I,J)
      X4 = C23(I,J)
      X5 = C24(I,J)
      X6 = C25(I,J)
      X7 = C37(I,J)
      X8 = C38(I,J)
C
    5 CONTINUE
C
      L1 = 0
      YLAT(1) = X3
C
C
C             DETERMINE IF UPSTREAM END IS FLARED
C
      IF(X5.GE.99.0.OR.X5.EQ.0.0)GO TO 10
      GO TO 15
C
C
   10 CONTINUE
C                             1 HAZARD ENVELOPE
C
      L1 = 1
      XU = 0.0
      XD = 0.0
      GO TO 30
C
C
C                             4 HAZARD ENVELOPES
   15 L1 = L1 + 4
C
C                             UPSTREAM FLARE LENGTH
C
      XU = X5*(X2-X3)
C
C                     LATERAL OFFSET DISTANCES UPSTREAM
C
      YLAT(2) = X3 + ((1.0/6.0)*XU)/X5
      YLAT(3) = X3 + ((3.0/6.0)*XU)/X5
      YLAT(4) = X3 + ((5.0/6.0)*XU)/X5
C
C
C
C                DETERMINE IF DOWNSTREAM END IS FLARED
C
      IF(X6.GE.99.0.OR.X6.EQ.0.0)GO TO 20
      GO TO 25
C
C
   20 XD = 0.0
      GO TO 30
C
   25 CONTINUE
C                           7 HAZARD ENVELOPES
      L1 = L1 + 3
C
C
C                     DOWNSTREAM FLARE LENGTH
C
      XD = X6*(X4-X3)
C
C
C
C                     LATERAL OFFSET DISTANCES DOWNSTREAM
C
      YLAT(5) = X3 + ((1.0/6.0)*XD)/X6
      YLAT(6) = X3 + ((3.0/6.0)*XD)/X6
      YLAT(7) = X3 + ((5.0/6.0)*XD)/X6
C
   30 CONTINUE
C
C
C                     CHECK FOR 4-LANE HIGHWAY
```

```
C
      IF(H1(I).EQ.1) GO TO 35
      GO TO 40
C
   35 IF(H2(I).EQ.1.OR.H2(I).EQ.2) GO TO 45
C
C
   40 CONTINUE
      IDIR = 2
      GO TO 50
C
   45 CONTINUE
      IDIR = 1
C
   50 CONTINUE
C
C
C          DETERMINE TOTAL LENGTH AND TANGENT GUARDRAIL LENGTHS
C
      XL = (ABS(X8-X7))*5280.0
      XT = XL - XU - XD
C
      IHIT = 1
        IH = 1
        LL = 1
      DLONG= XT
C
      GO TO(55,56), IFLAG
C
   55 CONTINUE
      IF(H19(I).EQ.2) GO TO 60
      IF(H19(I).EQ.5) GO TO 65
      IF(H19(I).EQ.6) GO TO 70
      IF(H19(I).EQ.7) GO TO 75
      ERROR1(I,J) = 13
      GO TO 80
C
   56 CONTINUE
      IF(C19(I,J).EQ.2) GO TO 60
      IF(C19(I,J).EQ.5) GO TO 65
      IF(C19(I,J).EQ.6) GO TO 70
      IF(C19(I,J).EQ.7) GO TO 75
      ERROR1(I,J) = 13
      GO TO 80
C
C
   60 CONTINUE
C           CABLE GUARDRAIL SEVERITIES
      CALL GRAIL2
      GO TO 80
C
   65 CONTINUE
C           W-BEAM, WEAK STEEL POSTS, SEVERITIES
      CALL GRAIL5
      GO TO 80
C
   70 CONTINUE
C           W-BEAM, STRONG WOOD POSTS, SEVERITIES
      CALL GRAIL6
      GO TO 80
C
   75 CONTINUE
C          W-BEAM, STRONG STEEL POSTS,SEVERITIES
      CALL GRAIL7
C
C
   80 CONTINUE
C
C         SET VARIABLES FOR SIDE IMPACTS, NEARSIDE TRAFFIC
C
C      MOVED TO STATEMENT 50 TO 55
C
   85 CONTINUE
      ID = 1
C
```

```
   90 CONTINUE
      IAUTO = 1
      JAUTO = AUTO(1)
         IA = IAUTO
      INVIR = 1
C
C                                   ENVIROMENTAL CONDITIONS
C           INVIR = 1 ....... DRY CONDITION
C           INVIR = 2 ....... WET CONDITION
C           INVIR = 3 ....... FROZEN CONDITION
C
   95 CONTINUE
      GO TO(100,120,140), INVIR
C
  100 CONTINUE
      ENVIRO = ENVIR(1)
C
      IF(IHIT.GT.1) GO TO 110
C
C                        IHIT = 1     SIDE IMPACTS
C
      DO 101 M=1,5
      DO 101 N=1,5
      SI(M,N) = SIS1(IA,M,N)
  101 CONTINUE
      GO TO 200
C
C
  110 CONTINUE
C
C                 IHIT .GT. 1       END IMPACTS
C
      IF(ID.EQ.1) GO TO 115
C
      DO 111 M=1,5
      DO 111 N=1,5
      SI(M,N) = SIE1D(IA,M,N)
      SIDE(M,N) = 0.0
  111 CONTINUE
      GO TO 200
C
C
  115 CONTINUE
      DO 116 M=1,5
      DO 116 N=1,5
      SI(M,N) = SIE1U(IA,M,N)
      SIDE(M,N) = 0.0
  116 CONTINUE
      GO TO 200
C
C
  120 CONTINUE
      ENVIRO = ENVIR(2)
C
      IF(IHIT.GT.1) GO TO 130
C
C                          SIDE IMPACT
C
      DO 121 M=1,5
      DO 121 N=1,5
      SI(M,N) = SIS2(IA,M,N)
  121 CONTINUE
      GO TO 200
C
C                        END IMPACT
C
  130 CONTINUE
      IF(ID.EQ.1) GO TO 135
C
      DO 131 M=1,5
      DO 131 N=1,5
      SI(M,N) = SIE2D(IA,M,N)
      SIDE(M,N) = 0.0
  131 CONTINUE
      GO TO 200
```

```
C
C
  135 CONTINUE
C
      DO 136 M=1,5
      DO 136 N=1,5
      SI(M,N) = SIE2U(IA,M,N)
      SIDE(M,N) = 0.0
  136 CONTINUE
      GO TO 200
C
C
  140 CONTINUE
      ENVIRO = ENVIR(3)
C
      IF(IHIT.GT.1) GO TO 150
C
C                         SIDE IMPACT
C
      DO 141 M=1,5
      DO 141 N=1,5
      SI(M,N) = SIS3(IA,M,N)
  141 CONTINUE
      GO TO 200
C
C                        END IMPACT
C
  150 CONTINUE
      IF(ID.EQ.1) GO TO 155
C
      DO 151 M=1,5
      DO 151 N=1,5
      SI(M,N) = SIE3D(IA,M,N)
      SIDE(M,N) = 0.0
  151 CONTINUE
      GO TO 200
C
  155 CONTINUE
      DO 156 M=1,5
      DO 156 N=1,5
      SI(M,N) = SIE3U(IA,M,N)
      SIDE(M,N) = 0.0
  156 CONTINUE
      GO TO 200
C
C
C
  200 CONTINUE
C
      CALL PROB3
C
C                        CALCULATE HAZARD INDEX
C
      GO TO(210,230),ID
C
C
  210 CONTINUE
C
      IF(IHIT.EQ.1)GO TO 220
C
      DLAT1 = X2
      DO 215 M=1,5
      DO 215 N=1,5
      END(M,N) = PI(M,N)
  215 CONTINUE
      GO TO 250
C
  220 CONTINUE
      DLAT1 = YLAT(LL)
      DO 225 M=1,5
      DO 225 N=1,5
      SIDE(M,N) = PI(M,N)
  225 CONTINUE
      GO TO 250
C
```

```
C
C
  230 CONTINUE
C
      IF(IHIT.EQ.1) GO TO 240
C
      DLAT1 = X1 + X4
      DO 235 M=1,5
      DO 235 N=1,5
      END(M,N) = PI(M,N)
  235 CONTINUE
      GO TO 250
C
  240 CONTINUE
      DLAT1 = YLAT(LL) + X1
      DO 245 M=1,5
      DO 245 N=1,5
      SIDE(M,N) = PI(M,N)
  245 CONTINUE
C
C
  250 CALL COMPUT
C
      HI = XX
C
C
C                    DETERMINE ACCIDENT COSTS
C
C
      CALL COST3
C
      GO TO(260,280),ID
C
C
  260 CONTINUE
C
      IF(IHIT.EQ.1)GO TO 270
C
      DLAT1 = X2
      DO 265 M=1,5
      DO 265 N=1,5
      END(M,N) = TAC(M,N)
  265 CONTINUE
      GO TO 300
C
  270 CONTINUE
C
      DLAT1 = YLAT(LL)
      DO 275 M=1,5
      DO 275 N=1,5
      SIDE(M,N) = TAC(M,N)
  275 CONTINUE
      GO TO 300
C
C
  280 CONTINUE
C
      IF(IHIT.EQ.1) GO TO 290
C
      DLAT1 = X1 + X4
      DO 285 M=1,5
      DO 285 N=1,5
      END(M,N) = TAC(M,N)
  285 CONTINUE
      GO TO 300
C
  290 CONTINUE
C
      DLAT1 = YLAT(LL) +X1
      DO 295 M=1,5
      DO 295 N=1,5
      SIDE(M,N) = TAC(M,N)
  295 CONTINUE
C
C
  300 CALL COMPUT
```

```
C
      AC = XX
C
C
C                                  DETERMINE REPAIR MAINTINENCE COSTS
      DL = DLONG
      CALL COST4
C
      GO TO(310,330),ID
C
  310 CONTINUE
C
      IF(IHIT.EQ.1) GO TO 320
C
      DLAT1 = X2
      DO 315 M=1,5
      DO 315 N=1,5
      END(M,N) = RC(M,N)
  315 CONTINUE
      GO TO 350
C
  320 CONTINUE
C
      DLAT1 = YLAT(LL)
      DO 325 M=1,5
      DO 325 N=1,5
      SIDE(M,N) = RC(M,N)
  325 CONTINUE
      GO TO 350
C
C
  330 CONTINUE
C
      IF(IHIT.EQ.1)GO TO 340
C
      DLAT1 = X1 + X4
      DO 335 M=1,5
      DO 335 N=1,5
      END(M,N) = RC(M,N)
  335 CONTINUE
      GO TO 350
C
  340 CONTINUE
      DLAT1 = YLAT(LL) + X1
      DO 345 M=1,5
      DO 345 N=1,5
      SIDE(M,N) = RC(M,N)
  345 CONTINUE
      GO TO 350
C
C
  350 CALL COMPUT
C
      CM = XX
C
C
      GO TO(360,365,370), IAUTO
C
  360 JAUTO = AUTO(1)
      GO TO 380
C
  365 JAUTO = AUTO(2)
      GO TO 380
C
  370 JAUTO = AUTO(3)
C
  380 CONTINUE
C
C
      HI = HI*JAUTO*ENVIRO
      AC = AC*JAUTO*ENVIRO
      CM = CM*JAUTO*ENVIRO
C
      GO TO(390,395),IFLAG
C
```

```
  390 CONTINUE
C
C
C
      HI1(I) = HI1(I) + HI
      AC1(I) = AC1(I) + AC
      CM1(I) = CM1(I) + CM
      GO TO 400
C
  395 CONTINUE
C
C
C
      HI2(I,J) = HI2(I,J) + HI
      AC2(I,J) = AC2(I,J) + AC
      CM2(I,J) = CM2(I,J) + CM
C
C
C
  400 CONTINUE
C
      IF(INVIR.EQ.3)GO TO 410
C
      INVIR = INVIR + 1
      GO TO 95
C
  410 CONTINUE
C
      IF(IAUTO.EQ.3) GO TO 420
C
      IAUTO = IAUTO + 1
      INVIR = 1
        IA = IAUTO
      GO TO 95
C
  420 CONTINUE
C
      IF(IDIR.EQ.1.OR.ID.EQ.2)GO TO 430
      ID = ID + 1
      GO TO 90
C
  430 CONTINUE
C
      IF(LL.EQ.L1)GO TO 450
C
      LL = LL + 1
C
      IF(LL.LE.4)GO TO 440
C
      DLONG = XD/3.0
      GO TO 85
C
C
  440 CONTINUE
C
      DLONG = XU/3.0
      GO TO 85
C
C
C
  450 CONTINUE
C
C                           END IMPACT IS CONSIDERED
C
      IHIT = 3
C
      IF(IH.EQ.2)GO TO 460
      IH = IH + 1
      GO TO 85
C
C
  460 CONTINUE
      CALL CRF
      GO TO(470,475),IFLAG
C
```

