# PILOT STUDY OF AN UNSTABLE SLOPE MANAGEMENT SYSTEM

WA-RD 297.1

Final Technical Report
October 1994

Washington State Department of Transportation

Washington State Transportation Commission
Planning and Programming Service Center
in cooperation with the U.S. Department of Transportation
Federal Highway Administration

# TECHNICAL REPORT STANDARD TITLE PAGE

| 1. REPORT NO. | 2. GOVERNMENT ACCESSION NO. | 3. RECIPIENT'S CATALOG NO. |
| --- | --- | --- |
| WA-RD 297.1 | | |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
| --- | --- |
| Pilot Study of an Unstable Slope Management System | October 1994 |
| | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S)<br>Carlton L. Ho and Russell A. Knutson, Washington State University | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Washington State Transportation Center (TRAC)<br>Civil and Environmental Engineering; Sloan Hall, Room 101<br>Washington State University<br>Pullman, Washington 99164 | 10. WORK UNIT NO.<br><br>11. CONTRACT OR GRANT NO.<br>GC-8720, T16 |
| 12. SPONSORING AGENCY NAME AND ADDRESS<br>Washington State Department of Transportation<br>Transportation Building, MS 7370<br>Olympia, Washington 98504-7370 | 13. TYPE OF REPORT AND PERIOD COVERED<br>Technical Report, 5/91 -12/92<br><br>14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

Previously, an Unstable Slope Management System (USMS) had been developed to prioritize the repair of unstable slopes. This report describes the process of implementing and testing the USMS. The original system was comprised of two parts, a database and programs that determined the priority ratings of the slopes. These components of the USMS were modified to create a system that was more user friendly and better able to prevent errors than the original USMS. During the course of the project changes were made as necessary to the programs or databases to correct for errors. Modifications to the USMS included upgrading the software used to create the USMS. The USMS was tested using data on actual slopes having various degrees of active failure located in District 4 of the Washington State Department of Transportation (WSDOT). District 4 was selected because it exhibits a wide variety of conditions applicable to the USMS. Sites were selected by WSDOT personnel who were familiar with the area. A total of thirty-nine failure sites were identified and entered into the USMS. A parametric study of the results was performed to determine the effect of changing of the weighting factors used.

| 17. KEY WORDS | 18. DISTRIBUTION STATEMENT |
| --- | --- |
| landslides, slopes, management system | No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616 |

| 19. SECURITY CLASSIF. (of this report) | 20. SECURITY CLASSIF. (of this page) | 21. NO. OF PAGES | 22. PRICE |
| --- | --- | --- | --- |
| None | None | 65 | |

**Final Technical Report**

Research Project GC-8720, Task 16
Pilot Study of an Unstable Slope Management System

# PILOT STUDY OF AN UNSTABLE SLOPE MANAGEMENT SYSTEM

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Department of Transportation
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**U.S. Department of Transportation**
Federal Highway Administration

October 1994

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**SUMMARY**

Previously, an Unstable Slope Management System (USMS) had been developed to prioritize the repair of unstable slopes. This report describes the process of implementing and testing the USMS. The original system was comprised of two parts, a database and programs that determined the priority ratings of the slopes. These components of the USMS were modified to create a system that was more user friendly and better able to prevent errors than the original USMS. During the course of the project, changes were made as necessary to the programs or databases to correct for errors. Modifications to the USMS included upgrading the software used to create the USMS. The USMS was tested using data from actual slopes having various degrees of active failure located in District 4 of the Washington State Department of Transportation (WSDOT). District 4 was selected because it exhibits a wide variety of conditions applicable to the USMS. Sites were selected by WSDOT personnel who were familiar with the area. A total of forty failure sites were identified and entered into the USMS. A parametric study of the results was performed to determine the effect of changing the weighting factors used. A user guide is included in the appendix.

