AD-A097 889 STEVENS INST OF TECH HOBOKEN NJ DAVIDSON LAB F/G 19/3
AN OUTPUT DIAGNOSIS PROGRAM FOR THE NATO REFERENCE MOBILITY MOD--ETC(U)
DEC 80 P M BRADY DAAK30-80-C-0032
UNCLASSIFIED SIT-DL-80-9-2183 NL

AD
A097889

END
DATE
FILMED
5 81
DTIC

R-2183

AD A097889

LEVEL

DAVIDSON LABORATORY

Report Number SIT-DL-80-9-2183

December 1980

AN OUTPUT DIAGNOSIS PROGRAM FOR THE NATO REFERENCE MOBILITY MODEL

By:

Peter M. Brady, Jr.

Prepared for:

U. S. ARMY TANK-AUTOMOTIVE COMMAND

WARREN, MI 48090

Under Contract:

DAAK-30-C-0032

(DL Project 413/4814)

STEVENS INSTITUTE OF TECHNOLOGY

CASTLE POINT STATION

HOBOKEN, NEW JERSEY 07030

STEVENS INSTITUTE OF TECHNOLOGY · PER ASPERA AD ASTRA · A.D. 1870

81 4 13 135

R-2183

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A097	3. RECIPIENT'S CATALOG NUMBER 889
4. TITLE (and Subtitle) An Output Diagnosis Program for the NATO Reference Mobility Model		5. TYPE OF REPORT & PERIOD COVERED Final rept.
		6. PERFORMING ORG. REPORT NUMBER SIT-DL-80-9-2183
7. AUTHOR(s) Peter M. Brady, Jr.		8. CONTRACT OR GRANT NUMBER(s) DAAK-30-80-C-0032
9. PERFORMING ORGANIZATION NAME AND ADDRESS Stevens Institute of Technology Castle Point Station Hoboken, NJ 07030		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Tank-Automotive Command Warren, MI 48090		12. REPORT DATE December 1980
		13. NUMBER OF PAGES Thrity Three (33)
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited.

15 DAAK30-80-C-0032

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ground Mobility Model
Off-Road Mobility
Vehicle Performance
Mobility
Mobility Modelling

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The NATO Reference Mobility Model (NRMM) produces a prediction of the speed at which a vehicle can traverse an area (terrain unit). The program described here uses selected values calculated in the NRMM to determine the factor which is the limiter for a vehicle and terrain unit. In the case of a NO-GO prediction, the reason for the NO-GO is deduced. Detailed and summary diagnostic tables are produced together with a graphical presentation of the diagnostics.

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

410475

STEVENS INSTITUTE OF TECHNOLOGY
DAVIDSON LABORATORY
CASTLE POINT STATION
HOBOKEN, NEW JERSEY

REPORT NUMBER SIT-DL-80-9-2183

December 1980

AN OUTPUT DIAGNOSIS PROGRAM FOR THE NATO REFERENCE MOBILITY MODEL

by:

Peter M. Brady, Jr.

prepared for:

U. S. Army Tank-Automotive Command
Warren, MI 48090

under:

Contract DAAK-30-C-0032
(Davidson Lab File No. 4814/413)

APPROVED:

Irmin O. Kamm, Manager
Transportation Research Group

ABSTRACT

The NATO Reference Mobility Model (NRMM) produces a prediction of the maximum average speed at which a vehicle can traverse an area (terrain unit). The program described here uses selected values calculated in the NRMM to determine the factor which is the limiter of speed for a vehicle and terrain unit. In the case of a NO-GO prediction, the reason for the NO-GO is deduced. Detailed and summary diagnostic tables are produced together with a graphical presentation of the diagnostics.

KEY WORDS

Ground Mobility Model
Off-Road Mobility
Vehicle Performance
Mobility
Mobility Modelling

TABLE OF CONTENTS

INTRODUCTION AND BACKGROUND

The NATO Reference Mobility Model (NRMM) [1] is a computer program which provides a comprehensive assessment of cross-country performance of a vehicle. The basic output of the NRMM is the speed at which a vehicle can travel in a terrain region (patch) judged uniform with respect to mobility. (This speed is often referred to as "Speed-Made-Good" since the path need not be a straight line due to maneuvers around trees and obstacles.) This speed-made-good for a patch is calculated as an interaction of a variety of descriptors of the terrain, vehicle and scenario and includes assessment of the effects of such things as the vehicle powertrain and geometry, the strength of the soil in the patch, vegetation, driver dictated limits, etc. In addition to the single output number of speed-made-good, results of literally hundreds of intermediate computations may be obtained from the NRMM.

The objective of this study was to identify those intermediate computations in the NRMM which could be used to give to the user better insight into the vehicle/terrain interaction without the need for total immersion in a sea of numbers. The identification of an intermediate result as useful for insight has been governed by prior use of the NRMM and the needs expressed by the users during and after these prior studies.

In particular, the way in which the model has been used (for vehicle studies) in the last few years is the following:

1. Several regions in the world have been identified as being of interest to the military user community for mobility study purposes.

2. Available terrain data has been analyzed to yield a description of these regions as a mosaic of patches

(areas judged uniform with respect to mobility) overlaid with roads, trails, rivers and other features which appear as curves and lines on a map.

3. The values of the terrain descriptors (soil strength, topographic slope, roughness, etc.) have been established and amassed into computer data files.

4. The NRMM was run to obtain a speed-made-good for each terrain unit (patch, road, or trail) in these files.

5. This set of speeds was processed to obtain a few performance measures -- usually percentage of terrain denied (zero speed or NO-GO) and the average speed (weighted by area) on the least severe 90% of the terrain (without regard to the spatial distribution of the most severe terrain). A speed profile is often presented as well.

While these data are useful in comparing vehicles, in certain studies (WHEELS [2], HIMO [3]) which used predecessors of the NRMM, information on the causes of NO-GO's and/or the factors which limit the speed were judged to be required and were produced. The program developed in this study produces similar diagnostic output for runs of the NRMM and was developed with some attention being paid to program portability.

In the NRMM, various single-factor aspects of the terrain-vehicle interaction which can cause a NO-GO condition or limit speed are evaluated (e.g., limitation due to driver tolerance or lack of braking ability) and then multi-factor combinations of effects are assessed. These calculations are performed (when appropriate) traveling with and against the input topographic slope (up and down) and (in the Areal Module) at zero topographic slope (level). When one of the calculations produces a NO-GO, many subsequent calculations are skipped; otherwise, a variety of candidate speeds which reflect the effects of some of the constraints are computed and then the feasibility speed is obtained. If any of the up, level and down speeds is zero, the speed-made-good for the terrain unit is set to zero, otherwise the harmonic average is the output.

RESULTS OF CURRENT STUDY

Since the factor which controls the speed may be different when traveling with the slope, on the level and against the slope, it was decided, for this study, to analyze these cases separately. Another consideration in setting up this analysis was that the mechanism for making changes to the NRMM is time-consuming, so that all modifications required for the output analysis were restricted to the Control and Input/Output (C&I/O) module in which local changes are permitted by the rules governing the use of NRMM established by the NATO Technical Management Committee. The organization of the Areal Module of the NRMM (with its own control subprogram) allows the changes required to be minimal and concentrated in a few subroutines of the C&I/O Module. These changes are fully described later. Creation of the same type of output analysis for the Road Module is straightforward but requires changes in the Module itself since there is no separate control subprogram for this Module.