```
  470 CONTINUE
      HIB = HIB + HI1(I)
      ACB = ACB + AC1(I)
      CMB = CMB + CM1(I)
      THCHAZ = CMB
      GO TO 500
C
  475 CONTINUE
      HIA(J) = HIA(J) + HI2(I,J)
      ACA(J) = ACA(J) + AC2(I,J)
          HC = C11(I,J)*CR - C14(I,J) + C15(I,J)
      THCIMP(J) = THCIMP(J) + HC + CM2(I,J)
C
C
  500 CONTINUE
C
      RETURN
      END
C
C
C    ***********************************************************************
C    *
      SUBROUTINE GRAIL2
C    *
C    ***********************************************************************
C    *
C    *     THIS SUBROUTINE CALCULATES SEVERITY INDEXES FOR THE CABLE GUARDRA
C    *
C    *
C    ***********************************************************************
C    ***********************************************************************
C
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
      COMMON/CRF1/CR
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *         SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *              SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
```

```
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
C     SIS1(W,V,T) ...... SIDE IMPACT (DRY)
C     SIS2(W,V,T) ...... SIDE IMPACT (WET)
C     SIS3(W,V,T) ...... SIDE IMPACT (FROZEN)
C
C
      V=40.0
C     1700# ADJUSTMENT DETERMINED FROM PAPER BY H.E. ROSS
      T1 = 1.20
C
C
      DO 15 K=1,5
C
C                              4500 LB. AUTO
C
      SIS1(1,K,1) = 0.0083*V - 0.0293
      SIS1(1,K,2) = 0.0125*V - 0.1292
      SIS1(1,K,3) = 0.0100*V + 0.1529
      SIS1(1,K,4) = 0.0073*V + 0.4960
      SIS1(1,K,5) = 0.0183*V + 0.0833
C
C                              2250 LB. AUTO
C
      SIS1(2,K,1) = 0.0200*V - 0.4963
      SIS1(2,K,2) = 0.0193*V - 0.1990
      SIS1(2,K,3) = 0.0233*V - 0.1733
      SIS1(2,K,4) = 0.0326*V - 0.3910
      SIS1(2,K,5) = 0.0333*V - 0.1333
C
C                              1700 LB. AUTO
C
      SIS1(3,K,1) = SIS1(2,K,1)*T1
      SIS1(3,K,2) = SIS1(2,K,2)*T1
```

```
      SIS1(3,K,3) = SIS1(2,K,3)*T1
      SIS1(3,K,4) = SIS1(2,K,4)*T1
      SIS1(3,K,5) = SIS1(2,K,5)*T1
C
      V = V + 10.0
C
C
      DO 17 K1 = 1,5
      DO 17 K2 = 1,3
      SIS2(K2,K,K1) = SIS1(K2,K,K1)
      SIS3(K2,K,K1) = SIS1(K2,K,K1)
C
   17 CONTINUE
   15 CONTINUE
C
C ** END IMPACT SEVERITIES **
C
      CALL GREND2
C
      CONTINUE
      RETURN
      END
C
C
C
C   ************************************************************************
C   *
      SUBROUTINE GREND2
C   *
C   ************************************************************************
C   *
C   *     THIS SUBROUTINE OBTAINS SEVERITY-INDEXES FOR CABLE GUARDRAIL END
C   *         TERMINAL IMPACTS.
C   *
C   ************************************************************************
C   ************************************************************************
C
C
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
```

```
     *          SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *                SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
C
      REAL IAC
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
      V = 40.0
C
      DO 50 K=1,5
C
C                4000 LB. AUTO, DRY CONDITION
C
      SI1(1,K,1) = 0.011*V
      SI1(1,K,2) = 0.009*V
      SI1(1,K,3) = 0.007*V
      SI1(1,K,4) = 0.006*V
      SI1(1,K,5) = 0.006*V
C
C                4000 LB. AUTO, WET CONDITION
C
      SI2(1,K,1) = 0.011*V
      SI2(1,K,2) = 0.009*V
      SI2(1,K,3) = 0.007*V
      SI2(1,K,4) = 0.006*V
      SI2(1,K,5) = 0.006*V
C
C                4000 LB. AUTO, FROZEN CONDITION
C
      SI3(1,K,1) = 0.011*V
      SI3(1,K,2) = 0.009*V
      SI3(1,K,3) = 0.007*V
      SI3(1,K,4) = 0.006*V
      SI3(1,K,5) = 0.006*V
```

```
C
C                    2250 LB. AUTO, DRY CONDITION
C
      SI1(2,K,1) = 0.020*V
      SI1(2,K,2) = 0.016*V
      SI1(2,K,3) = 0.013*V
      SI1(2,K,4) = 0.011*V
      SI1(2,K,5) = 0.010*V
C
C                    2250 LB. AUTO, WET CONDITION
C
      SI2(2,K,1) = 0.020*V
      SI2(2,K,2) = 0.016*V
      SI2(2,K,3) = 0.013*V
      SI2(2,K,4) = 0.011*V
      SI2(2,K,5) = 0.010*V
C
C                    2250 LB. AUTO, FROZEN CONDITION
C
      SI3(2,K,1) = 0.020*V
      SI3(2,K,2) = 0.016*V
      SI3(2,K,3) = 0.013*V
      SI3(2,K,4) = 0.011*V
      SI3(2,K,5) = 0.010*V
C
C                    1700 LB. AUTO, DRY CONDITION
C
      SI1(3,K,1) = 0.026*V
      SI1(3,K,2) = 0.021*V
      SI1(3,K,3) = 0.017*V
      SI1(3,K,4) = 0.015*V
      SI1(3,K,5) = 0.013*V
C
C                    1700 LB. AUTO, WET CONDITION
C
      SI2(3,K,1) = 0.026*V
      SI2(3,K,2) = 0.021*V
      SI2(3,K,3) = 0.017*V
      SI2(3,K,4) = 0.015*V
      SI2(3,K,5) = 0.013*V
C
C                    1700 LB. AUTO, FROZEN CONDITION
C
      SI3(3,K,1) = 0.026*V
      SI3(3,K,2) = 0.021*V
      SI3(3,K,3) = 0.017*V
      SI3(3,K,4) = 0.015*V
      SI3(3,K,5) = 0.013*V
C
      V = V + 10.0
C
   50 CONTINUE
C
C
      DO 400 N=1,IDIR
C
      GO TO(402,403),N
C
  402 CONTINUE
C
C              UPSTREAM END TERMINAL
C
      DO 404 K1=1,3
      DO 404 K2=1,5
      DO 404 K3=1,5
C
      SIE1U(K1,K2,K3) = SI1(K1,K2,K3)
      SIE2U(K1,K2,K3) = SI2(K1,K2,K3)
      SIE3U(K1,K2,K3) = SI3(K1,K2,K3)
C
  404 CONTINUE
      GO TO 410
C
  403 CONTINUE
C
```

```
C         DOWNSTREAM END TERMINAL
C
      DO 405 K1=1,3
      DO 405 K2=1,5
      DO 405 K3=1,5
C
      SIE1D(K1,K2,K3) = SI1(K1,K2,K3)
      SIE2D(K1,K2,K3) = SI2(K1,K2,K3)
      SIE3D(K1,K2,K3) = SI3(K1,K2,K3)
C
  405 CONTINUE
C
  410 CONTINUE
C
  400 CONTINUE
C
C
      RETURN
      END
C
C
C
C
C
C
C
C
C    **********************************************************************
C    *
     SUBROUTINE GRAIL6
C    *
C    **********************************************************************
C    *
C    *    THIS SUBROUTINE CALCULATES SEVERITY INDEXES FOR THE W-BEAM
C    *       (G4 - 1W,2W) GUARDRAIL.
C    *
C    **********************************************************************
C    **********************************************************************
C
C
C
C
      DIMENSION POO(6), IAC(6), FA(6), YLAT(7)
C
C
C
C
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
```

```
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *          SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *             SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, IO, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
C     ******** 6 FT. 3 IN. POST SPACING *******
C
      V = 40.0
      T1= 2250.0/ 1700.0
C
      DO 15 K=1,5
C
C                             4500 AUTO; DRY CONDITION
C
      SIS1(1,K,1) = 0.0148*V - 0.2660
      SIS1(1,K,2) = 0.0123*V - 0.0470
      SIS1(1,K,3) = 0.0122*V + 0.2470
      SIS1(1,K,4) = 0.0145*V + 0.1678
      SIS1(1,K,5) = 0.0173*V + 0.1827
C
C                          2250 LB AUTO; DRY CONDITION
C
      SIS1(2,K,1) = 0.01875*V - 0.3908
      SIS1(2,K,2) = 0.0208*V - 0.3025
      SIS1(2,K,3) = 0.0235*V - 0.2050
```

```
      SIS1(2.K.4) = 0.0255*V - 0.1650
      SIS1(2.K.5) = 0.0288*V - 0.1342
C
C                              1700 LB AUTO; DRY CONDITION
C
      SIS1(3.K.1) = SIS1(2.K.1)*T1
      SIS1(3.K.2) = SIS1(2.K.2)*T1
      SIS1(3.K.3) = SIS1(2.K.3)*T1
      SIS1(3.K.4) = SIS1(2.K.4)*T1
      SIS1(3.K.5) = SIS1(2.K.5)*T1
C
      V = V + 10.0
   15 CONTINUE
C
C
      GO TO(20.21).IFLAG
C
   20 IF(H41(I).NE.6.0) GO TO 30
      GO TO 50
C
   21 IF(C29(I.J).NE.6.0) GO TO 30
      GO TO 50
C
   30 CONTINUE
C
C ******** 12 FT. 6 IN. POST SPACING ********
C          (ADJUSTMENT FACTORS ASSUMED)
C
      V=40.0
      DO 100 K=1.5
C     4500 LB. CAR   (DRY CONDITION)
      SIS1(1.K.1) = (0.0148*V-0.266)*0.89
      SIS1(1.K.2) = (0.0123*V-0.047)*0.91
      SIS1(1.K.3) = (0.0122*V+0.247)*0.93
      SIS1(1.K.4) = (0.0145*V+0.1678)*1.01
      SIS1(1.K.5) = (0.1073*V+0.1827)*1.12
C     2250 LB. CAR (DRY CONDITION)
      SIS1(2.K.1) = (0.01875*V-0.3908)*0.89
      SIS1(2.K.2) = (0.0208*V-0.3025)*0.91
      SIS1(2.K.3) = (0.0235*V-0.2050)*0.93
      SIS1(2.K.4) = (0.0255*V-0.1650)*1.01
      SIS1(2.K.5) = (0.0288*V-0.1342)*1.12
C     1700 LB. CAR    (DRY CONDITION)
      SIS1(3.K.1) = SIS1(2.K.1)*1.16
      SIS1(3.K.2) = SIS1(2.K.2)*1.16
      SIS1(3.K.3) = SIS1(2.K.3)*1.16
      SIS1(3.K.4) = SIS1(2.K.4)*1.16
      SIS1(3.K.5) = SIS1(2.K.5)*1.16
      V = V + 10.0
  100 CONTINUE
   50 CONTINUE
C
      CALL GRADJ6
      CALL GREND6
C
      RETURN
      END
C
C
C ***********************************************************************
C *
      SUBROUTINE GRADJ6
C *
C ***********************************************************************
C *
C *      SI ADJUSTMENTS OF WET AND FROZEN CONDITIONS FOR W-BEAM (G4-1W.2W )
C *      GUARDRAIL.
C *
C ***********************************************************************
C ***********************************************************************
C
C
C
      DIMENSION POO(6). IAC(6). FA(6). YLAT(7)
C
```

```
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *       SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *           SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
```

```
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
C                            SET VARIABLES
C
      GO TO(101,102),IFLAG
C
C                   PHT = POST HEIGHT
C                 SPACE = POST SPACING
C                  IBLK = BLOCK OUT
C                  IRUB = RUB RAIL
C                 IFILL = POST BACKFILL MATERIAL
C                  SLPE = TERRAIN SLOPE
C
C
  101   PHT = H40(I)
      SPACE = H41(I)
       IBLK = H42(I)
       IRUB = H43(I)
      IFILL = H48(I)
       SLPE = H39(I)
      IF(LL.EQ.1)  SLPE = H38(I)
      GO TO 105
C
  102   PHT = C28(I,J)
      SPACE = C29(I,J)
       IBLK = C30(I,J)
       IRUB = C31(I,J)
      IFILL = C36(I,J)
       SLPE = C27(I,J)
      IF(LL.EQ.1)  SLPE = C26(I,J)
C
C
  105 CONTINUE
C
C
C
C                            WET CONDITION
C
C
      IF(SLPE.NE.8.0)GO TO 300
C
      IF(IBLK.NE.1) GO TO 300
      IF(IFILL.NE.2) GO TO 300
C
C                              POST SPACING - 6 FT. 3 IN.
C                              BLOCK OUT    - YES
C                              TERRAIN SLOPE- 8:1
C                              SOIL TYPE    - COHESIVE
C
C
C
C
C
C                            4500 LB. AUTO
C
      IF(PHT.NE.27.0)GO TO 220
      GO TO(215,216), IRUB
C
C                          27 INCH RAIL HEIGHT
C                            WITH RUB RAIL
C
  215 CONTINUE
C
      SIS2(1,1,1) = SIS1(1,1,1) * 1.0
      SIS2(1,1,2) = SIS1(1,1,2) * 1.0
      SIS2(1,1,3) = SIS1(1,1,3) * 0.9
      SIS2(1,1,4) = SIS1(1,1,4) * 0.9
      SIS2(1,1,5) = SIS1(1,1,5) * 0.8
      SIS2(1,2,1) = SIS1(1,2,1) * 1.0
      SIS2(1,2,2) = SIS1(1,2,2) * 0.9
      SIS2(1,2,3) = SIS1(1,2,3) * 0.9
```