# INTRODUCTION

Each year it is estimated that landslides destroy more property and cause more loss of life than other natural disasters [1]. By 1978 the costs associated with these slope failures was estimated to exceed one billion dollars per year worldwide [2]. Slope failures cost the Washington State Department of Transportation (WSDOT) millions of dollars to stabilize, repair, and cleanup. To prevent the failures from occurring is possible but not feasible due to the tremendous cost (more than $200 million) required. The system now in place to correct slope failures is a reactive one. When the slope fails, emergency repairs are made. To reduce the threat to public safety, possible road closures, and to arrive at the best balance between the cost of preventing failures and repairing them, WSDOT funded research to develop an Unstable Slope Management System (USMS) to determine the feasibility and priority for repair prior to failure [3,4].

The prototype USMS was designed to be the first step towards developing a proactive system that would allow a consistent method of determining the priority for repair of unstable slopes. The system uses factors relating to slope instability, economic impact, road use, public safety, and failure frequency to determine the priority. This report presents the test of the USMS with data from actual unstable slopes.

## PROBLEM STATEMENT

This project was directed toward conducting a pilot study of the USMS that was developed in earlier research. Data was collected from one district of the WSDOT to test the system and determine the areas of the USMS that need improvement. The district selected was to exhibit a wide range of conditions in order to test the system. Preliminary work was also done to evaluate the weighting factors in the current USMS. Improvements to the system included modifying the existing USMS interface and adding error checking. Other improvements and changes to the programs were made as necessary.

## RESEARCH APPROACH

This research was divided into four major areas:

1. Evaluation of the Existing USMS
2. Program Modifications
3. Data Acquisition
4. Parametric Study

The first two areas were further divided into portions covering the dBASE and CLIPS programs described below.

### EVALUATION OF EXISTING USMS

The prototype USMS was designed to run on a standard IBM compatible computer (PC) using commercially available software. It was determined that the USMS would consist of two parts: a database management system (DBMS) and an expert system shell. One of the objectives of the system was that it should be able to collect and maintain data from past failures to build a knowledge-base of the conditions that cause failures. The system would also allow the editing and sorting of the data as well as a way to export the data to the expert system shell. Based on these criteria, dBASE III+ was selected as the DBMS for the study [5]. The expert system shell CLIPS version 4.3 (C Language Integrated Production System) was developed and is maintained by NASA's Software Technology Branch at the Johnson Space Center [6]. At the time of software selection expert system shells were (and are) relatively expensive. CLIPS has the advantage of a low cost for unlimited copies, no royalties, and is portable to other computer operating systems.

The DBMS part of the USMS consisted of two parts. The first part consisted of the programs used to enter data into the system, manage the files, and programs that created the menus and data entry screen forms. The other dBASE component of the USMS consisted of the database files that contained the information obtained from the failure sites. The information contained in the databases were organized by records and fields. A record represents the information for one failure site. A field is a part of the record that holds the data. The CLIPS part of the system contained the programs necessary to determine the priority ratings.

To use the USMS the operator would enter dBASE and execute the main program. The main program was a system of menus, sub-menus, and sub-programs. The sub-programs let the user enter, edit, delete, and display the data for the failure sites. This data was kept in eight separate databases. After the data was entered into the databases, the CLIPS part of the system was run. First the data would be exported as ASCII (American Standard Code for Information Interchange) text files so the CLIPS programs could use it. To run the CLIPS programs the user would exit dBASE and enter the CLIPS shell. A batch program was loaded and executed. The batch program loaded the CLIPS programs into the CLIPS shell and ran them, one at a time. Each CLIPS program opened its corresponding text file, processed the data, and wrote the results to an output file. The results from the CLIPS programs were imported into dBASE and converted into the dBASE (DBF) file format. After these files were imported the weights were applied and the total priority rating for the site determined.

The USMS was designed so that failure frequency at any site would be taken into account. There could be more than one failure at a site. In order to reduce the amount of data entry and processing time, the data was divided into two types, temporary and permanent. Temporary data refers to data that will likely change with each failure at a given site. Examples of temporary data are the failure types, size of the failure, the ground water level, and the time of the year. Permanent data does not tend to change with each failure and need be entered only once for each site. Examples of permanent data are site geology and the average daily traffic count (ADT). If any of the permanent data does change, i. e. the ADT, it is easily edited through the dBASE programs. The permanent and temporary data are processed separately and then linked by the site identification number to arrive at the total priority rating.