The output analysis is performed as follows:

1. The additions to the NRMM Control and Input/Output Module are entered. (This, of course, is done only once.)

2. The NRMM is run for the desired vehicle and terrain with the new control variable KDIAG set to 1 which produces the additional output required.

3. The output analysis/diagnosis program is run to summarize and present the results of the analysis.

OUTPUT ANALYSIS/DIAGNOSIS PROGRAM

The output analysis/diagnosis program performs the following actions:

1. The selected intermediate calculations of the Areal Module of the NRMM for a single terrain unit are transferred to the diagnosis subroutine.

2. For each slope condition (up, level, and down) the output is first checked to determine whether the terrain unit is a GO or NO-GO patch. If GO, the factor which limits the speed is determined. Otherwise the reasons for the NO-GO is determined. In either case a code is assigned for the terrain unit and slope condition.

3. Steps 1 and 2 are repeated until the data for all terrain units have been read and analyzed. An output file containing the terrain unit number, speed-made-good, up, level and down speeds and diagnosis codes, and terrain unit area for each terrain unit is written.

4. The area (factor area) in which each of the limiting factors is the controlling factor is determined together with the average speed in that portion of the total area (for the GO factors). More precisely, the factor area is the sum of the areas of all terrain units for which the factor is the controlling factor. This summary is written out. (See Appendix A - Table A1).

5. The "Speed Profile" is generated for each slope condition, i.e., the terrain units are sorted into decreasing order of speeds and the cumulative sum of the area and average speed are computed. The speed profile data are written out with the limit code for each terrain unit (generated in Step 2). (See Appendix A - Table A2)

6. The speed profiles are plotted. On the plots of maximum speed versus percent area, different symbols are used for each of the limiting condition codes. (See Appendix A - Figure A1)

Steps 1 - 3 are most efficiently performed during a run of the NRMM, by a diagnosis subroutine, whereas Steps 4 - 6 are now performed by a separate program. The portion of this program which effects Step 6 is somewhat non-portable as it contains calls to a plotter routine, of necessity device and system dependent. The remainder is standard FORTRAN and the plotting section is quite simple. Furthermore, Step 6 only presents the data already available from Step 5 in a different way. However, it is felt that the presentation of this data graphically does provide a good way to handle the data. The symbols used in the graphical presentation on the plotter are an arbitrary set available conveniently on one system. An even better choice would be a color coding which would be easily implemented on a color-graphics terminal, but this presents difficulties in obtaining hard-copy output.

The output of the analysis program consists of:

1. A list of any terrain units for which the program was unable to determine the controlling factor.

2. The summary which lists the factor area for each limiting factor.

3. The list of all terrain units in decreasing order of speed-made-good with the controlling factor code.

4. Speed profile plots including symbols designating the various limiting factors.

In the case of a terrain unit which is "GO" for the vehicle and slope condition (i.e., the NRMM predicts a non-zero speed-made-good), the analysis is based on various sets of factors which, in combination, give rise to limiting speeds, one for each set of factors. In NRMM, after an initial screening, candidate speeds are established and then reduced for interactions of obstacles and vegetation with the sets of factors first addressed (soil, slope, ride, tire damage, etc.). Since each of the candidate speeds is an upper performance limit, the final speed prediction is the lowest of the various limiting speeds (in the order of their computation in the NRMM). In the output Analysis/Diagnosis Program, the diagnosis stops when one of these candidate speeds is equaled (or exceeded to account for rounding) and the corresponding code assigned. The candidate speeds and the limiting factors to which they correspond are listed in Table I.

In the case of a NO-GO terrain unit, a more varied collection of variables is checked to determine the reason for the NO-GO prediction. Again, these are assessed in the order of their computation and evaluation in the NRMM. As a programming convenience, the values assigned to the limiting factor code are negative for the NO-GO analysis. The variables used, the comparison made, and the corresponding reasons are listed in Table II.

TABLE I

LIMITING FACTOR ANALYSIS AND CODE ASSIGNMENTS

SPEED	CODE	LIMITING FACTOR
VRIDE	1	Driver tolerance to ride over rough terrain
VTIRE	2	Tire destruction (applies to wheeled vehicles only)
.99*VSOIL	3	Power available versus resistance due to soil, slope and overridden vegetation
VELV	4	Braking available relative to visibility restrictions
VAVOID	5	Maneuvering around obstacles and overriding small vegetation
VBO	6	Maneuvering around vegetation and between obstacles
VOLA	7	Obstacle impact
VOVER	8	Obstacle and small vegetation override
VWALK	9	Driver prudence in vegetation override

In all cases where the variable is an array dependent on vegetation class, the value used for the comparison is that of the vegetation class used to compute the output speed.

TABLE II

NO-GO CAUSE ANALYSIS AND CODE ASSIGNMENTS

VARIABLE AND DECISION	CODE	NO-GO CAUSE
TBF < 0	-1	Inability to brake
VSOIL ≤ 0	-2	Soil and slope
NEVERO = 3	-3	Obstacle interference
NEVERO = 1	-4	Belly hangup on obstacles
VBO ≤ 0	-5	Vegetation too dense to be avoided and too large to allow override
VXT ≤ 0	-6	Tractive force needed to override obstacles not available

The value of VSOIL used here is that without vegetation. The values of VBO and VXT are those of the vegetation class used for the corresponding computations in the NRMM.

The output diagnosis has been applied to runs of the NRMM for both wheeled and tracked vehicles over several terrain files, both artificial and real. All of the terrain units have been diagnosed. (The program outputs a code of ±99 to designate terrain units for which the limiting factor was not determined). The analysis program is listed in Appendix B. The additions to the NRMM including the diagnosis subroutine required are presented in Appendix C.

REFERENCES

[1] Haley, Peter W., M. Peter Jurkat, and Peter M. Brady, Jr., "NATO Reference Mobility Model, Edition I, Users Guide, Volume I", Technical Report Number 12503, October 1979, U. S. Army Tank-Automotive Research and Development Command, Warren, MI (AD B047 979 L).

[2] Rula, A. A., C. J. Nuttall, Jr., and H. Dugoff, "Vehicle Mobility Assessment for Project WHEELS Study Group," Technical Report M-73-1, April 1973, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, MS.

[3] Nuttall, C. J., and D. D. Randolph, "Mobility Analyses of Standard- and High-Mobility Tactical Support Vehicles", (HIMO Study) Technical Report M-76-3, February 1976, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, MS.