```
      SIS2(1,2,4) = SIS1(1,2,4) * 0.8
      SIS2(1,2,5) = SIS1(1,2,5) * 5.0
      SIS2(1,3,1) = SIS1(1,3,1) * 0.9
      SIS2(1,3,2) = SIS1(1,3,2) * 0.9
      SIS2(1,3,3) = SIS1(1,3,3) * 0.8
      SIS2(1,3,4) = SIS1(1,3,4) * 5.0
      SIS2(1,3,5) = SIS1(1,3,5) * 5.0
      SIS2(1,4,1) = SIS1(1,4,1) * 0.9
      SIS2(1,4,2) = SIS1(1,4,2) * 0.8
      SIS2(1,4,3) = SIS1(1,4,3) * 5.0
      SIS2(1,4,4) = SIS1(1,4,4) * 5.0
      SIS2(1,4,5) = SIS1(1,4,5) * 5.0
      SIS2(1,5,1) = SIS1(1,5,1) * 0.8
      SIS2(1,5,2) = SIS1(1,5,2) * 5.0
      SIS2(1,5,3) = SIS1(1,5,3) * 5.0
      SIS2(1,5,4) = SIS1(1,5,4) * 5.0
      SIS2(1,5,5) = SIS1(1,5,5) * 5.0
C
      GO TO 240
C
C
C                           27 INCH RAIL HEIGHT
C                            WITHOUT RUB RAIL
  216 CONTINUE
C
      SIS2(1,1,1) = SIS1(1,1,1) * 1.0
      SIS2(1,1,2) = SIS1(1,1,2) * 1.0
      SIS2(1,1,3) = SIS1(1,1,3) * 0.9
      SIS2(1,1,4) = SIS1(1,1,4) * 0.9
      SIS2(1,1,5) = SIS1(1,1,5) * 0.8
      SIS2(1,2,1) = SIS1(1,2,1) * 1.0
      SIS2(1,2,2) = SIS1(1,2,2) * 0.9
      SIS2(1,2,3) = SIS1(1,2,3) * 0.9
      SIS2(1,2,4) = SIS1(1,2,4) * 0.8
      SIS2(1,2,5) = SIS1(1,2,5) * 5.0
      SIS2(1,3,1) = SIS1(1,3,1) * 0.9
      SIS2(1,3,2) = SIS1(1,3,2) * 0.9
      SIS2(1,3,3) = SIS1(1,3,3) * 0.8
      SIS2(1,3,4) = SIS1(1,3,4) * 5.0
      SIS2(1,3,5) = SIS1(1,3,5) * 5.0
      SIS2(1,4,1) = SIS1(1,4,1) * 0.9
      SIS2(1,4,2) = SIS1(1,4,2) * 0.8
      SIS2(1,4,3) = SIS1(1,4,3) * 5.0
      SIS2(1,4,4) = SIS1(1,4,4) * 5.0
      SIS2(1,4,5) = SIS1(1,4,5) * 5.0
      SIS2(1,5,1) = SIS1(1,5,1) * 0.8
      SIS2(1,5,2) = SIS1(1,5,2) * 5.0
      SIS2(1,5,3) = SIS1(1,5,3) * 5.0
      SIS2(1,5,4) = SIS1(1,5,4) * 5.0
      SIS2(1,5,5) = SIS1(1,5,5) * 5.0
C
      GO TO 240
C
C
  220 CONTINUE
C
      IF(PHT.NE.24.0)GO TO 300
      GO TO(300,221), IRUB
C
C
C                             24 INCH RAIL HEIGHT
C                              WITHOUT RUB RAIL
C
  221 CONTINUE
C
      SIS2(1,1,1) = SIS1(1,1,1) * 1.0
      SIS2(1,1,2) = SIS1(1,1,2) * 1.0
      SIS2(1,1,3) = SIS1(1,1,3) * 0.9
      SIS2(1,1,4) = SIS1(1,1,4) * 0.9
      SIS2(1,1,5) = SIS1(1,1,5) * 0.8
      SIS2(1,2,1) = SIS1(1,2,1) * 1.0
      SIS2(1,2,2) = SIS1(1,2,2) * 0.9
      SIS2(1,2,3) = SIS1(1,2,3) * 0.9
      SIS2(1,2,4) = SIS1(1,2,4) * 0.8
      SIS2(1,2,5) = SIS1(1,2,5) * 5.0
```

```
      SIS2(1,3,1) = SIS1(1,3,1) * 0.9
      SIS2(1,3,2) = SIS1(1,3,2) * 0.9
      SIS2(1,3,3) = SIS1(1,3,3) * 0.8
      SIS2(1,3,4) = SIS1(1,3,4) * 5.0
      SIS2(1,3,5) = SIS1(1,3,5) * 5.0
      SIS2(1,4,1) = SIS1(1,4,1) * 0.9
      SIS2(1,4,2) = SIS1(1,4,2) * 0.8
      SIS2(1,4,3) = SIS1(1,4,3) * 5.0
      SIS2(1,4,4) = SIS1(1,4,4) * 5.0
      SIS2(1,4,5) = SIS1(1,4,5) * 5.0
      SIS2(1,5,1) = SIS1(1,5,1) * 0.8
      SIS2(1,5,2) = SIS1(1,5,2) * 5.0
      SIS2(1,5,3) = SIS1(1,5,3) * 5.0
      SIS2(1,5,4) = SIS1(1,5,4) * 5.0
      SIS2(1,5,5) = SIS1(1,5,5) * 5.0
C
      GO TO 240
C
C
  240 CONTINUE
C
C                         2250 LB. AUTO
C
      IF(PHT.NE.27.0)GO TO 250
      GO TO(245,246), IRUB
C
C                                     27 INCH RAIL HEIGHT
C                                       WITH RUB RAIL
C
C
  245 CONTINUE
C
      SIS2(2,1,1) = SIS1(2,1,1) * 1.0
      SIS2(2,1,2) = SIS1(2,1,2) * 1.0
      SIS2(2,1,3) = SIS1(2,1,3) * 1.0
      SIS2(2,1,4) = SIS1(2,1,4) * 0.9
      SIS2(2,1,5) = SIS1(2,1,5) * 0.9
      SIS2(2,2,1) = SIS1(2,2,1) * 1.0
      SIS2(2,2,2) = SIS1(2,2,2) * 1.0
      SIS2(2,2,3) = SIS1(2,2,3) * 0.9
      SIS2(2,2,4) = SIS1(2,2,4) * 0.9
      SIS2(2,2,5) = SIS1(2,2,5) * 0.8
      SIS2(2,3,1) = SIS1(2,3,1) * 1.0
      SIS2(2,3,2) = SIS1(2,3,2) * 0.9
      SIS2(2,3,3) = SIS1(2,3,3) * 0.9
      SIS2(2,3,4) = SIS1(2,3,4) * 0.8
      SIS2(2,3,5) = SIS1(2,3,5) * 5.0
      SIS2(2,4,1) = SIS1(2,4,1) * 0.9
      SIS2(2,4,2) = SIS1(2,4,2) * 0.9
      SIS2(2,4,3) = SIS1(2,4,3) * 0.8
      SIS2(2,4,4) = SIS1(2,4,4) * 5.0
      SIS2(2,4,5) = SIS1(2,4,5) * 5.0
      SIS2(2,5,1) = SIS1(2,5,1) * 0.9
      SIS2(2,5,2) = SIS1(2,5,2) * 0.8
      SIS2(2,5,3) = SIS1(2,5,3) * 5.0
      SIS2(2,5,4) = SIS1(2,5,4) * 5.0
      SIS2(2,5,5) = SIS1(2,5,5) * 5.0
C
      GO TO 270
C
C
C                                   27 INCH RAIL HEIGHT
C                                    WITHOUT RUB RAIL
C
C
C
  246 CONTINUE
C
      SIS2(2,1,1) = SIS1(2,1,1) * 1.0
      SIS2(2,1,2) = SIS1(2,1,2) * 1.0
      SIS2(2,1,3) = SIS1(2,1,3) * 1.0
      SIS2(2,1,4) = SIS1(2,1,4) * 0.9
      SIS2(2,1,5) = SIS1(2,1,5) * 0.9
      SIS2(2,2,1) = SIS1(2,2,1) * 1.0
      SIS2(2,2,2) = SIS1(2,2,2) * 1.0
```

```
      SIS2(2,2,3) = SIS1(2,2,3) * 0.9
      SIS2(2,2,4) = SIS1(2,2,4) * 0.9
      SIS2(2,2,5) = SIS1(2,2,5) * 1.5
      SIS2(2,3,1) = SIS1(2,3,1) * 1.0
      SIS2(2,3,2) = SIS1(2,3,2) * 0.9
      SIS2(2,3,3) = SIS1(2,3,3) * 0.9
      SIS2(2,3,4) = SIS1(2,3,4) * 1.5
      SIS2(2,3,5) = SIS1(2,3,5) * 5.0
      SIS2(2,4,1) = SIS1(2,4,1) * 0.9
      SIS2(2,4,2) = SIS1(2,4,2) * 0.9
      SIS2(2,4,3) = SIS1(2,4,3) * 1.5
      SIS2(2,4,4) = SIS1(2,4,4) * 5.0
      SIS2(2,4,5) = SIS1(2,4,5) * 5.0
      SIS2(2,5,1) = SIS1(2,5,1) * 0.9
      SIS2(2,5,2) = SIS1(2,5,2) * 1.5
      SIS2(2,5,3) = SIS1(2,5,3) * 5.0
      SIS2(2,5,4) = SIS1(2,5,4) * 5.0
      SIS2(2,5,5) = SIS1(2,5,5) * 5.0
C
      GO TO 270
C
C
  250 CONTINUE
C
      IF(PHT.NE.24.0)GO TO 300
      GO TO(300,251), IRUB
C
C
C                                 24 INCH RAIL HEIGHT
C                                  WITHOUT RUB RAIL
C
C
  251 CONTINUE
C
      SIS2(2,1,1) = SIS1(2,1,1) * 1.0
      SIS2(2,1,2) = SIS1(2,1,2) * 1.0
      SIS2(2,1,3) = SIS1(2,1,3) * 1.0
      SIS2(2,1,4) = SIS1(2,1,4) * 0.9
      SIS2(2,1,5) = SIS1(2,1,5) * 0.9
      SIS2(2,2,1) = SIS1(2,2,1) * 1.0
      SIS2(2,2,2) = SIS1(2,2,2) * 1.0
      SIS2(2,2,3) = SIS1(2,2,3) * 0.9
      SIS2(2,2,4) = SIS1(2,2,4) * 0.9
      SIS2(2,2,5) = SIS1(2,2,5) * 0.8
      SIS2(2,3,1) = SIS1(2,3,1) * 1.0
      SIS2(2,3,2) = SIS1(2,3,2) * 0.9
      SIS2(2,3,3) = SIS1(2,3,3) * 0.9
      SIS2(2,3,4) = SIS1(2,3,4) * 0.8
      SIS2(2,3,5) = SIS1(2,3,5) * 5.0
      SIS2(2,4,1) = SIS1(2,4,1) * 0.9
      SIS2(2,4,2) = SIS1(2,4,2) * 0.9
      SIS2(2,4,3) = SIS1(2,4,3) * 0.8
      SIS2(2,4,4) = SIS1(2,4,4) * 5.0
      SIS2(2,4,5) = SIS1(2,4,5) * 5.0
      SIS2(2,5,1) = SIS1(2,5,1) * 0.9
      SIS2(2,5,2) = SIS1(2,5,2) * 0.8
      SIS2(2,5,3) = SIS1(2,5,3) * 5.0
      SIS2(2,5,4) = SIS1(2,5,4) * 5.0
      SIS2(2,5,5) = SIS1(2,5,5) * 5.0
C
      GO TO 270
C
C
C
  270 CONTINUE
C
C                                 1700 LB. AUTO
C
      IF(PHT.NE.27.0)GO TO 280
      GO TO(275,276), IRUB
C
C
C                                 27 INCH RAIL HEIGHT
C                                     WITH RUB RAIL
C
```