The prototype USMS worked effectively from a computational perspective. Improvements could be made to simplify operation of the system and reduce the potential for user error. This would involve modification of the user interface of the system (menu screens, help screens, program access, etc).

A useful modification would allow for checking of data input errors. The most common errors encountered were spelling or case errors. The CLIPS programming language is sensitive to both case and spelling. To a CLIPS program *rockfall* is not the same thing as *Rockfall* or *ROCKFALL*. The dBASE programs allowed any of the variations but the CLIPS programs would accept only the one specified in the CLIPS program code. In the prototype USMS, there was no way to find the error until the CLIPS programs were run. The CLIPS programs, on not finding the proper term, would abort and continue with the next program in the batch. To find these errors required the user to open the CLIPS output files to find where execution stopped. When the location of the error was known the data could be edited in the database files, and the system rerun.

In the prototype configuration, it was very easy to input improper site identification numbers. Each site is represented by a number, generally the sign route number and the milepost. This identification number is very important because this value provides the relationship between the databases. If different identification values for one site were entered in two or more of the databases, the data entry program would not inform the user that there was a discrepancy. A useful modification would be to insure proper site identification.

## SOFTWARE UPGRADES

At the beginning of the pilot study both of the software packages that were used were upgraded. The dBASE III+ was upgraded to dBASE IV version 1.1 and the CLIPS version 4.3 was upgraded to CLIPS version 5.0 [7], [8], [9].

The upgrade of the dBASE part of the program allowed a greater number of open databases. This was useful when importing the results from CLIPS programs into one database instead of the ten that had to be opened and closed in the development stage under dBASE III+. dBASE IV also provided a method for generating menus that was much improved over what could be achieved in dBASE III+. The same improvements were also seen in the printed reports and in the data entry screens. dBASE IV also provided multiple choice data entry forms that could eliminate the problems associated with the incorrect data being sent to the CLIPS programs.

The improvements to the CLIPS shell were not as noticeable. They include the ability to save the programs as binary files rather than as text files. This does not improve the speed of execution but vastly improves the speed of loading the programs. The upgrade also provides the possibility of compiling the CLIPS programs to run independently of the CLIPS shell.

## MODIFICATIONS TO USMS PROGRAMS

The USMS programs were modified as needed throughout the testing of the system. Many of the modifications were minor such as refining the user interface, correcting programming errors, and adding error checking. Some of the modifications came about from the incorporation of new versions of the software that was used to write the USMS.

## DATA ACQUISITION

The district selected for the pilot study of the USMS was District 4, in the southeastern part of the state of Washington. District 4, headquartered in Vancouver, covers a wide range of conditions from the Pacific Ocean to the west, The Cascade Mountains to the east, and the Columbia River to the south. A total of 39 sites were found representing a wide variety of conditions from throughout the district. The sites along US-12 are in a mountain pass where the terrain is steep and rocky. The sites along State Route (SR)-14 lie along the Columbia River Gorge. The sites on SR-101, SR-401, SR-403 all lie along the coast. SR-4, I-5, SR-6, SR-411, SR-504, and SR-505 all lie in the lowlands between the Cascade and Coastal Mountain Ranges.

The sites were selected by the WSDOT District 4 Materials Engineer who was very familiar with the area. To gather the data necessary for the USMS a "tear sheet" was compiled from the programs (Appendix B). The "tear sheet" and the seismic zonation map gave the list of responses that the system would accept [10].

The sites were identified by a Site Identification Number. For the pilot study the Site ID was represented by a five to seven digit number. This number was a combination of the highway number and the mile post. The numbers were in the format *hhhnnnd*, where *hhh* = the highway number (leading zeros ignored), *nnnd* the mile post in miles and tenths of miles (leading zeros required). The site number 140776 represented a site on highway 14 at mile post 77.6.