APPENDIX A

SAMPLE OUTPUTS OF ANALYSIS/DIAGNOSIS PROGRAM

LIMITING FACTOR	UP SLOPE			LEVEL			DOWN SLOPE		
	NO.OF T U'S	FACTOR AREA	AVERAGE SPEED	NO.OF T U'S	FACTOR AREA	AVERAGE SPEED	NO.OF T U'S	FACTOR AREA	AVERAGE SPEED
GO TERRAIN UNITS									
1 RIDE	11	0.68	14.53	17	1.12	12.96	14	0.97	13.00
2 TIRE CONST	12	1.45	37.15	12	1.45	37.15	12	1.45	37.15
3 POWER/RES	5	0.42	11.55	0	0.00	0.00	0	0.00	0.00
4 VISIBILITY	13	1.37	16.68	15	1.41	16.78	19	1.60	16.21
5 MANEUVER	138	12.35	12.65	144	12.71	13.26	138	12.37	13.61
6 MANEUVER	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
7 OBS IMPACT	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
8 OBS FORCE	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
9 DRVR.PRDNC	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
TOTAL	179	16.27	15.22	188	16.69	15.61	183	16.39	15.91
NOGO TERRAIN UNITS									
-1 NO BRAKING	0	0.00		0	0.00		7	0.41	
-2 SOIL/SLOPE	17	1.19		9	0.78		7	0.68	
-3 OBS INTRF	3	0.21		3	0.21		3	0.21	
-4 BELLY HANG	0	0.00		0	0.00		0	0.00	
-5 VEGETATION	1	0.01		0	0.00		0	0.00	
-6 OBS FORCE	0	0.00		0	0.00		0	0.00	
TOTAL	21	1.42		12	0.99		17	1.30	

TABLE A1. SUMMARY OUTPUT FROM OUTPUT ANALYSIS/DIAGNOSIS PROGRAM

UP SLOPE

NO	TERRAIN UNIT MAX SPEED	TERRAIN UNIT LIMIT CODE	TERRAIN UNIT AREA	CUMULATIVE AVG SPEED	CUMULATIVE PCT AREA
32	37.1	2	0.04	37.1	0.22
43	37.1	2	0.45	37.1	2.75
54	37.1	2	0.08	37.1	3.21
55	37.1	2	0.02	37.1	3.32
60	37.1	2	0.07	37.1	3.69
96	37.1	2	0.12	37.1	4.37
132	37.1	2	0.16	37.1	5.26
136	37.1	2	0.31	37.1	7.01
137	37.1	2	0.03	37.1	7.21
157	37.1	2	0.02	37.1	7.34
161	37.1	2	0.14	37.1	8.12
199	37.1	2	0.01	37.1	8.19
93	34.4	4	0.02	37.1	8.32
168	26.1	5	0.08	36.6	8.76
149	25.1	5	0.05	36.2	9.04
148	24.4	5	0.19	34.9	10.11
92	23.3	5	0.02	34.8	10.22
121	23.1	5	0.03	34.6	10.41
8	22.9	5	0.00	34.6	10.44
105	22.3	5	0.06	34.2	10.76
98	21.7	5	0.08	33.7	11.22
122	21.6	5	0.03	33.5	11.42
90	21.6	5	0.16	32.6	12.31
26	21.5	5	0.05	32.4	12.58
7	21.5	5	0.04	32.2	12.79
178	21.1	5	0.03	32.1	12.97
91	21.0	5	0.07	31.7	13.36
22	21.0	1	0.17	31.0	14.34
173	20.7	5	0.06	30.7	14.69
85	20.2	5	0.16	30.1	15.61
106	19.1	3	0.08	29.8	16.07
164	19.0	3	0.03	29.7	16.22
28	19.0	5	0.04	29.6	16.46

LEVEL

NO	TERRAIN UNIT MAX SPEED	TERRAIN UNIT LIMIT CODE	TERRAIN UNIT AREA	CUMULATIVE AVG SPEED	CUMULATIVE PCT AREA
32	37.1	2	0.04	37.1	0.22
43	37.1	2	0.45	37.1	2.75
54	37.1	2	0.08	37.1	3.21
55	37.1	2	0.02	37.1	3.32
60	37.1	2	0.07	37.1	3.69
96	37.1	2	0.12	37.1	4.37
132	37.1	2	0.16	37.1	5.26
136	37.1	2	0.31	37.1	7.01
137	37.1	2	0.03	37.1	7.21
157	37.1	2	0.02	37.1	7.34
161	37.1	2	0.14	37.1	8.12
199	37.1	2	0.01	37.1	8.19
93	34.4	4	0.02	37.1	8.32
168	26.1	5	0.08	36.6	8.76
149	25.1	5	0.05	36.2	9.04
8	24.9	5	0.00	36.2	9.06
85	24.7	5	0.16	35.1	9.98
148	24.4	5	0.19	34.1	11.05
92	24.2	5	0.02	34.0	11.16
164	24.0	4	0.03	33.8	11.31
121	23.8	5	0.03	33.7	11.51
90	23.5	5	0.16	32.9	12.40
105	23.1	5	0.06	32.7	12.73
106	22.7	5	0.08	32.3	13.19
7	22.3	5	0.04	32.2	13.41
122	22.0	5	0.03	32.0	13.60
91	22.0	5	0.07	31.7	14.00
98	22.0	5	0.08	31.4	14.45
26	21.5	5	0.05	31.3	14.72
178	21.5	5	0.03	31.1	14.89
28	21.1	5	0.04	31.0	15.13
22	21.0	1	0.17	30.4	16.11
173	20.8	5	0.06	30.2	16.46

DOWN SLOPE

NO	TERRAIN UNIT MAX SPEED	TERRAIN UNIT LIMIT CODE	TERRAIN UNIT AREA	CUMULATIVE AVG SPEED	CUMULATIVE PCT AREA
32	37.1	2	0.04	37.1	0.22
43	37.1	2	0.45	37.1	2.75
54	37.1	2	0.08	37.1	3.21
55	37.1	2	0.02	37.1	3.32
60	37.1	2	0.07	37.1	3.69
96	37.1	2	0.12	37.1	4.37
132	37.1	2	0.16	37.1	5.26
136	37.1	2	0.31	37.1	7.01
137	37.1	2	0.03	37.1	7.21
157	37.1	2	0.02	37.1	7.34
161	37.1	2	0.14	37.1	8.12
199	37.1	2	0.01	37.1	8.19
93	34.4	4	0.02	37.1	8.32
148	26.1	5	0.19	35.9	9.39
168	26.1	5	0.08	35.4	9.83
85	25.9	5	0.16	34.6	10.74
8	25.9	5	0.00	34.6	10.77
26	25.8	5	0.05	34.4	11.03
149	25.1	5	0.05	34.1	11.31
90	25.0	5	0.16	33.5	12.21
121	24.7	5	0.03	33.3	12.40
92	24.6	5	0.02	33.3	12.51
164	24.0	4	0.03	33.1	12.66
106	23.7	4	0.08	32.8	13.12
105	23.4	5	0.06	32.6	13.45
91	23.1	5	0.07	32.3	13.84
7	23.0	5	0.04	32.2	14.06
28	22.7	5	0.04	32.0	14.30
122	22.3	5	0.03	31.9	14.50
98	22.2	5	0.08	31.6	14.96
30	21.9	5	0.21	30.9	16.16
178	21.8	5	0.03	30.8	16.33
22	21.0	1	0.17	30.2	17.31