```
C
  275 CONTINUE
C
      SIS2(3,1,1) = SIS1(3,1,1) * 1.0
      SIS2(3,1,2) = SIS1(3,1,2) * 1.0
      SIS2(3,1,3) = SIS1(3,1,3) * 1.0
      SIS2(3,1,4) = SIS1(3,1,4) * 0.9
      SIS2(3,1,5) = SIS1(3,1,5) * 0.9
      SIS2(3,2,1) = SIS1(3,2,1) * 1.0
      SIS2(3,2,2) = SIS1(3,2,2) * 1.0
      SIS2(3,2,3) = SIS1(3,2,3) * 0.9
      SIS2(3,2,4) = SIS1(3,2,4) * 0.9
      SIS2(3,2,5) = SIS1(3,2,5) * 0.8
      SIS2(3,3,1) = SIS1(3,3,1) * 1.0
      SIS2(3,3,2) = SIS1(3,3,2) * 0.9
      SIS2(3,3,3) = SIS1(3,3,3) * 0.9
      SIS2(3,3,4) = SIS1(3,3,4) * 0.8
      SIS2(3,3,5) = SIS1(3,3,5) * 0.8
      SIS2(3,4,1) = SIS1(3,4,1) * 0.9
      SIS2(3,4,2) = SIS1(3,4,2) * 0.9
      SIS2(3,4,3) = SIS1(3,4,3) * 0.8
      SIS2(3,4,4) = SIS1(3,4,4) * 0.8
      SIS2(3,4,5) = SIS1(3,4,5) * 5.0
      SIS2(3,5,1) = SIS1(3,5,1) * 0.9
      SIS2(3,5,2) = SIS1(3,5,2) * 0.8
      SIS2(3,5,3) = SIS1(3,5,3) * 0.8
      SIS2(3,5,4) = SIS1(3,5,4) * 5.0
      SIS2(3,5,5) = SIS1(3,5,5) * 5.0
C
      GO TO 600
C
C
C                              27 INCH RAIL HEIGHT
C                               WITHOUT RUB RAIL
C
C
  276 CONTINUE
C
      SIS2(3,1,1) = SIS1(3,1,1) * 1.0
      SIS2(3,1,2) = SIS1(3,1,2) * 1.0
      SIS2(3,1,3) = SIS1(3,1,3) * 1.0
      SIS2(3,1,4) = SIS1(3,1,4) * 0.9
      SIS2(3,1,5) = SIS1(3,1,5) * 0.9
      SIS2(3,2,1) = SIS1(3,2,1) * 1.0
      SIS2(3,2,2) = SIS1(3,2,2) * 1.0
      SIS2(3,2,3) = SIS1(3,2,3) * 0.9
      SIS2(3,2,4) = SIS1(3,2,4) * 0.9
      SIS2(3,2,5) = SIS1(3,2,5) * 1.5
      SIS2(3,3,1) = SIS1(3,3,1) * 1.0
      SIS2(3,3,2) = SIS1(3,3,2) * 0.9
      SIS2(3,3,3) = SIS1(3,3,3) * 0.9
      SIS2(3,3,4) = SIS1(3,3,4) * 1.5
      SIS2(3,3,5) = SIS1(3,3,5) * 1.5
      SIS2(3,4,1) = SIS1(3,4,1) * 0.9
      SIS2(3,4,2) = SIS1(3,4,2) * 0.9
      SIS2(3,4,3) = SIS1(3,4,3) * 1.5
      SIS2(3,4,4) = SIS1(3,4,4) * 1.5
      SIS2(3,4,5) = SIS1(3,4,5) * 5.0
      SIS2(3,5,1) = SIS1(3,5,1) * 0.9
      SIS2(3,5,2) = SIS1(3,5,2) * 1.5
      SIS2(3,5,3) = SIS1(3,5,3) * 1.5
      SIS2(3,5,4) = SIS1(3,5,4) * 5.0
      SIS2(3,5,5) = SIS1(3,5,5) * 5.0
C
      GO TO 600
C
C
C
  280 CONTINUE
C
      IF(PHT.NE.24.0)GO TO 300
      GO TO(300,281), IRUB
C
C
C                              24 INCH RAIL HEIGHT
```

```
C                                   WITHOUT RUB RAIL
C
C
  281 CONTINUE
C
      SIS2(3,1,1) = SIS1(3,1,1) * 1.0
      SIS2(3,1,2) = SIS1(3,1,2) * 1.0
      SIS2(3,1,3) = SIS1(3,1,3) * 1.0
      SIS2(3,1,4) = SIS1(3,1,4) * 0.9
      SIS2(3,1,5) = SIS1(3,1,5) * 0.9
      SIS2(3,2,1) = SIS1(3,2,1) * 1.0
      SIS2(3,2,2) = SIS1(3,2,2) * 1.0
      SIS2(3,2,3) = SIS1(3,2,3) * 0.9
      SIS2(3,2,4) = SIS1(3,2,4) * 0.9
      SIS2(3,2,5) = SIS1(3,2,5) * 0.8
      SIS2(3,3,1) = SIS1(3,3,1) * 1.0
      SIS2(3,3,2) = SIS1(3,3,2) * 0.9
      SIS2(3,3,3) = SIS1(3,3,3) * 0.9
      SIS2(3,3,4) = SIS1(3,3,4) * 0.8
      SIS2(3,3,5) = SIS1(3,3,5) * 0.8
      SIS2(3,4,1) = SIS1(3,4,1) * 0.9
      SIS2(3,4,2) = SIS1(3,4,2) * 0.9
      SIS2(3,4,3) = SIS1(3,4,3) * 0.8
      SIS2(3,4,4) = SIS1(3,4,4) * 0.8
      SIS2(3,4,5) = SIS1(3,4,5) * 5.0
      SIS2(3,5,1) = SIS1(3,5,1) * 0.9
      SIS2(3,5,2) = SIS1(3,5,2) * 0.8
      SIS2(3,5,3) = SIS1(3,5,3) * 0.8
      SIS2(3,5,4) = SIS1(3,5,4) * 5.0
      SIS2(3,5,5) = SIS1(3,5,5) * 5.0
C
      GO TO 600
C
C
  300 CONTINUE
C
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C*   FUTURE EXPANSION OF SUBROUTINE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
C
C
C                             FROZEN CONDITION
C
  600 CONTINUE
C
      IF(SLPE.NE.8.0)GO TO 700
C
      IF(IBLK.NE.1)GO TO 700
      IF(IFILL.NE.2)GO TO 700
C
C                       POST SPACING   -   6 FT. 3 IN.
C                       BLOCK OUT      -   YES
C                       TERRAIN SLOPE  -   8:1
C                       SOIL TYPE      -   COHESIVE
C
C
C
C                              4500 LB. AUTO
C
      IF(PHT.NE.27.0)GO TO 620
      GO TO(615,616),IRUB
C
C
C                          27 INCH RAIL HEIGHT
C                             WITH RUB RAIL
C
C
  615 CONTINUE
C
      SIS3(1,1,1) = SIS1(1,1,1) * 1.0
      SIS3(1,1,2) = SIS1(1,1,2) * 1.0
      SIS3(1,1,3) = SIS1(1,1,3) * 1.1
      SIS3(1,1,4) = SIS1(1,1,4) * 1.1
      SIS3(1,1,5) = SIS1(1,1,5) * 1.2
```

```
      SIS3(1,2,1) = SIS1(1,2,1) * 1.0
      SIS3(1,2,2) = SIS1(1,2,2) * 1.1
      SIS3(1,2,3) = SIS1(1,2,3) * 1.1
      SIS3(1,2,4) = SIS1(1,2,4) * 1.2
      SIS3(1,2,5) = SIS1(1,2,5) * 5.0
      SIS3(1,3,1) = SIS1(1,3,1) * 1.1
      SIS3(1,3,2) = SIS1(1,3,2) * 1.1
      SIS3(1,3,3) = SIS1(1,3,3) * 1.2
      SIS3(1,3,4) = SIS1(1,3,4) * 5.0
      SIS3(1,3,5) = SIS1(1,3,5) * 5.0
      SIS3(1,4,1) = SIS1(1,4,1) * 1.1
      SIS3(1,4,2) = SIS1(1,4,2) * 1.2
      SIS3(1,4,3) = SIS1(1,4,3) * 5.0
      SIS3(1,4,4) = SIS1(1,4,4) * 5.0
      SIS3(1,4,5) = SIS1(1,4,5) * 5.0
      SIS3(1,5,1) = SIS1(1,5,1) * 1.2
      SIS3(1,5,2) = SIS1(1,5,2) * 5.0
      SIS3(1,5,3) = SIS1(1,5,3) * 5.0
      SIS3(1,5,4) = SIS1(1,5,4) * 5.0
      SIS3(1,5,5) = SIS1(1,5,5) * 5.0
C
      GO TO 640
C
C
C                                 27 INCH RAIL HEIGHT
C                                  WITHOUT RUB RAIL
C
C
  616 CONTINUE
C
      SIS3(1,1,1) = SIS1(1,1,1) * 1.0
      SIS3(1,1,2) = SIS1(1,1,2) * 1.0
      SIS3(1,1,3) = SIS1(1,1,3) * 1.1
      SIS3(1,1,4) = SIS1(1,1,4) * 1.1
      SIS3(1,1,5) = SIS1(1,1,5) * 1.2
      SIS3(1,2,1) = SIS1(1,2,1) * 1.0
      SIS3(1,2,2) = SIS1(1,2,2) * 1.1
      SIS3(1,2,3) = SIS1(1,2,3) * 1.1
      SIS3(1,2,4) = SIS1(1,2,4) * 1.2
      SIS3(1,2,5) = SIS1(1,2,5) * 5.0
      SIS3(1,3,1) = SIS1(1,3,1) * 1.1
      SIS3(1,3,2) = SIS1(1,3,2) * 1.1
      SIS3(1,3,3) = SIS1(1,3,3) * 1.2
      SIS3(1,3,4) = SIS1(1,3,4) * 5.0
      SIS3(1,3,5) = SIS1(1,3,5) * 5.0
      SIS3(1,4,1) = SIS1(1,4,1) * 1.1
      SIS3(1,4,2) = SIS1(1,4,2) * 1.2
      SIS3(1,4,3) = SIS1(1,4,3) * 5.0
      SIS3(1,4,4) = SIS1(1,4,4) * 5.0
      SIS3(1,4,5) = SIS1(1,4,5) * 5.0
      SIS3(1,5,1) = SIS1(1,5,1) * 1.2
      SIS3(1,5,2) = SIS1(1,5,2) * 5.0
      SIS3(1,5,3) = SIS1(1,5,3) * 5.0
      SIS3(1,5,4) = SIS1(1,5,4) * 5.0
      SIS3(1,5,5) = SIS1(1,5,5) * 5.0
C
      GO TO 640
C
C
  620 CONTINUE
C
      IF(PHT.NE.24.0)GO TO 700
      GO TO(700,621), IRUB
C
C
C                                24 INCH RAIL HEIGHT
C                                  WITHOUT RUB RAIL
C
C
  621 CONTINUE
C
      SIS3(1,1,1) = SIS1(1,1,1) * 1.0
      SIS3(1,1,2) = SIS1(1,1,2) * 1.0
      SIS3(1,1,3) = SIS1(1,1,3) * 1.1
      SIS3(1,1,4) = SIS1(1,1,4) * 1.1
```