Because this was the initial collection of data, the sites considered to be candidates for repair were all at different stages of failure. Therefore no information was available for the failure frequency, repair cost, road damage and impedance, or failure size. The failure dates were all entered as January 1, 1992. This was done so that all sites would receive the same rating in that category. Repair costs were estimated by the District 4 Materials Engineer. One of the sites (Site ID 40499) is listed as having two failures. This site actually has only one failure but there are two possible repair strategies. In this case the repairs suggested had two greatly different estimated repair costs. This site was treated as two failures at the same site with the only difference being the repair cost. The failure at this site was a rockfall, the first repair option was a realignment of the roadway at an estimated cost of $1,000,000 (failure number 1). The second option was to place wire mesh over the rockfall at a cost of $150,000 (failure number 2). The road damage and traffic impedance were also estimated by the Materials Engineer based on the consequences of a possible failure. The failure size was estimated from photographs of the sites. Another area where data were not readily available in the field was the soil type. Many of the failures occurred under the roadbed and the soil type and layering is not always readily apparent. The information for the soil type was acquired from the geologic maps of the area published by the Washington State Department of Natural Resources [11].

## FINDINGS: PARAMETRIC STUDY

To develop the priority ratings for the sites, the USMS uses weighting factors applied to the output data from the CLIPS programs. The output values from the CLIPS programs range from zero to ten. Obviously some of the factors have more bearing on the priority of a slope failure than others. To differentiate between these factors, the weights were applied when the priorities were calculated.

The priorities developed using the original values of the weights were much as expected. The sites with the highest calculated priorities were those with the most severe consequences if a failure occurred. Those with the lowest priority ratings were at sites that had little traffic or were subject to minor failures. The numerical values of the priority ratings for the sites in between these extremes were very close. To determine the sensitivity of the priority ratings to the changes in the value of the weights, each weighting factor was adjusted by ± 50% and ± 25%.

The original weighting factors were based on estimates of each factor's relative importance. The ratings from the CLIPS programs all have the same range of numerical values from zero to ten, but some factors are more important to the priority of a site than others. The USMS was designed to differentiate between the factors considered more important to the priority of a site by the use of weighting factors. These weighting factors were applied in the dBASE programs for the temporary data (TEMPWT.PRG) and for the permanent data (PERMWT.PRG). These programs calculated the raw ratings of the sites from the CLIPS output. Applying the weighting factors in this manner allows them to be easily changed if it is determined that they are not correct or need to be adjusted.

In the prototype the total priority rating was defined as the sum of the temporary and permanent priority rating divided by nineteen (the total number of weights) (Equation 1) [3,4].

$$TPR = \frac{\Sigma T + \Sigma P}{19} \tag{1}$$

Where ***TPR*** is the Total Priority Rating, $\Sigma \boldsymbol{T}$ is the sum of the temporary priority ratings, and $\Sigma \boldsymbol{P}$ is the sum of the permanent priority ratings. This method yielded satisfactory results when ranking the sites but the numerical values of the results were so closely bunched that determination of the sites was difficult (Table I). To create a greater spread of the results, the method of calculating the total priority ratings was changed. Instead of dividing the sum of the temporary and permanent priority ratings by nineteen the new method divides the sum of the temporary and permanent priority ratings by one-hundred fifty and uses the result as the exponent of three (Equation 2).

$$TPR = 3^{\frac{\Sigma T + \Sigma P}{150}} \tag{2}$$

Although this change provides a better indication of the sites importance it does not affect the ranking of the sites. A direct comparison of the values is shown in Table II and a graphical comparison in Figure 1, using the original weighting values.