TABLE A2. INDIVIDUAL TERRAIN UNIT OUTPUT FROM OUTPUT ANALYSIS/DIAGNOSIS PROGRAM

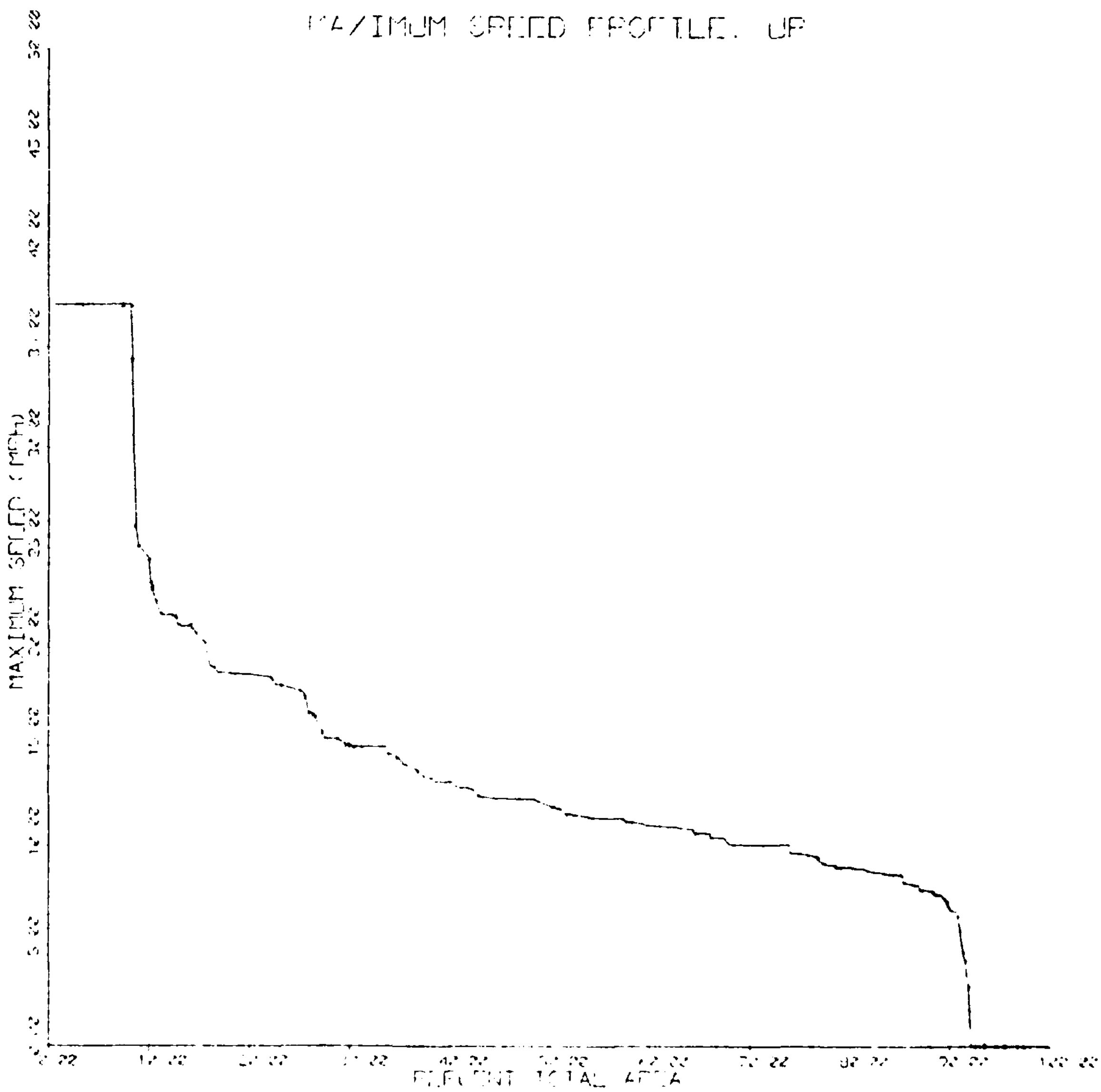

FIGURE A1. MAXIMUM SPEED UP SLOPE VS. PERCENT OF TOTAL AREA WITH LIMIT CODES

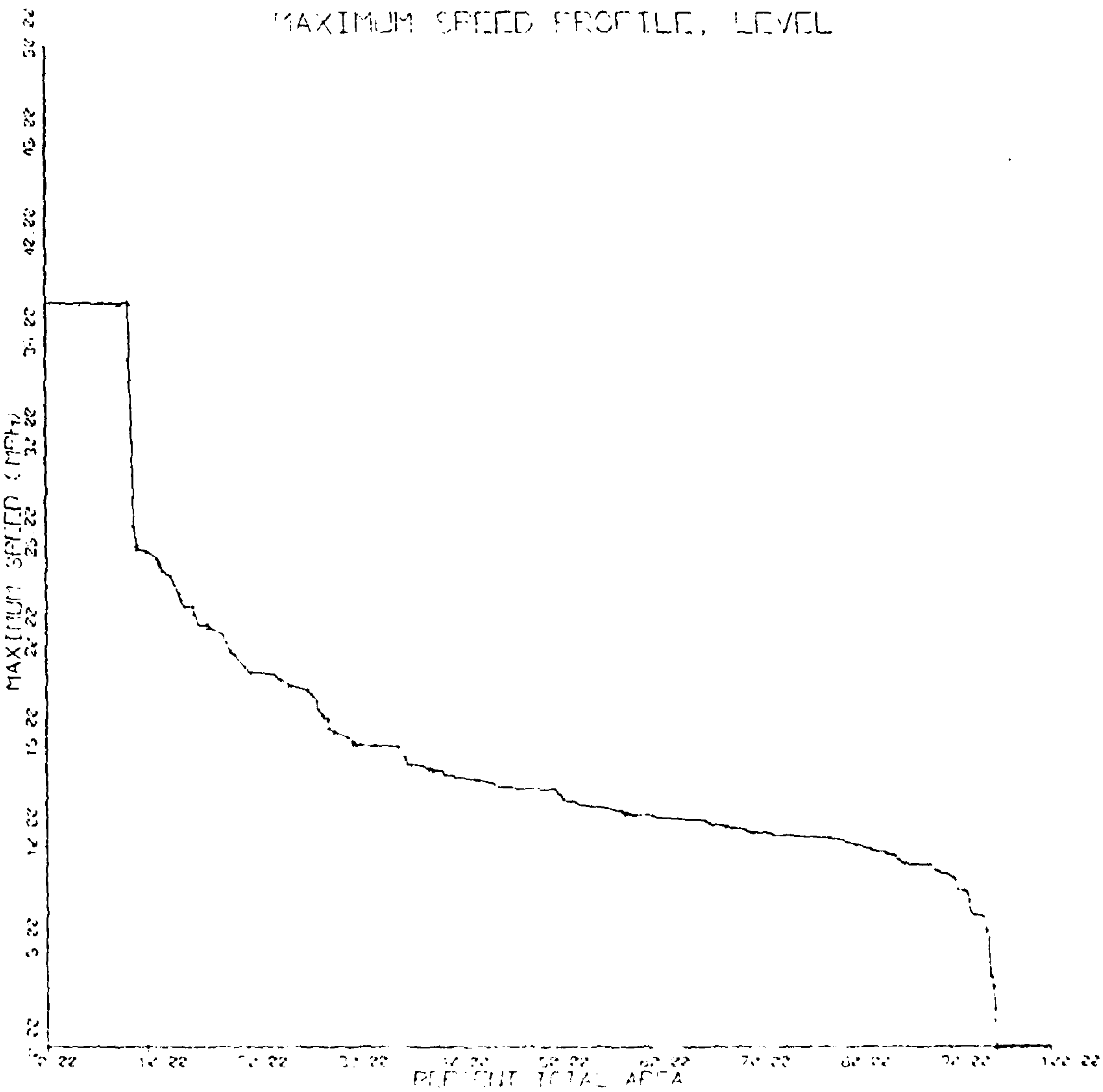

FIGURE A2. <u>MAXIMUM SPEED ON LEVEL VS. PERCENT OF TOTAL AREA WITH LIMIT CODES</u>