```
      SIS3(1,1,5) = SIS1(1,1,5) * 1.2
      SIS3(1,2,1) = SIS1(1,2,1) * 1.0
      SIS3(1,2,2) = SIS1(1,2,2) * 1.1
      SIS3(1,2,3) = SIS1(1,2,3) * 1.1
      SIS3(1,2,4) = SIS1(1,2,4) * 1.2
      SIS3(1,2,5) = SIS1(1,2,5) * 5.0
      SIS3(1,3,1) = SIS1(1,3,1) * 1.1
      SIS3(1,3,2) = SIS1(1,3,2) * 1.1
      SIS3(1,3,3) = SIS1(1,3,3) * 1.2
      SIS3(1,3,4) = SIS1(1,3,4) * 5.0
      SIS3(1,3,5) = SIS1(1,3,5) * 5.0
      SIS3(1,4,1) = SIS1(1,4,1) * 1.1
      SIS3(1,4,2) = SIS1(1,4,2) * 1.2
      SIS3(1,4,3) = SIS1(1,4,3) * 5.0
      SIS3(1,4,4) = SIS1(1,4,4) * 5.0
      SIS3(1,4,5) = SIS1(1,4,5) * 5.0
      SIS3(1,5,1) = SIS1(1,5,1) * 1.2
      SIS3(1,5,2) = SIS1(1,5,2) * 5.0
      SIS3(1,5,3) = SIS1(1,5,3) * 5.0
      SIS3(1,5,4) = SIS1(1,5,4) * 5.0
      SIS3(1,5,5) = SIS1(1,5,5) * 5.0
C
      GO TO 640
C
C
  640 CONTINUE
C
C                               2250 LB. AUTO
C
       IF(PHT.NE.27.0)GO TO 650
      GO TO(645,646), IRUB
C
C
C                               27 INCH RAIL HEIGHT
C                                 WITH RUB RAIL
C
C
  645 CONTINUE
C
      SIS3(2,1,1) = SIS1(2,1,1) * 1.0
      SIS2(2,1,2) = SIS1(2,1,2) * 1.0
      SIS3(2,1,3) = SIS1(2,1,3) * 1.0
      SIS3(2,1,4) = SIS1(2,1,4) * 1.1
      SIS3(2,1,5) = SIS1(2,1,5) * 1.2
      SIS3(2,2,1) = SIS1(2,2,1) * 1.0
      SIS3(2,2,2) = SIS1(2,2,2) * 1.0
      SIS3(2,2,3) = SIS1(2,2,3) * 1.1
      SIS3(2,2,4) = SIS1(2,2,4) * 1.2
      SIS3(2,2,5) = SIS1(2,2,5) * 1.3
      SIS3(2,3,1) = SIS1(2,3,1) * 1.0
      SIS3(2,3,2) = SIS1(2,3,2) * 1.1
      SIS3(2,3,3) = SIS1(2,3,3) * 1.2
      SIS3(2,3,4) = SIS1(2,3,4) * 1.3
      SIS3(2,3,5) = SIS1(3,3,5) * 5.0
      SIS3(2,4,1) = SIS1(2,4,1) * 1.1
      SIS3(2,4,2) = SIS1(2,4,2) * 1.2
      SIS3(2,4,3) = SIS1(2,4,3) * 1.3
      SIS3(2,4,4) = SIS1(2,4,4) * 5.0
      SIS3(2,4,5) = SIS1(2,4,5) * 5.0
      SIS3(2,5,1) = SIS1(2,5,1) * 1.2
      SIS3(2,5,2) = SIS1(2,5,2) * 1.3
      SIS3(2,5,3) = SIS1(2,5,3) * 5.0
      SIS3(2,5,4) = SIS1(2,5,4) * 5.0
      SIS3(2,5,5) = SIS1(2,5,5) * 5.0
C
      GO TO 670
C
C
C                              27 INCH RAIL HEIGHT
C                                WITHOUT RUB RAIL
C
C
  646 CONTINUE
C
      SIS3(2,1,1) = SIS1(2,1,1) * 1.0
```

```
      SIS3(2,1,2) = SIS1(2,1,2) * 1.0
      SIS3(2,1,3) = SIS1(2,1,3) * 1.0
      SIS3(2,1,4) = SIS1(2,1,4) * 1.1
      SIS3(2,1,5) = SIS1(2,1,5) * 1.2
      SIS3(2,2,1) = SIS1(2,2,1) * 1.0
      SIS3(2,2,2) = SIS1(2,2,2) * 1.0
      SIS3(2,2,3) = SIS1(2,2,3) * 1.1
      SIS3(2,2,4) = SIS1(2,2,4) * 1.2
      SIS3(2,2,5) = SIS1(2,2,5) * 2.0
      SIS3(2,3,1) = SIS1(2,3,1) * 1.0
      SIS3(2,3,2) = SIS1(2,3,2) * 1.1
      SIS3(2,3,3) = SIS1(2,3,3) * 1.2
      SIS3(2,3,4) = SIS1(2,3,4) * 2.0
      SIS3(2,3,5) = SIS1(2,3,5) * 5.0
      SIS3(2,4,1) = SIS1(2,4,1) * 1.1
      SIS3(2,4,2) = SIS1(2,4,2) * 1.2
      SIS3(2,4,3) = SIS1(2,4,3) * 2.0
      SIS3(2,4,4) = SIS1(2,4,4) * 5.0
      SIS3(2,4,5) = SIS1(2,4,5) * 5.0
      SIS3(2,5,1) = SIS1(2,5,1) * 1.2
      SIS3(2,5,2) = SIS1(2,5,2) * 2.0
      SIS3(2,5,3) = SIS1(2,5,3) * 5.0
      SIS3(2,5,4) = SIS1(2,5,4) * 5.0
      SIS3(2,5,5) = SIS1(2,5,5) * 5.0
C
      GO TO 670
C
C
  650 CONTINUE
C
      IF(PHT.NE.24.0)GO TO 700
      GO TO(700,651), IRUB
C
C
C                            24 INCH RAIL HEIGHT
C                             WITHOUT RUB RAIL
C
C
  651 CONTINUE
C
      SIS3(2,1,1) = SIS1(2,1,1) * 1.0
      SIS3(2,1,2) = SIS1(2,1,2) * 1.0
      SIS3(2,1,3) = SIS1(2,1,3) * 1.0
      SIS3(2,1,4) = SIS1(2,1,4) * 1.1
      SIS3(2,1,5) = SIS1(2,1,5) * 1.2
      SIS3(2,2,1) = SIS1(2,2,1) * 1.0
      SIS3(2,2,2) = SIS1(2,2,2) * 1.0
      SIS3(2,2,3) = SIS1(2,2,3) * 1.1
      SIS3(2,2,4) = SIS1(2,2,4) * 1.2
      SIS3(2,2,5) = SIS1(2,2,5) * 1.3
      SIS3(2,3,1) = SIS1(2,3,1) * 1.0
      SIS3(2,3,2) = SIS1(2,3,2) * 1.1
      SIS3(2,3,3) = SIS1(2,3,3) * 1.2
      SIS3(2,3,4) = SIS1(2,3,4) * 1.3
      SIS3(2,3,5) = SIS1(2,3,5) * 5.0
      SIS3(2,4,1) = SIS1(2,4,1) * 1.1
      SIS3(2,4,2) = SIS1(2,4,2) * 1.2
      SIS3(2,4,3) = SIS1(2,4,3) * 1.3
      SIS3(2,4,4) = SIS1(2,4,4) * 5.0
      SIS3(2,4,5) = SIS1(2,4,5) * 5.0
      SIS3(2,5,1) = SIS1(2,5,1) * 1.2
      SIS3(2,5,2) = SIS1(2,5,2) * 1.3
      SIS3(2,5,3) = SIS1(2,5,3) * 5.0
      SIS3(2,5,4) = SIS1(2,5,4) * 5.0
      SIS3(2,5,5) = SIS1(2,5,5) * 5.0
C
      GO TO 670
C
C
  670 CONTINUE
C
C                              1700 LB. AUTO
C
      IF(PHT.NE.27.0)GO TO 680
      GO TO(675,676), IRUB
```

```
C
C
C                                    27 INCH RAIL HEIGHT
C                                      WITH RUB RAIL
C
C
  675 CONTINUE
C
      SIS3(3,1,1) = SIS1(3,1,1) * 1.0
      SIS3(3,1,2) = SIS1(3,1,2) * 1.0
      SIS3(3,1,3) = SIS1(3,1,3) * 1.0
      SIS3(3,1,4) = SIS1(3,1,4) * 1.1
      SIS3(3,1,5) = SIS1(3,1,5) * 1.1
      SIS3(3,2,1) = SIS1(3,2,1) * 1.0
      SIS3(3,2,2) = SIS1(3,2,2) * 1.0
      SIS3(3,2,3) = SIS1(3,2,3) * 1.1
      SIS3(3,2,4) = SIS1(3,2,4) * 1.1
      SIS3(3,2,5) = SIS1(3,2,5) * 1.2
      SIS3(3,3,1) = SIS1(3,3,1) * 1.0
      SIS3(3,3,2) = SIS1(3,3,2) * 1.1
      SIS3(3,3,3) = SIS1(3,3,3) * 1.1
      SIS3(3,3,4) = SIS1(3,3,4) * 1.2
      SIS3(3,3,5) = SIS1(3,3,5) * 1.3
      SIS3(3,4,1) = SIS1(3,4,1) * 1.1
      SIS3(3,4,2) = SIS1(3,4,2) * 1.1
      SIS3(3,4,3) = SIS1(3,4,3) * 1.2
      SIS3(3,4,4) = SIS1(3,4,4) * 1.3
      SIS3(3,4,5) = SIS1(3,4,5) * 5.0
      SIS3(3,5,1) = SIS1(3,5,1) * 1.1
      SIS3(3,5,2) = SIS1(3,5,2) * 1.2
      SIS3(3,5,3) = SIS1(3,5,3) * 1.3
      SIS3(3,5,4) = SIS1(3,5,4) * 5.0
      SIS3(3,5,5) = SIS1(3,5,5) * 5.0
C
      GO TO 1000
C
C
C                                    27 INCH RAIL HEIGHT
C                                     WITHOUT RUB RAIL
C
C
  676 CONTINUE
C
      SIS3(3,1,1) = SIS1(3,1,1) * 1.0
      SIS3(3,1,2) = SIS1(3,1,2) * 1.0
      SIS3(3,1,3) = SIS1(3,1,3) * 1.0
      SIS3(3,1,4) = SIS1(3,1,4) * 1.1
      SIS3(3,1,5) = SIS1(3,1,5) * 1.1
      SIS3(3,2,1) = SIS1(3,2,1) * 1.0
      SIS3(3,2,2) = SIS1(3,2,2) * 1.0
      SIS3(3,2,3) = SIS1(3,2,3) * 1.1
      SIS3(3,2,4) = SIS1(3,2,4) * 1.1
      SIS3(3,2,5) = SIS1(3,2,5) * 2.0
      SIS3(3,3,1) = SIS1(3,3,1) * 1.0
      SIS3(3,3,2) = SIS1(3,3,2) * 1.1
      SIS3(3,3,3) = SIS1(3,3,3) * 1.1
      SIS3(3,3,4) = SIS1(3,3,4) * 2.0
      SIS3(3,3,5) = SIS1(3,3,5) * 2.0
      SIS3(3,4,1) = SIS1(3,4,1) * 1.1
      SIS3(3,4,2) = SIS1(3,4,2) * 1.1
      SIS3(3,4,3) = SIS1(3,4,3) * 2.0
      SIS3(3,4,4) = SIS1(3,4,4) * 2.0
      SIS3(3,4,5) = SIS1(3,4,5) * 5.0
      SIS3(3,5,1) = SIS1(3,5,1) * 1.1
      SIS3(3,5,2) = SIS1(3,5,2) * 2.0
      SIS3(3,5,3) = SIS1(3,5,3) * 2.0
      SIS3(3,5,4) = SIS1(3,5,4) * 5.0
      SIS3(3,5,5) = SIS1(3,5,5) * 5.0
C
      GO TO 1000
C
C
  680 CONTINUE
C
      IF(PHT.NE.24.0)GO TO 700
```

```
      GO TO(700,681), IRUB
C
C
C                                   24 INCH RAIL HEIGHT
C                                    WITHOUT RUB RAIL
C
C
  681 CONTINUE
C
      SIS3(3,1,1) = SIS1(3,1,1) * 1.0
      SIS3(3,1,2) = SIS1(3,1,2) * 1.0
      SIS3(3,1,3) = SIS1(3,1,3) * 1.0
      SIS3(3,1,4) = SIS1(3,1,4) * 1.1
      SIS3(3,1,5) = SIS1(3,1,5) * 1.1
      SIS3(3,2,1) = SIS1(3,2,1) * 1.0
      SIS3(3,2,2) = SIS1(3,2,2) * 1.0
      SIS3(3,2,3) = SIS1(3,2,3) * 1.1
      SIS3(3,2,4) = SIS1(3,2,4) * 1.1
      SIS3(3,2,5) = SIS1(3,2,5) * 1.2
      SIS3(3,3,1) = SIS1(3,3,1) * 1.0
      SIS3(3,3,2) = SIS1(3,3,2) * 1.1
      SIS3(3,3,3) = SIS1(3,3,3) * 1.1
      SIS3(3,3,4) = SIS1(3,3,4) * 1.2
      SIS3(3,3,5) = SIS1(3,3,5) * 2.0
      SIS3(3,4,1) = SIS1(3,4,1) * 1.1
      SIS3(3,4,2) = SIS1(3,4,2) * 1.1
      SIS3(3,4,3) = SIS1(3,4,3) * 1.2
      SIS3(3,4,4) = SIS1(3,4,4) * 2.0
      SIS3(3,4,5) = SIS1(3,4,5) * 5.0
      SIS3(3,5,1) = SIS1(3,5,1) * 1.1
      SIS3(3,5,2) = SIS1(3,5,2) * 1.2
      SIS3(3,5,3) = SIS1(3,5,3) * 2.0
      SIS3(3,5,4) = SIS1(3,5,4) * 5.0
      SIS3(3,5,5) = SIS1(3,5,5) * 5.0
C
      GO TO 1000
C
C
  700 CONTINUE
C
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C*      FUTURE EXPANSION OF SUBROUTINE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
C
 1000 CONTINUE
C
      RETURN
      END
C
C
C
C    ***********************************************************************
C    *
      SUBROUTINE GREND6
C    *
C    ***********************************************************************
C    *
C    *    THIS SUBROUTINE OBTAINS SEVERITY-INDEXES FOR W-BEAM(G4-1W,2W) END
C    *                        TERMINAL IMPACTS
C    *
C    ***********************************************************************
C    ***********************************************************************
C
C
C
      DIMENSION POO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
```