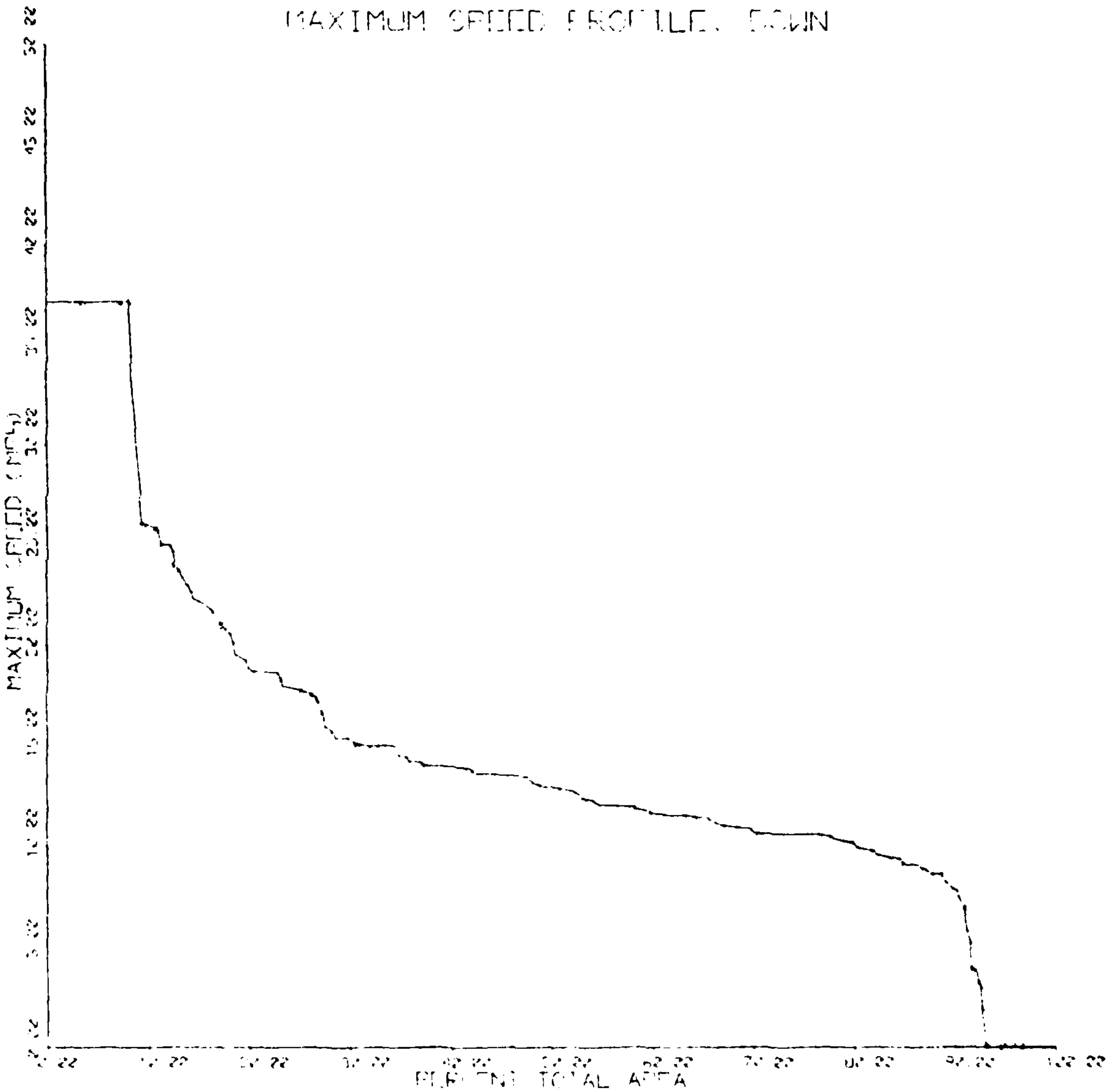

FIGURE A3. MAXIMUM SPEED DOWN SLOPE VS. PERCENT OF TOTAL AREA WITH LIMIT CODES

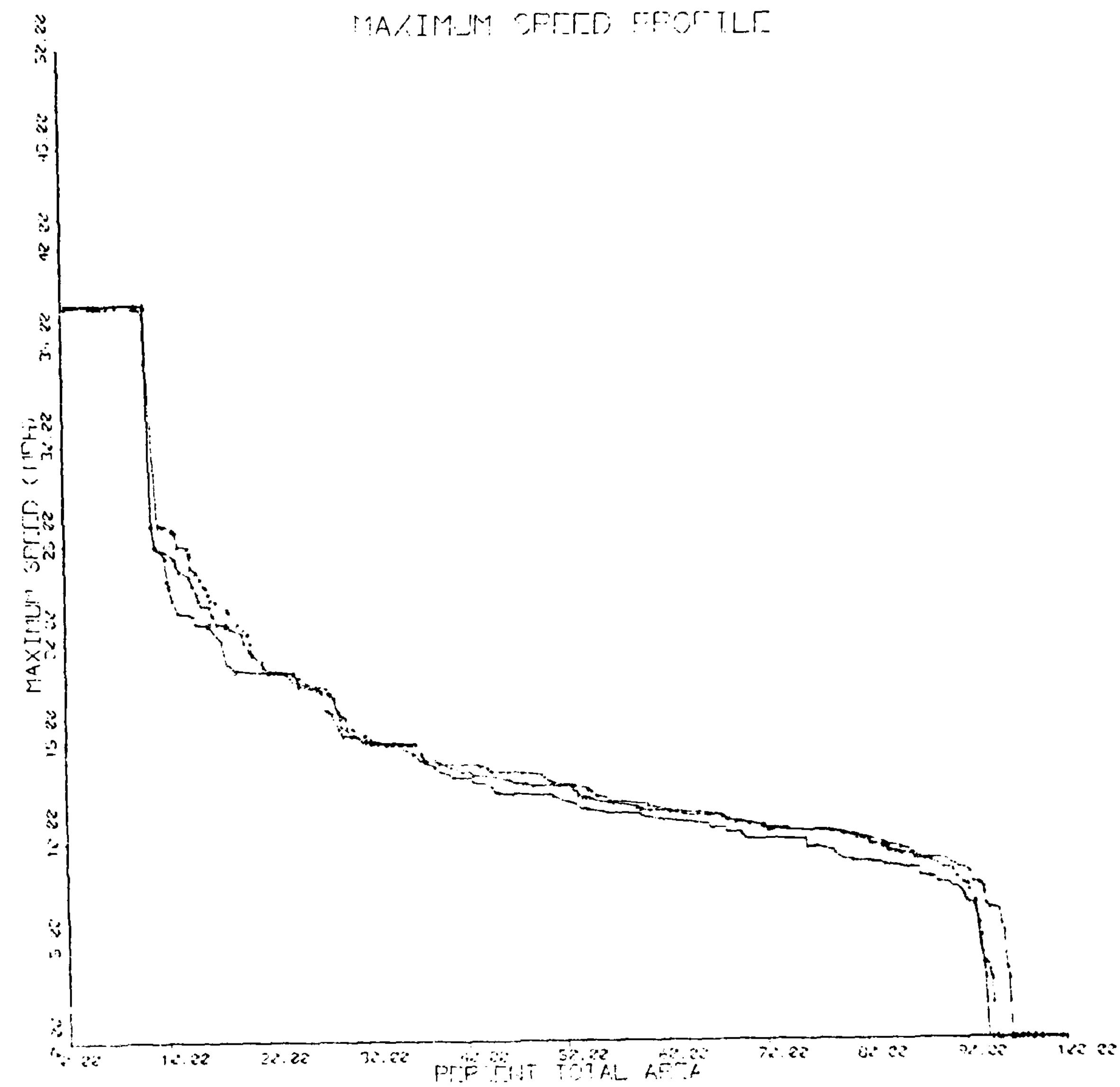

FIGURE A4. MAXIMUM SPEED VS. PERCENT OF TOTAL AREA WITH LIMIT CODES FOR ALL SLOPE CONDITIONS

(Original in Color)