```
     *                 H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *        SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *              SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NOES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTG, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
```

```
      GO TO(10,11), IFLAG
C
   10 CONTINUE
C
C            HAZARD
C
      N1 = H46(I)
      N2 = H47(I)
      GO TO 12
C
   11 CONTINUE
C
C            IMPROVEMENT
C
      N1 = C34(I,J)
      N2 = C35(I,J)
C
   12 CONTINUE
C
C
      DO 400 N=1,IDIR
      GO TO(13,14), N
C
   13 CONTINUE
C
C                 UPSTREAM END TERMINAL
C
      GO TO(20,21,22,23,24,24,24,24), N1
C
   14 CONTINUE
C
C                 DOWNSTREAM END TERMINAL
C
      GO TO(20,21,22,23,24,24,24,24), N2
C
   20 CONTINUE
C
C                 ANCHORED (NON - BREAKAWAY)
C
      V = 40.0
C
      DO 50 K=1,5
C
C            4000 LB. AUTO, DRY CONDITION
C
      SI1(1,K,1) = 0.046*V
      SI1(1,K,2) = 0.046*V
      SI1(1,K,3) = 0.046*V
      SI1(1,K,4) = 0.046*V
      SI1(1,K,5) = 0.046*V
C
C            4000 LB. AUTO, WET CONDITION
C
      SI2(1,K,1) = 0.046*V
      SI2(1,K,2) = 0.046*V
      SI2(1,K,3) = 0.046*V
      SI2(1,K,4) = 0.046*V
      SI2(1,K,5) = 0.046*V
C
C            4000 LB. AUTO, FROZEN CONDITION
C
      SI3(1,K,1) = 0.055*V
      SI3(1,K,2) = 0.055*V
      SI3(1,K,3) = 0.055*V
      SI3(1,K,4) = 0.055*V
      SI3(1,K,5) = 0.055*V
C
C            2250 LB. AUTO, DRY CONDITION
C
      SI1(2,K,1) = 0.081*V
      SI1(2,K,2) = 0.081*V
      SI1(2,K,3) = 0.081*V
      SI1(2,K,4) = 0.081*V
      SI1(2,K,5) = 0.081*V
C
```

```
C         2250 LB. AUTO. WET CONDITION
C
      SI2(2,K,1) = 0.081*V
      SI2(2,K,2) = 0.081*V
      SI2(2,K,3) = 0.081*V
      SI2(2,K,4) = 0.081*V
      SI2(2,K,5) = 0.081*V
C
C         2250 LB. AUTO. FROZEN CONDITION
C
      SI3(2,K,1) = 0.097*V
      SI3(2,K,2) = 0.097*V
      SI3(2,K,3) = 0.097*V
      SI3(2,K,4) = 0.097*V
      SI3(2,K,5) = 0.097*V
C
C         1700 LB. AUTO. DRY CONDITION
C
      SI1(3,K,1) = 0.110*V
      SI1(3,K,2) = 0.110*V
      SI1(3,K,3) = 0.110*V
      SI1(3,K,4) = 0.110*V
      SI1(3,K,5) = 0.110*V
C
C         1700 LB. AUTO. WET CONDITION
C
      SI2(3,K,1) = 0.110*V
      SI2(3,K,2) = 0.110*V
      SI2(3,K,3) = 0.110*V
      SI2(3,K,4) = 0.110*V
      SI2(3,K,5) = 0.110*V
C
C         1700 LB. AUTO. FROZEN CONDITION
C
      SI3(3,K,1) = 0.132*V
      SI3(3,K,2) = 0.132*V
      SI3(3,K,3) = 0.132*V
      SI3(3,K,4) = 0.132*V
      SI3(3,K,5) = 0.132*V
C
      V = V +10.0
C
   50 CONTINUE
      GO TO 200
C
C
C
C
C
C
   21 CONTINUE
C
C               NOT ANCHORED( NON - BREAKAWAY)
C
      V = 40.0
C
      DO 51 K=1,5
C
C         4000 LB. AUTO. DRY CONDITION
C
      SI1(1,K,1) = 0.040*V
      SI1(1,K,2) = 0.040*V
      SI1(1,K,3) = 0.040*V
      SI1(1,K,4) = 0.040*V
      SI1(1,K,5) = 0.040*V
C
C         4000 LB. AUTO. WET CONDITION
C
      SI2(1,K,1) = 0.040*V
      SI2(1,K,2) = 0.040*V
      SI2(1,K,3) = 0.040*V
      SI2(1,K,4) = 0.040*V
      SI2(1,K,5) = 0.040*V
C
C         4000 LB. AUTO. FROZEN CONDITION
```

```
C
      SI3(1,K,1) = 0.048*V
      SI3(1,K,2) = 0.048*V
      SI3(1,K,3) = 0.048*V
      SI3(1,K,4) = 0.048*V
      SI3(1,K,5) = 0.048*V
C
C           2250 LB. AUTO, DRY CONDITION
C
      SI1(2,K,1) = 0.070*V
      SI1(2,K,2) = 0.070*V
      SI1(2,K,3) = 0.070*V
      SI1(2,K,4) = 0.070*V
      SI1(2,K,5) = 0.070*V
C
C           2250 LB. AUTO, WET CONDITION
C
      SI2(2,K,1) = 0.070*V
      SI2(2,K,2) = 0.070*V
      SI2(2,K,3) = 0.070*V
      SI2(2,K,4) = 0.070*V
      SI2(2,K,5) = 0.070*V
C
C           2250 LB. AUTO, FROZEN CONDITION
C
      SI3(2,K,1) = 0.085*V
      SI3(2,K,2) = 0.085*V
      SI3(2,K,3) = 0.085*V
      SI3(2,K,4) = 0.085*V
      SI3(2,K,5) = 0.085*V
C
C           1700 LB. AUTO, DRY CONDITION
C
      SI1(3,K,1) = 0.097*V
      SI1(3,K,2) = 0.097*V
      SI1(3,K,3) = 0.097*V
      SI1(3,K,4) = 0.097*V
      SI1(3,K,5) = 0.097*V
C
C           1700 LB. AUTO, WET CONDITION
C
      SI2(3,K,1) = 0.097*V
      SI2(3,K,2) = 0.097*V
      SI2(3,K,3) = 0.097*V
      SI2(3,K,4) = 0.097*V
      SI2(3,K,5) = 0.097*V
C
C           1700 LB. AUTO, FROZEN CONDITION
C
      SI3(3,K,1) = 0.116*V
      SI3(3,K,2) = 0.116*V
      SI3(3,K,3) = 0.116*V
      SI3(3,K,4) = 0.116*V
      SI3(3,K,5) = 0.116*V
C
      V = V +10.0
C
   51 CONTINUE
      GO TO 200
C
C
C
C
C
   22 CONTINUE
C
C                 TURNDOWN(BREAKAWAY)
C
      THETA = 5.0
C
      DO 52 K=1,5
C
C           4000 LB. AUTO, DRY CONDITION
C
      SI1(1,1,K) = 0.00889*THETA+0.37
```

```
      SI1(1,2,K) = 0.00889*THETA+0.45
      SI1(1,3,K) = 0.00889*THETA+0.54
      SI1(1,4,K) = 0.00889*THETA+0.63
      SI1(1,5,K) = 0.00889*THETA+0.72
C
C           4000 LB. AUTO, WET CONDITION
C
      SI2(1,1,K) = 0.00889*THETA+0.37
      SI2(1,2,K) = 0.00889*THETA+0.45
      SI2(1,3,K) = 0.00889*THETA+0.54
      SI2(1,4,K) = 0.00889*THETA+0.63
      SI2(1,5,K) = 0.00889*THETA+0.72
C
C           4000 LB. AUTO, FROZEN CONDITION
C
      SI3(1,1,K) = 0.00889*THETA+0.37
      SI3(1,2,K) = 0.00889*THETA+0.45
      SI3(1,3,K) = 0.00889*THETA+0.54
      SI3(1,4,K) = 0.00889*THETA+0.63
      SI3(1,5,K) = 0.00889*THETA+0.72
C
C           2250 LB. AUTO, DRY CONDITION
C
      SI1(2,1,K) = SI1(1,1,K)*1.23
      SI1(2,2,K) = SI1(1,2,K)*1.23
      SI1(2,3,K) = SI1(1,3,K)*1.23
      SI1(2,4,K) = SI1(1,4,K)*1.23
      SI1(2,5,K) = SI1(1,5,K)*1.23
C
C           2250 LB. AUTO, WET CONDITION
C
      SI2(2,1,K) = SI1(1,1,K)*1.23
      SI2(2,2,K) = SI1(1,2,K)*1.23
      SI2(2,3,K) = SI1(1,3,K)*1.23
      SI2(2,4,K) = SI1(1,4,K)*1.23
      SI2(2,5,K) = SI1(1,5,K)*1.23
C
C           2250 LB. AUTO, FROZEN CONDITION
C
      SI3(2,1,K) = SI1(1,1,K)*1.23
      SI3(2,2,K) = SI1(1,2,K)*1.23
      SI3(2,3,K) = SI1(1,3,K)*1.23
      SI3(2,4,K) = SI1(1,4,K)*1.23
      SI3(2,5,K) = SI1(1,5,K)*1.23
C
C           1700 LB. AUTO, DRY CONDITION
C
      SI1(3,1,K) = SI1(1,1,K)*1.51
      SI1(3,2,K) = SI1(1,2,K)*1.51
      SI1(3,3,K) = SI1(1,3,K)*1.51
      SI1(3,4,K) = SI1(1,4,K)*1.51
      SI1(3,5,K) = SI1(1,5,K)*1.51
C
C           1700 LB. AUTO, WET CONDITION
C
      SI2(3,1,K) = SI1(1,1,K)*1.51
      SI2(3,2,K) = SI1(1,2,K)*1.51
      SI2(3,3,K) = SI1(1,3,K)*1.51
      SI2(3,4,K) = SI1(1,4,K)*1.51
      SI2(3,5,K) = SI1(1,5,K)*1.51
C
C           1700 LB. AUTO, FROZEN CONDITION
C
      SI3(3,1,K) = SI1(1,1,K)*1.51
      SI3(3,2,K) = SI1(1,2,K)*1.51
      SI3(3,3,K) = SI1(1,3,K)*1.51
      SI3(3,4,K) = SI1(1,4,K)*1.51
      SI3(3,5,K) = SI1(1,5,K)*1.51
C
      THETA = THETA + 5.0
C
   52 CONTINUE
      GO TO 200
C
C
```

```
C
C
C
   23 CONTINUE
C
C                 TURNDOWN(NON-BREAKAWAY)
C
      V = 40.0
C
      DO 53 K=1,5
C
C           4000 LB. AUTO, DRY CONDITION
C
      SI1(1,K,1) = 0.013*V
      SI1(1,K,2) = 0.011*V
      SI1(1,K,3) = 0.008*V
      SI1(1,K,4) = 0.007*V
      SI1(1,K,5) = 0.007*V
C
C           4000 LB. AUTO, WET CONDITION
C
      SI2(1,K,1) = 0.013*V
      SI2(1,K,2) = 0.011*V
      SI2(1,K,3) = 0.008*V
      SI2(1,K,4) = 0.007*V
      SI2(1,K,5) = 0.007*V
C
C           4000 LB. AUTO, FROZEN CONDITION
C
      SI3(1,K,1) = 0.013*V
      SI3(1,K,2) = 0.011*V
      SI3(1,K,3) = 0.008*V
      SI3(1,K,4) = 0.007*V
      SI3(1,K,5) = 0.007*V
C
C           2250 LB. AUTO, DRY CONDITION
C
      SI1(2,K,1) = 0.026*V
      SI1(2,K,2) = 0.021*V
      SI1(2,K,3) = 0.017*V
      SI1(2,K,4) = 0.014*V
      SI1(2,K,5) = 0.013*V
C
C           2250 LB. AUTO, WET CONDITION
C
      SI2(2,K,1) = 0.026*V
      SI2(2,K,2) = 0.021*V
      SI2(2,K,3) = 0.017*V
      SI2(2,K,4) = 0.014*V
      SI2(2,K,5) = 0.013*V
C
C           2250 LB. AUTO, FROZEN CONDITION
C
      SI3(2,K,1) = 0.026*V
      SI3(2,K,2) = 0.021*V
      SI3(2,K,3) = 0.017*V
      SI3(2,K,4) = 0.014*V
      SI3(2,K,5) = 0.013*V
C
C           1700 LB. AUTO, DRY CONDITION
C
      SI1(3,K,1) = 0.034*V
      SI1(3,K,2) = 0.027*V
      SI1(3,K,3) = 0.022*V
      SI1(3,K,4) = 0.020*V
      SI1(3,K,5) = 0.017*V
C
C           1700 LB. AUTO, WET CONDITION
C
      SI2(3,K,1) = 0.034*V
      SI2(3,K,2) = 0.027*V
      SI2(3,K,3) = 0.022*V
      SI2(3,K,4) = 0.020*V
      SI2(3,K,5) = 0.017*V
C
```