APPENDIX B

LISTING OF OUTPUT ANALYSIS PROGRAM

```
      PROGRAM PPNRMM
C
C  OUTPUT ANALYSIS PROGRAM FOR NRMM AREAL MODULE
C
      DIMENSION V1(500,3),V2(500,3),A1(500,3),AA(3),
     1         V1U(500),V1L(500),V1D(500),V2U(500),V2L(500),V2D(500),
     2         PAU(500),PAL(500),PAD(500),ICODE(500,3),N1(500,3)
      DIMENSION NTGO(15,3),ATGO(15,3),VTGO(15,3),NTNOGO(10,3),
     1         ATNOGO(10,3),AGO(3),NGO(3),VGO(3),NNOGO(3),ANOGO(3),
     2         LIMIT(15),NREAS(10)
      DOUBLE PRECISION LIMIT,NREAS
      EQUIVALENCE (V1(1,1),V1U(1))
      EQUIVALENCE (V1(1,2),V1L(1))
      EQUIVALENCE (V1(1,3),V1D(1))
      EQUIVALENCE (A1(1,1),PAU(1))
      EQUIVALENCE (A1(1,2),PAL(1))
      EQUIVALENCE (A1(1,3),PAD(1))
      EQUIVALENCE (V2(1,1),V2U(1))
      EQUIVALENCE (V2(1,2),V2L(1))
      EQUIVALENCE (V2(1,3),V2D(1))
      DATA (LIMIT(I),I=1,9)/4HRIDE,10HTIRE CONST,9HPOWER/RES,
     + 10HVISIBILITY,8HMANEUVER,8HMANEUVER,10HOBS IMPACT,9HOBS FORCE,
     + 10HDRVR.PRDNC/

      DATA (NREAS(I),I=1,6)/10HNO BRAKING,10HSOIL/SLOPE,9HOBS INTRF,
     + 10HBELLY HANG,10HVEGETATION,9HOBS FORCE/
      ATOT=0.
      NPATCH=0
      LIN=10
      LOUT=22
 100  NPATCH=NPATCH + 1
C     INPUT OF SPEEDS AND CODES FROM DIAGNOSIS SUBROUTINE
      READ (LIN,END=1000)NTU,ITUT,ZMPH1,(V1(NPATCH,K),K=1,3),
     + ZMPH5,ZMPH6,ZMPH7,ZMPH8,GRADE,AREA,(ICODE(NPATCH,K),K=1,3)
 110  FORMAT(I7,F10.4,3(F10.4,I4),F10.4)
      DO 150 K=1,3
               A1(NPATCH,K)=AREA
               N1(NPATCH,K)=NTU
 150  CONTINUE
      ATOT=ATOT+AREA
      GOTO 100
 1000 CONTINUE
C     INITIALIZATION
      NPATCH=NPATCH-1
      DO 1020 K=1,3
               DO 1010 L=1,15
                        NTGO(L,K)=0
                        ATGO(L,K)=0.
                        VTGO(L,K)=0.
 1010          CONTINUE
               DO 1015 L=1,10
                        NTNOGO(L,K)=0
                        ATGO(L,K)=0.
 1015          CONTINUE
               NGO(K)=0
               NNOGO(K)=0
               AGO(K)=0.
               ANOGO(K)=0.
               VGO(K)=0.
 1020 CONTINUE
```

```
C          SUMMARIZATION
           DO 1100 K=1,3
                     DO 1060 I=1,NPATCH
                                L=ICODE(I,K)
                                IF(L.LT.0)GOTO 1040
                                IF((L.EQ.0).OR.(L.GT.15))GOTO 1050
                                NTGO(L,K)=NTGO(L,K)+1
                                ATGO(L,K)=ATGO(L,K)+A1(I,K)
                                VTGO(L,K)=VTGO(L,K)+V1(I,K)*A1(I,K)
                                NGO(K)=NGO(K)+1
                                AGO(K)=AGO(K)+A1(I,K)
                                VGO(K)=VGO(K)+V1(I,K)*A1(I,K)
                     GOTO 1060
C          NO GO
1040                            IF(L.LT.-10) GOTO 1050
                                L=-L
                                NTNOGO(L,K)=NTNOGO(L,K)+1
                                NNOGO(K)=NNOGO(K)+1
                                ATNOGO(L,K)=ATNOGO(L,K)+A1(I,K)
                                ANOGO(K)=ANOGO(K)+A1(I,K)
                     GOTO 1060
C          ERROR IN ENCODING OR DIMENSIONS
1050                 WRITE(6,1052) L,N1(I,K),V1(I,K),K
1052                 FORMAT(' ICODE=',I4,' NOT RECOGNIZED'/
     +               ' NTU,SPEED,SLOPE:',I6,F10.2,I3/)
1060                 CONTINUE

                                DO 1070 L=1,15
                                          IF(ATGO(L,K).EQ.0.)GOTO 1070
                                          VTGO(L,K)=VTGO(L,K)/ATGO(L,K)
1070                            CONTINUE
                                IF(AGO(K).EQ.0.)GOTO 1100
                                VGO(K)=VGO(K)/AGO(K)
1100       CONTINUE
C          SUMMARY OUTPUT

           WRITE(6,1110)
1110       FORMAT(///33X,8HUP SLOPE,20X,5HLEVEL,19X,10HDOWN SLOPE,/
     1          1H+,22X,3(4X,22H______________________)/
     2          2X,8HLIMITING,13X,3(4X,5HNO.OF,2X,6HFACTOR,2X,
     3          7HAVERAGE)/3X,6HFACTOR,13X,3(5X,5HT U'S,3X,4HAREA,4X,
     4          5HSPEED)///17H GO TERRAIN UNITS/)
           DO 1140 L=1,9
           WRITE(6,1130)L,LIMIT(L),(NTGO(L,K),ATGO(L,K),VTGO(L,K),K=1,3)
1130       FORMAT(1X,I3,1X,A10,7X,3(I10,2F8.2))
1140       CONTINUE
           WRITE(6,1150),(NGO(K),AGO(K),VGO(K),K=1,3)
1150       FORMAT(/1X,5HTOTAL,16X,3(I10,2F8.2))

           WRITE(6,1160)
1160       FORMAT(//' NOGO TERRAIN UNITS'/)

           DO 1180 L=1,6
           LL=-L
           WRITE(6,1170)LL,NREAS(L),(NTNOGO(L,K),ATNOGO(L,K),K=1,3)
1170       FORMAT(1X,I3,1X,A10,7X,3(I10,F8.2,8X))
1180       CONTINUE
           WRITE(6,1190),(NNOGO(K),ANOGO(K),K=1,3)
1190       FORMAT(/1X,5HTOTAL,16X,3(I10,F8.2,8X)///)
C
```

```
C  SORT OF SPEEDS
C
        NL1=NPATCH-1
        DO 1300 K=1,3
              ATEMP=0.
              NTEMP=0
              VTEMP=0.
              DO 1300 IC=1,NL1
                    ICP=IC+1
                    DO 1320 IL=ICP,NPATCH
                          IF(V1(IL,K).LE.V1(IC,K))GO TO 1320
                          VTEMP=V1(IL,K)
                          ATEMP=A1(IL,K)
                          NTEMP=N1(IL,K)
                          ITEMP=ICODE(IL,K)
                          V1(IL,K)=V1(IC,K)
                          A1(IL,K)=A1(IC,K)
                          N1(IL,K)=N1(IC,K)
                          ICODE(IL,K)=ICODE(IC,K)
                          V1(IC,K)=VTEMP
                          A1(IC,K)=ATEMP
                          N1(IC,K)=NTEMP
                          ICODE(IC,K)=ITEMP
 1320               CONTINUE
 1300   CONTINUE
        DO 1350 K=1,3
              VSUM=0.
              ACUM=0.
              DO 1350 I=1,NPATCH
                    ACUM=ACUM+A1(I,K)
                    VSUM=VSUM+V1(I,K)*A1(I,K)
                    A1(I,K)=(ACUM/ATOT)*100.
                    IF(V1(I,K).LE.0.)GOTO 1350
                    V2(I,K)=VSUM/ACUM
 1350   CONTINUE
        WRITE(22,1380)
 1380   FORMAT(/16X,8HUP SLOPE,29X,5HLEVEL,27X,10HDOWN SLOPE,/
     1    1H+,2X,3(2X,30H______________________________,3X)/
     2    3X,3(6X,12HTERRAIN UNIT,4X,10HCUMULATIVE,3X)/
     3    4X,3(3H NO,2X,3HMAX,2X,5HLIMIT,1X,4HAREA,2X,3HAVG,3X,
     4    3HPCT,4X)/3X,3(5X,5HSPEED,2X4HCODE,5X,5HSPEED,2X,4HAREA,3X))
        DO 1410 I=1,NPATCH
              DO 1425 K=1,3
                    DIFF=A1(I,K)
                    IF(I.GT.1)DIFF=DIFF-A1(I-1,K)
                    AA(K)=DIFF*ATOT/100.
 1425         CONTINUE
              WRITE(22,1400)(N1(I,K),V1(I,K),ICODE(I,K),AA(K),
     1        V2(I,K),A1(I,K),K=1,3)
 1400   FORMAT(3(2X,I5,F6.1,1X,I3,F6.2,F6.1,F6.2))
 1410   CONTINUE
        TYPE 1500
 1500   FORMAT('  GRAPHIC OUTPUT DESIRED? Y OR N:',$)
        ACCEPT 1510,IG
 1510   FORMAT(A1)
        IF(IG.NE.'Y')STOP
        AMAX=AMAX1(V1(1,1),V1(1,2),V1(1,3))
C
C       SPEED PROFILE PLOTS
C
```

```
      CALL CSCL(AMAX,YMAX)
      CALL GRAF(1,0.,0.,PAU,V1U,NPATCH,0.,100.,0.,YMAX,10.,10.,
     1  'PERCENT TOTAL AREA',18,'MAXIMUM SPEED (MPH)',19,
     2  'MAXIMUM SPEED PROFILE, UP',25,1,5,0,1,0,'PLT1',0)
      CALL POINTS(1,NPATCH,V1,A1,ICODE)
      CALL GRAF(-1)
      CALL GRAF(0.,0.,PAU,V2U,NPATCH,0.,100.,0.,YMAX,10.,10.,'PERCENT
     1 TOTAL AREA',18,'MEAN SPEED (MPH)',16,'AVERAGE SPEED PROFILE',
     221,1,5,0,1,0,'PLT2',0)
      CALL GRAF(1,0.,0.,PAL,V1L,NPATCH,0.,100.,0.,YMAX,10.,10.,
     1  'PERCENT TOTAL AREA',18,'MAXIMUM SPEED (MPH)',19,
     2  'MAXIMUM SPEED PROFILE, LEVEL',28,1,5,0,1,0,'PLT3',0)
      CALL POINTS(2,NPATCH,V1,A1,ICODE)
      CALL GRAF(-1)
      CALL GRAF(0.,0.,PAL,V2L,NPATCH,0.,100.,0.,YMAX,10.,10.,'PERCENT
     1 TOTAL AREA',18,'MEAN SPEED (MPH)',16,'AVERAGE SPEED PROFILE',
     221,1,5,0,1,0,'PLT4',0)
      CALL GRAF(1,0.,0.,PAD,V1D,NPATCH,0.,100.,0.,YMAX,10.,10.,
     1  'PERCENT TOTAL AREA',18,'MAXIMUM SPEED (MPH)',19,
     2  'MAXIMUM SPEED PROFILE, DOWN',27,1,5,0,1,0,'PLT5',0)
      CALL POINTS(3,NPATCH,V1,A1,ICODE)
      CALL GRAF(-1)
      CALL GRAF(0.,0.,PAD,V2D,NPATCH,0.,100.,0.,YMAX,10.,10.,'PERCENT
     1 TOTAL AREA',18,'MEAN SPEED (MPH)',16,'AVERAGE SPEED PROFILE',
     221,1,5,0,1,0,'PLT6',0)
 2000 FORMAT(' PEN ',I2,'USED, ENTER PEN #')
 2010 FORMAT(I)
C
C     COMBINED PLOTS OF UP,LEVEL & DOWN PROFILES
C
      CALL GRAF(1,0.,0.,PAU,V1U,NPATCH,0.,100.,0.,YMAX,10.,10.,
     1  'PERCENT TOTAL AREA',18,'MAXIMUM SPEED (MPH)',19,
     2  'MAXIMUM SPEED PROFILE',21,1,1,0.,1,0,'PLT7',1.)
      CALL POINTS(1,NPATCH,V1,A1,ICODE)
C     CHANGE PEN
      IP=NEWPEN(0)
      TYPE 2000,IP
      ACCEPT 2010,IP
      IP2=NEWPEN(IP)
      CALL GRAF(0,PAL,V1L,NPATCH,1,2)
      CALL POINTS(2,NPATCH,V1,A1,ICODE)
C     CHANGE PEN
      IP=NEWPEN(0)
      TYPE 2000,IP
      ACCEPT 2010,IP
      IP2=NEWPEN(IP)
      CALL GRAF(0,PAD,V1D,NPATCH,1,3)
      CALL POINTS(3,NPATCH,V1,A1,ICODE)
      CALL GRAF(-1)
      CALL GRAF(1,0.,0.,PAU,V2U,NPATCH,0.,100.,0.,YMAX,10.,10.,
     1  'PERCENT TOTAL AREA',18,'MEAN SPEED (MPH)',16,
     2  'AVERAGE SPEED PROFILE',21,1,1,0.,1,0,'PLT8',1.)
C     CHANGE PEN
      IP=NEWPEN(0)
      TYPE 2000,IP
      ACCEPT 2010,IP
      IP2=NEWPEN(IP)
      CALL GRAF(0,PAL,V2L,NPATCH,1,2)
C     CHANGE PEN
      IP=NEWPEN(0)
```

```
      TYPE 2001,IP
      ACCEPT 2010,IP
      IP2=NEWPEN(IP)
      CALL GRAF(0,PAD,V2D,NPATCH,1,3)
      CALL GRAF(-1)
      STOP
      END
      SUBROUTINE CSCL(AMAX,XMAX)
C    SCALING SUBROUTINE FOR PLOT AXES
      IF(AMAX.LE.0.)GO TO 200
      FAC = 1.
      AL5 = ALOG10(5.)
      AL = ALOG10(AMAX)
      EXP = AINT(AL)
      IF(EXP.EQ.AL)GO TO 20
      IF(AMAX.LT.1.)EXP= EXP-1.
      R = AL-EXP
      FAC = 10.
      IF(R.LE.AL5)FAC = 5.
20    XMAX = FAC * (10.**EXP)
C     WRITE(21,100)AMAX,AL,EXP,R,FAC,XMAX
100   FORMAT(1X,6G)
      RETURN
200   XMAX = 0.
      RETURN
      END
      SUBROUTINE POINTS(K,NPATCH,V1,PA,ICODE)
C   SUBROUTINE FOR OUTPUT OF CODED DATA POINTS ON SPEED PROFILE PLOTS
      DIMENSION V1(500,3),PA(500,3),ICODE(500,3)
      DIMENSION PP(500),VP(500)
      DO 2200 J=1,8
      NTU = 0
      DO 2100 I =1,NPATCH
      IF(ICODE(I,K).NE.J)GO TO 2100
      NTU = NTU +1
      VP(NTU) = V1(I,K)
      PP(NTU) = PA(I,K)
2100  CONTINUE
      IF(NTU.EQ.0)GO TO 2200
      CALL GRAF(0,PP,VP,NTU,-1,J)
2200  CONTINUE
C
C     NO GO'S
C
      DO 2500 J=1,6
      NTU = 0
      DO 2400 I =1,NPATCH
      IF(ICODE(I,K).NE.-J)GO TO 2400
      NTU = NTU +1
      VP(NTU) = V1(I,K)
      PP(NTU) = PA(I,K)
2400  CONTINUE
      IF(NTU.EQ.0)GO TO 2500
      CALL GRAF(0,PP,VP,NTU,-1,15-J)
2500  CONTINUE
      RETURN
      END
```