```
C
C         1700 LB. AUTO. FROZEN CONDITION
C
      SI3(3,K,1) = 0.034*V
      SI3(3,K,2) = 0.027*V
      SI3(3,K,3) = 0.022*V
      SI3(3,K,4) = 0.020*V
      SI3(3,K,5) = 0.017*V
C
      V = V +10.0
C
   53 CONTINUE
      GO TO 200
C
C
C
C
   24 CONTINUE
C
C              CRASHWORTHY TERMINAL
C
      V = 40.0
C
      DO 54 K=1,5
C
C         4000 LB. AUTO. DRY CONDITION
C
      SI1(1,K,1) = 0.023*V
      SI1(1,K,2) = 0.023*V
      SI1(1,K,3) = 0.023*V
      SI1(1,K,4) = 0.023*V
      SI1(1,K,5) = 0.023*V
C
C         4000 LB. AUTO. WET CONDITION
C
      SI2(1,K,1) = 0.023*V
      SI2(1,K,2) = 0.023*V
      SI2(1,K,3) = 0.023*V
      SI2(1,K,4) = 0.023*V
      SI2(1,K,5) = 0.023*V
C
C         4000 LB. AUTO. FROZEN CONDITION
C
      SI3(1,K,1) = 0.028*V
      SI3(1,K,2) = 0.028*V
      SI3(1,K,3) = 0.028*V
      SI3(1,K,4) = 0.028*V
      SI3(1,K,5) = 0.028*V
C
C         2250 LB. AUTO. DRY CONDITION
C
      SI1(2,K,1) = 0.046*V
      SI1(2,K,2) = 0.046*V
      SI1(2,K,3) = 0.046*V
      SI1(2,K,4) = 0.046*V
      SI1(2,K,5) = 0.046*V
C
C         2250 LB. AUTO. WET CONDITION
C
      SI2(2,K,1) = 0.046*V
      SI2(2,K,2) = 0.046*V
      SI2(2,K,3) = 0.046*V
      SI2(2,K,4) = 0.046*V
      SI2(2,K,5) = 0.046*V
C
C         2250 LB. AUTO. FROZEN CONDITION
C
      SI3(2,K,1) = 0.056*V
      SI3(2,K,2) = 0.056*V
      SI3(2,K,3) = 0.056*V
      SI3(2,K,4) = 0.056*V
      SI3(2,K,5) = 0.056*V
C
C         1700 LB. AUTO. DRY CONDITION
C
      SI1(3,K,1) = 0.061*V
```

```
      SI1(3,K,2) = 0.061*V
      SI1(3,K,3) = 0.061*V
      SI1(3,K,4) = 0.061*V
      SI1(3,K,5) = 0.061*V
C
C            1700 LB. AUTO, WET CONDITION
C
      SI2(3,K,1) = 0.061*V
      SI2(3,K,2) = 0.061*V
      SI2(3,K,3) = 0.061*V
      SI2(3,K,4) = 0.061*V
      SI2(3,K,5) = 0.061*V
C
C            1700 LB. AUTO, FROZEN CONDITION
C
      SI3(3,K,1) = 0.074*V
      SI3(3,K,2) = 0.074*V
      SI3(3,K,3) = 0.074*V
      SI3(3,K,4) = 0.074*V
      SI3(3,K,5) = 0.074*V
C
      V = V +10.0
C
   54 CONTINUE
C
  200 CONTINUE
C
C
      GO TO(402,403), N
C
  402 CONTINUE
C
C                    UPSTREAM END TERMINAL
C
      DO 404 K1=1,3
      DO 404 K2=1,5
      DO 404 K3=1,5
C
      SIE1U(K1,K2,K3) = SI1(K1,K2,K3)
      SIE2U(K1,K2,K3) = SI2(K1,K2,K3)
      SIE3U(K1,K2,K3) = SI3(K1,K2,K3)
C
  404 CONTINUE
      GO TO 410
C
  403 CONTINUE
C
C                    DOWNSTREAM END TERMINAL
C
      DO 405 K1=1,3
      DO 405 K2=1,5
      DO 405 K3=1,5
C
      SIE1D(K1,K2,K3) = SI1(K1,K2,K3)
      SIE2D(K1,K2,K3) = SI2(K1,K2,K3)
      SIE3D(K1,K2,K3) = SI3(K1,K2,K3)
C
  405 CONTINUE
C
  410 CONTINUE
C
  400 CONTINUE
C
      RETURN
      END
C
C
C    ******************************************************************
C    *
      SUBROUTINE NOIMPR
C    *
C    ******************************************************************
C    *
C    *            NO IMPROVEMENT SUBROUTINE FOR SLOPES
C    *
```

```
C    *****************************************************************
C    *****************************************************************
C
C
C
C
      DIMENSION PDG(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *        SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *            SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
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```
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
      HI2(I,J) = HI1(I)
      AC2(I,J) = AC1(I)
      CM2(I,J) = CM1(I)
C
C
      HIA(J) = HIA(J) + HI2(I,J)
      ACA(J) = ACA(J) + AC2(I,J)
C
      THCIMP(J) = THCIMP(J) + CM2(I,J)
C
C
      RETURN
      END
C
C
C ***********************************************************************
C *
      SUBROUTINE RESULT
C *
C ***********************************************************************
C *
C *   SUBROUTINE COMPUTES THE COST-EFFECTIVENESS AND BENEFIT-COST RATIOS
C *
C ***********************************************************************
C
C
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
      COMMON/CRF1/ CR
C
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
```

```
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *         SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *              SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
      COMMON/AUT1/ AUTO(3),IA, IAUTO
C
      COMMON/ENVR/ ENVIR(3), INVIR
C
      COMMON/TAC1/ TAC(5,5)
C
      COMMON/RESLT/CE(4), BC(4), ICE(4), NOTCE(4), ICOST(4), IGR
C
      COMMON/IMPROB/ IMP(5,5)
C
      COMMON/CST4/ RC(5,5),DL
C
C
      REAL MB1, MB2, MB3, MB9, MB4W, MB4S, MBET1, MBET2
C
      REAL LIFE, INT, JAUTO, IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1, H2, H3, H4, H14, H16, H17, H18, H19, H20, H21,
     *        H30, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51
C
      INTEGER C1, C2, C16, C17, C18, C19, C30, C31, C32, C33, C34,
     *        C35, C36, C39, C40, C41, C42, C50, C3, C4, C51
C
C
      LIFE = G16
      DO 100 J=1,IALT
C     IF(HIA(J) .GE. HIB) GO TO 10
C     IF(ACA(J) .GE. ACB) GO TO 10
      EFFECT = HIB - HIA(J)
      BENEFT = ACB - ACA(J)
      ZERO = 2.718**(EFFECT*LIFE)
      ZERO = 1.0/ZERO
      IZERO(J) = IFIX( ZERO*100.0 )
      TCOST = THCIMP(J) - THCHAZ
      ICOST(J) = IFIX( TCOST )
      CE(J) = TCOST/EFFECT
      ICE(J) = CE(J)
      BC(J) = BENEFT/TCOST
      GO TO 99
 10   CONTINUE
      NOTCE(J) = 1
C
C
C
C     NOTCE(J) = 1 ... IMPROVEMNT ALTERNATIVE NOT COST-EFFECTIVE
C
```

```
 99   CONTINUE
 100  CONTINUE
      RETURN
      END
C
C
C    ***********************************************************************
C    *
      SUBROUTINE OUTPUT
C    *
C    ***********************************************************************
C    *
C    *        SUBROUTINE PRINTS OUTPUT FOR PROGRAM
C    *
C    ***********************************************************************
C    ***********************************************************************
C
C
      DIMENSION PDO(6), IAC(6), FA(6), YLAT(7)
C
C
      COMMON/DATA1/ H1(6), H2(6), H3(6), H4(6), H5(6), H6(6), H7(6),
     *              H8(6), H9(6), H10(6), H11(6), H12(6), H13(6),
     *              H14(6), H15(6), H16(6), H17(6), H18(6), H19(6),
     *              H20(6), H21(6), H22(6), H23(6), H30(6), H31(6),
     *              H32(6), H33(6), H34(6), H35(6), H36(6), H37(6),
     *              H38(6), H39(6), H40(6), H41(6), H42(6), H43(6),
     *              H44(6), H45(6), H46(6), H47(6), H48(6), H49(6),
     *              H50(6), H51(6)
C
C
      COMMON/DATA2/ C1(6,4), C2(6,4), C3(6,4), C4(6,4), C5(6,4),
     *              C11(6,4), C12(6,4), C13(6,4), C14(6,4), C15(6,4),
     *              C16(6,4), C17(6,4), C18(6,4), C19(6,4), C20(6,4),
     *              C21(6,4), C22(6,4), C23(6,4), C24(6,4), C25(6,4),
     *              C26(6,4), C27(6,4), C28(6,4), C29(6,4), C30(6,4),
     *              C31(6,4), C32(6,4), C33(6,4), C34(6,4), C35(6,4),
     *              C36(6,4), C37(6,4), C38(6,4), C39(6,4), C40(6,4),
     *              C41(6,4), C42(6,4), C50(6,4), C51(6,4)
C
C
      COMMON/DATA3/ G10, G12, G13, G14, G15, G16, G17, G18, G19, G20
C
      COMMON/CRF1/ CR
      COMMON/ERROR/ ERROR1(6,4)
C
C
      COMMON/HURT/ PI(5,5), SI(5,5), SISL(5,5)
C
      COMMON/LATOF/ OFSET(5), DLAT, DLONG, DLAT1
C
      COMMON/ENFRE/ENFR
C
C
      COMMON/GRSI/ SIS1(3,5,5), SIS2(3,5,5), SIS3(3,5,5), SIE1U(3,5,5),
     *          SIE2U(3,5,5), SIE3U(3,5,5), SIE1D(3,5,5), SIE2D(3,5,5),
     *              SIE3D(3,5,5), SI1(3,5,5), SI2(3,5,5), SI3(3,5,5)
C
C
      COMMON/GRCST/ G1, G2, G3, G9, G41W, G42W, G41S, G42S, MB1,MB2,
     *              MB3, MB9, MB4W, MB4S, GRE1,GRE2, GRE3, GRE4, GRE5,
     *              GET1, GET2, MBET1, MBET2
C
      COMMON/COMP/ SIDE(5,5), END(5,5), IHIT, XX
C
      COMMON/MAINC/ HIB, HI, HIA(4), HI1(6), HI2(6,4), CMB, CM, CMA(4),
     *              CM1(6), CM2(6,4), ACB, AC, ACA(4), AC1(6),
     *              AC2(6,4), IZERO(4), THCHAZ,THCIMP(4)
C
C
      COMMON/IDENT/I, J, IHAZ, IALT, IFLAG, NTITLE, IDIR, ID, LL
C
      COMMON/NCONT/ NCOUNT,IPAGE, LINES, NDES(100), NSPD(100),
     *              NADT(100), NHWY(100)
C
```