APPENDIX C

CHANGES TO NRMM FOR DIAGNOSIS PROGRAM

APPENDIX C

CHANGES TO NRMM TO IMPLEMENT DIAGNOSIS

1. Add array ICODE (with DIMENSION 3) to COMMON block DERIVE. DERIVE appears in the main program and subroutines AREAL, ROAD, and BUFFØ.

2. Add the control variable KDIAG to the COMMON block SCEN. SCEN is in the main program and subroutines SCN, VPP, TERTL, AREAL, ROAD and BUFFØ.

3. Add KDIAG to the NAMELIST CONTRL, lines SCN16-SCN25 of subroutine SCN. This allows KDIAG to be read.

4. In subroutine SCN, change line SCN-55 to:

```
IF (DETAIL.EQ.3) GO TO 313
```

   Add between lines SCN 65 and SCN 66 the following:

```
313 CONTINUE
      KDIAG = 1
      GO TO 330
```

   These changes permit diagnosis to be specified as output detail level 3.

5. In subroutine AREAL, add between lines AREAL-219 and AREAL-220 the following:

```
IF (KDIAG.EQ.1) CALL DIAG (AREA, IDCODE, IMAX, ITUT, NEVERO,
NTU, TBF, VAVOID, VBO, VELV, VMAX, VMAX1, VOLA, VOVER, VRID,
VSOIL, VTIRE, VXT)
```

6. Change line BUFFØ 34 of subroutine BUFFØ to:

```
ZMPH7, ZMPH8, GRADE, AREA, ICODE.
```

This addition to the binary output file written to LUN10 allows this output file to be used by the analysis program.

7. The diagnosis subroutine DIAG must be included. The listing of this subroutine follows.

```
      SUBROUTINE DIAG(AREA,ICODE,IMAX,ITUT,NEVERO,NTU,TBF,
     1        VAVOID,VBO,VELV,VMAX,VMAX1,VOLA,VOVER,VRID,VSOIL,
     2        VTIRE,VXT,VWALK)
C  DIAGNOSTIC SUBROUTINE FOR NRMM AREAL MODULE
      DIMENSION ICODE(3),IMAX(3),TBF(3),VAVOID(3,9),VBO(3,9),
     1        VELV(3),VMAX1(3),VOVER(3,9),VSOIL(3,9),VXT(3,9)
      IF(ITUT.GE.11)GOTO 1000
C     ASSIGNMENT OF LIMITING FACTOR
      DO 600 K=1,3
              VC = VMAX1(K)
              IF(VC.EQ.0.)GO TO 400
C
C     PATCH IS GO
C
              IF(VC.LT.VRID)GO TO 210
C     RIDE LIMIT
              ICODE(K)=1
              GO TO 600
210           IF(VC.NE.VTIRE)GO TO 220
C     TIRE CONSTRUCTION LIMIT
              ICODE(K)=2
              GO TO 600
220           IF(VC.LT.(.99*VSOIL(K,IMAX(K))))GO TO 230
C     POWER VS. SOIL,SLOPE,VEGETATION RESISTANCE
              ICODE(K)=3
              GO TO 600
230           IF(VC.LT.VELV(K))GO TO 240
C     VISIBLITY LIMIT
              ICODE(K)=4
              GO TO 600
240           IF(VC.LT.VAVOID(K,IMAX(K)))GO TO 250
C     MANEUVER AROUND OBSTACLES AND VEGETATION
              ICODE(K)=5
              GO TO 600
250           IF(VC.LT.VBO(K,IMAX(K)))GO TO 260
C     MANEUVER AROUND VEGETATION
              ICODE(K)=6
              GO TO 600
260           IF(VC.LT.VOLA)GO TO 270
C     OBSTACLE IMPACT LIMIT
              ICODE(K)=7
              GO TO 600
270           IF(VC.LT.VOVER(K,IMAX(K)))GOTO 280
C     POWER TO OVERRIDE OBSTACLE
              ICODE(K)=8
              GOTO 600
C     DRIVER PRUDENCE OVERRIDING VEGETATION
280           IF(VC.NE.VWALK)GOTO 290
              ICODE(K)=9
              GOTO 600
C     LIMIT NOT DIAGNOSED
290           ICODE(K)=99
              GO TO 600
400           CONTINUE
C
C     PATCH IS NO GO
C
              IF(TBF(K).GE.0.0)GO TO 410
C     NO BRAKING NOGO
              ICODE(K)=-1
```

```
                  GO TO 600
410               IF(VSOIL(K,1).GT.0.0)GO TO 420
C        SOIL & SLOPE IMMOBILIZATION
                  ICODE(K)=-2
                  GO TO 600
420               IF(NEVERO.NE.3)GO TO 430
C        OBSTACLE INTERFERENCE
                  ICODE(K)=-3
                  GO TO 600
430               IF(NEVERO.NE.1)GOTO 440
C        BELLY HANGUP ON OBSTACLES
                  ICODE(K)=-1
                  GOTO 600
440               IF(VBO(K,IMAX(K)).GT.0.)GOTO 450
C        VEGETATION NO GO
                  ICODE(K)=-5
                  GOTO 600
450               IF((NEVERO.GT.0).OR.(VYT(K,IMAX(K)).GT.0.))GOTO 460
C        OBSTACLE OVERRIDE FORCE NOGO
                  ICODE(K)=-6
                  GOTO 600
C        NOGO REASON NOT DIAGNOSED
460               ICODE(K)=-99
600      CONTINUE
C        WRITE(21,610)NTU,VMAX,(VMAX1(K),ICODE(K),K=1,3),AREA
610      FORMAT(1X,I6,F14.4,3(F10.4,I4),F10.4)
         RETURN
1000     WRITE(6,1010)
1010     FORMAT(42H ROAD TERRAIN UNIT DIAGNOSIS NOT AVAILABLE)
         END
```

DATE

ILME