```
      COMMON/AUT1/ AUTO(3).IA. IAUTO
C
      COMMON/ENVR/ ENVIR(3). INVIR
C
      COMMON/TAC1/ TAC(5.5)
C
      COMMON/RESLT/CE(4). BC(4). ICE(4). NOTCE(4). ICOST(4). IGR
C
      COMMON/IMPROB/ IMP(5.5)
C
      COMMON/CST4/ RC(5.5).DL
C
C
      REAL MB1. MB2. MB3. MB9. MB4W. MB4S. MBET1. MBET2
C
      REAL LIFE. INT. JAUTO. IMP
      REAL IAC
C
C
      INTEGER ERROR1
C
      INTEGER H1. H2. H3. H4. H14. H16. H17. H18. H19. H20. H21.
     *        H30. H42. H43. H44. H45. H46. H47. H48. H49. H50. H51
C
      INTEGER C1. C2. C16. C17. C18. C19. C30. C31. C32. C33. C34.
     *        C35. C36. C39. C40. C41. C42. C50.C3. C4. C51
C
C
      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))GO TO 12
C
C
   10 CONTINUE
      WRITE(6.398) IPAGE
      WRITE(6.400)
C
      IF (C1(1.1).EQ.1) GO TO 800
      IF (C1(1.1).EQ.2) GO TO 801
      IF (C1(1.1).EQ.3) GO TO 802
      IF (C1(1.1).EQ.4) GO TO 803
      IF (C1(1.1).EQ.5) GO TO 804
C
  800 CONTINUE
      WRITE(6.900) C2(1.1)
      GO TO 905
  801 CONTINUE
      WRITE(6.901) C2(1.1)
      GO TO 905
  802 CONTINUE
      WRITE(6.902) C2(1.1)
      GO TO 905
  803 CONTINUE
      WRITE(6.903) C2(1.1)
      GO TO 905
  804 CONTINUE
      WRITE(6.904) C2(1.1)
  905 CONTINUE
      IF (H3(1) .EQ. 1) GO TO 811
      IF (H3(1) .EQ. 2) GO TO 810
      IF (H3(1) .EQ. 3) GO TO 812
      IF (H3(1) .EQ. 4) GO TO 813
  810 CONTINUE
      WRITE(6.910) H4(1)
      GO TO 915
  811 CONTINUE
      WRITE(6.911) H4(1)
      GO TO 915
  812 CONTINUE
      WRITE(6.912) H4(1)
      GO TO 915
  813 CONTINUE
```

```
      WRITE(6,913) H4(1)
  915 CONTINUE
      ISPEED = IFIX(H5(1))
      IADT = IFIX(H6(1))
C
      ICAR1 = IFIX(G15)
      ICAR2 = IFIX(G14)
      ICAR3 = IFIX(G13)
C
      IDRY = IFIX(12.0-G10-G12)
      IWET = IFIX(G10)
      IFRO = IFIX(G12)
C
      IPDO = IFIX(G20)
      INJURY = IFIX(G19)
      IFATAL = IFIX(G18)
C
C
      WRITE(6,815)ISPEED,IADT,ICAR1,ICAR2,ICAR3,IDRY,IWET,IFRO,IPDO,
     *              INJURY,IFATAL,G16,G17,C40(1,1),C41(1,1),C42(1,1)
      IPAGE = IPAGE + 1
      LINES = 0
      NCOUNT = NCOUNT + 1
      WRITE(6,404) IPAGE
      WRITE(6,406)
   12 CONTINUE
      MES = 0
      K = 0
C
      DO 200 JJ=1,IALT
      DO 200 II=1,IHAZ
C
      L = II
      M = JJ
      C11(L,M) = C11(L,M)*0.001
      IAC1 = AC1(L)
      IAC2 = AC2(L,M)
C
      IF(ERROR1(L,M) .GT. 0) GO TO 80
      K = K + 1
      IF(K .EQ. IHAZ) GO TO 60
C
C  WRITE "GROUP"
C
      WRITE(6,500) H17(L), H21(L), H18(L), H19(L),H20(L),H22(L),
     *H23(L), H11(L), IAC1, M, C16(L,M), C17(L,M),C18(L,M),C19(L,M),
     *C37(L,M), C38(L,M), C5(L,M), C11(L,M)
      GO TO 200
   80 CONTINUE
C
C  WRITE "ERROR MESSAGE NUMBER"
C
      WRITE(6,502) H17(L), H21(L), H18(L), H19(L),H20(L),H22(L),
     *H23(L), H11(L), IAC1, M, C16(L,M), C17(L,M),C18(L,M),C19(L,M),
     *C37(L,M), C38(L,M), C5(L,M), C11(L,M), ERROR1(L,M)
      K = K + 1
      IF(K .EQ. I) GO TO 90
      MES = MES + 1
      GO TO 200
C
   60 CONTINUE
      IF( NOTCE(M) .EQ. 1) GO TO 70
      IF( MES .GE. 1) GO TO 85
C
C  WRITE "COST-EFFECTIVENESS RATIO" AND "BENEFIT-COST RATIO"
C
      WRITE(6,504) H17(L), H21(L), H18(L), H19(L),H20(L),H22(L),
     *H23(L), H11(L), IAC1, M, C16(L,M), C17(L,M),C18(L,M),C19(L,M),
     *C37(L,M), C38(L,M), C5(L,M), C11(L,M),ICOST(M),H12(L,M),IAC2,
     *ICE(M),BC(M)
C
C  LINE COUNTER
C
      LINES = LINES + 1
      IF( LINES .GE. 45) GO TO 92
```

```
      GO TO 90
   92 CONTINUE
      WRITE(6,404)IPAGE
      WRITE(6,406)
      LINES = 0
      GO TO 90
   70 CONTINUE
C
C  WRITE "NOT COST-EFFECTIVE"
C
      WRITE(6,506) H17(L), H21(L), H18(L), H19(L),H20(L),H22(L),
     *H23(L), H11(L), IAC1, M, C16(L,M), C17(L,M),C18(L,M),C19(L,M),
     *C37(L,M), C38(L,M), C5(L,M), C11(L,M)
C
C  LINE COUNTER
C
      LINES = LINES + 1
      IF( LINES .GE. 45) GO TO 93
      GO TO 90
   93 CONTINUE
      WRITE(6,404) IPAGE
      WRITE(6,406)
      LINES = 0
      GO TO 90
C
   85 CONTINUE
C
C  WRITE "END GROUP"
C
      WRITE(6,508) H17(L), H21(L), H18(L), H19(L),H20(L),H22(L),
     *H23(L), H11(L), IAC1, M, C16(L,M), C17(L,M),C18(L,M),C19(L,M),
     *C37(L,M), C38(L,M), C5(L,M), C11(L,M)
C
C  LINE COUNTER
C
      LINES = LINES + 1
      IF( LINES .GE. 45) GO TO 94
      GO TO 90
   94 CONTINUE
      WRITE(6,404) IPAGE
      WRITE(6,406)
      LINES = 0
   90 CONTINUE
      K = 0
      MES = 0
      WRITE(6,600)
  200 CONTINUE
      WRITE(6,602)
C
      IF (IGR .EQ. 1) GO TO 300
      WRITE(6,604)
  300 CONTINUE
C
C **** FORMAT STATEMENTS ****
C
C
  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
 404  FORMAT(1H1,/,T122,'PAGE = ',I2,///,T4,
     *'* * * * *   H   A   Z   A   R   D   * * * * *',T56,
     *'* * * * * * *   I   M   P   R   O   V   E   M   E   N   T   * * *
     * * * * *',/)
C
C
 406  FORMAT(T2,'HAZ',T7,'GR',T11,'HAZ',T16,'SIDE',T23,'MILE-POST',
     *T36,'HAZARD',T44,'TOTAL',T54,'IMPR',T60,'IMPR',T69,'MILE-POST',
     *T81,'CLEAR',T88,'FIRST',T95,'TOTAL',T102,'HAZARD',T110,'TOTAL',
     *T119,'COST',T125,'BENEFIT',/,T3,'NO',T7,'NO',T10,'CODE',T17,
     *'OF',T37,'INDEX',T43,'ACCIDENT',T55,'ALT',T60,'CODE',T82,'ZONE',
     *T89,'COST',T96,'HWY',T103,'INDEX',T109,'ACCIDENT',T118,'EFFECT',
     *T126,'COST',/,T16,'ROAD',T22,'BEG',T30,'END',T45,'COST',T68,
     *'BEG',T76,'END',T95,'COST',T111,'COST',T119,'RATIO',T126,'RATIO',
     */,T35,'(INJ/YR)',T44,'($/YR)',T82,'(FT)',T87,'($1000)',T95,
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```
     *'($/YR)',T101,'(INJ/YR)',T110,'($/YR)',T117,'($/INJ)',/)
C
 500  FORMAT(T2,I3,T6,I3,T10,I2,T12,'-',T13,I2,T17,I1,T20,F7.3,
     *T28,F7.3,T36,F6.4,T43,I7,T55,I1,T58,I1,T59,'-',T60,I1,T61,
     *'-',T62,I1,T63,'-',T64,I1,T66,F7.3,T74,F7.3,T82,F4.1,T88,
     *F6.1,T95,'*************** GROUP ***************')
C
 502  FORMAT(T2,I3,T6,I3,T10,I2,T12,'-',T13,I2,T17,I1,T20,F7.3,
     *T28,F7.3,T36,F6.4,T43,I7,T55,I1,T58,I1,T59,'-',T60,I1,T61,
     *'-',T62,I1,T63,'-',T64,I1,T66,F7.3,T74,F7.3,T82,F4.1,T88,
     *F6.1,T95,'******* ERROR MESSAGE = ',I3,T124,'*******')
 504  FORMAT(T2,I3,T6,I3,T10,I2,T12,'-',T13,I2,T17,I1,T20,F7.3,
     *T28,F7.3,T36,F6.4,T43,I7,T55,I1,T58,I1,T59,'-',T60,I1,T61,
     *'-',T62,I1,T63,'-',T64,I1,T66,F7.3,T74,F7.3,T82,F4.1,T88,
     *F6.1,T95,I5,T102,F6.4,T109,I7,T117,I7,T126,F5.2)
C
C
 506  FORMAT(T2,I3,T6,I3,T10,I2,T12,'-',T13,I2,T17,I1,T20,F7.3,
     *T28,F7.3,T36,F6.4,T43,I7,T55,I1,T58,I1,T59,'-',T60,I1,T61,
     *'-',T62,I1,T63,'-',T64,I1,T66,F7.3,T74,F7.3,T82,F4.1,T88,
     *F6.1,T95,'******** NOT COST-EFFECTIVE ********')
C
 508  FORMAT(T2,I3,T6,I3,T10,I2,T12,'-',T13,I2,T17,I1,T20,F7.3,
     *T28,F7.3,T36,F6.4,T43,I7,T55,I1,T58,I1,T59,'-',T60,I1,T61,
     *'-',T62,I1,T63,'-',T64,I1,T66,F7.3,T74,F7.3,T82,F4.1,T88,
     *F6.1,T95,'************* END GROUP *************')
C
 600  FORMAT(/)
C
 602  FORMAT(//)
C
 604  FORMAT(//,T52,'* * *  END OF PROGRAM  * * *',/,1H1)
C
 398  FORMAT(1H1,/,T122,'PAGE = ',T128,I2)
C
 900  FORMAT(T52,'HIGHWAY DESIGN NUMBER = DR-',I2)
C
 901  FORMAT(T52,'HIGHWAY DESIGN NUMBER = DM-',I2)
C
 902  FORMAT(T52,'HIGHWAY DESIGN NUMBER = ROA-',I2)
C
 903  FORMAT(T52,'HIGHWAY DESIGN NUMBER = RC-',I2)
C
 904  FORMAT(T52,'HIGHWAY DESIGN NUMBER = RL-',I2)
C
 910  FORMAT(T61,'TYPE HIGHWAY = US-',I3)
C
 911  FORMAT(T61,'TYPE HIGHWAY = NH-',I3)
C
 912  FORMAT(T61,'TYPE HIGHWAY = IS-',I3)
C
 913  FORMAT(T61,'TYPE HIGHWAY = RUR-',I3)
C
 815  FORMAT(T61,'DESIGN SPEED = ',T76,I2,T79,'MPH',/,T70,
     *'ADT = ',T76,I5,//,T50,'AUTOMOBILE SPLITS',/,T63,
     *'4,450 (LB) =',T76,I2,T79,'%',/,T63,'2,250 (LB) =',T76,I2,T79,
     *'%',/,T63,'1,750 (LB) =',T76,I2,T79,'%',//,T50,
     *'ENVIROMENTAL CONDITIONS',/,T70,'DRY =',T76,I2,T79,'MO/YR',/,
     *T70,'WET =',T76,I2,T79,'MO/YR',/,T61,'SUB-FREEZING =',T76,I2,
     *T79,'MO/YR',//,T50,'SOCIETAL ACCIDENT COSTS',/,T70,'PDO = $',
     *T81,I4,/,T67,'INJURY = $',T80,I5,/,T68,'FATAL = $',T78,I7,//,
     *T57,'ECONOMIC FACTORS',/,T61,'PROJECT LIFE =',T76,F4.1,T81,
     *'YRS',/,T60,'INTEREST RATE = ',T76,F6.3,T83,'%',//,T69,'DATE =',
     *T76,I2,T78,'-',T79,I2,T81,'-',T82,I2,////)
C
      RETURN
      END
C
C
      SUBROUTINE MAIN1
      RETURN
      END
      SUBROUTINE MAIN2
      RETURN
      END
```