Since the weighting factors used in the USMS were based on estimates of each factor's relative importance, a sensitivity analysis was performed. In the prototype USMS the combined sum of the weights was equal to 100 (Table III). In the parametric study it was

**Table I** Ranks of sites using original weighting values

| Site Identification | Failure Number | Value | Rank |
|---|---|---|---|
| 50130 | 1 | 30.79 | 1 |
| 50414 | 1 | 30 | 2 |
| 140522 | 1 | 29.6 | 3 |
| 40499 | 1 | 29.1 | 4 |
| 50240 | 1 | 28.61 | 5 |
| 121457 | 1 | 28.6 | 6 |
| 121443 | 1 | 28.54 | 7 |
| 1010620 | 1 | 27.89 | 8 |
| 140273 | 1 | 27.02 | 9 |
| 1010630 | 1 | 26.95 | 10 |
| 60444 | 1 | 26.89 | 11 |
| 1010628 | 1 | 26.84 | 12 |
| 40499 | 2 | 26.73 | 13 |
| 5030499 | 1 | 26.71 | 14 |
| 4110053 | 1 | 26.24 | 15 |
| 1010277 | 1 | 26.21 | 16 |
| 40226 | 1 | 25.21 | 17 |
| 40457 | 1 | 25.14 | 18 |
| 4110054 | 1 | 24.66 | 19 |
| 140515 | 1 | 24.64 | 20 |
| 140252 | 1 | 24.44 | 21 |
| 140510 | 1 | 24.38 | 22 |
| 4010034 | 1 | 24.34 | 23 |
| 140776 | 1 | 24.32 | 24 |

**Table I** Ranks of sites using original weighting values (continued)

| Site Identification | Failure Number | Value | Rank |
|---|---|---|---|
| 140521 | 1 | 24.18 | 25 |
| 40211 | 1 | 24.16 | 26 |
| 1010615 | 1 | 23.79 | 27 |
| 140271 | 1 | 23.47 | 28 |
| 5040168 | 1 | 22.74 | 29 |
| 1050124 | 1 | 22.53 | 30 |
| 60209 | 1 | 22.47 | 31 |
| 121487 | 1 | 22.47 | 32 |
| 1010109 | 1 | 22.47 | 33 |
| 140913 | 1 | 22.45 | 34 |
| 5050104 | 1 | 22.16 | 35 |
| 60197 | 1 | 22.11 | 36 |
| 4030054 | 1 | 22.11 | 37 |
| 40088 | 1 | 20.33 | 38 |
| 1050069 | 1 | 19.95 | 39 |
| 40094 | 1 | 19.26 | 40 |

**Table II** Comparison of Original and Revised Scaling Factors

| Site ID | Failure Number | Original | Revised | Rank |
|---|---|---|---|---|
| 50130 | 1 | 30.79 | 72.58 | 1 |
| 50414 | 1 | 30 | 65.02 | 2 |
| 140522 | 1 | 29.6 | 61.50 | 3 |
| 40499 | 1 | 29.1 | 57.37 | 4 |
| 50240 | 1 | 28.61 | 53.59 | 5 |
| 121457 | 1 | 28.6 | 53.51 | 6 |
| 121443 | 1 | 28.54 | 53.07 | 7 |
| 1010620 | 1 | 27.89 | 48.48 | 8 |
| 140273 | 1 | 27.02 | 42.95 | 9 |
| 1010630 | 1 | 26.95 | 42.53 | 10 |
| 60444 | 1 | 26.89 | 42.18 | 11 |
| 1010628 | 1 | 26.84 | 41.89 | 12 |
| 40499 | 2 | 26.73 | 41.25 | 13 |
| 5030499 | 1 | 26.71 | 41.14 | 14 |
| 4110053 | 1 | 26.24 | 38.53 | 15 |
| 1010277 | 1 | 26.21 | 38.37 | 16 |
| 40226 | 1 | 25.21 | 33.39 | 17 |
| 40457 | 1 | 25.14 | 33.06 | 18 |
| 4110054 | 1 | 24.66 | 30.93 | 19 |
| 140515 | 1 | 24.64 | 30.84 | 20 |
| 140252 | 1 | 24.44 | 29.99 | 21 |
| 140510 | 1 | 24.38 | 29.75 | 22 |
| 4010034 | 1 | 24.34 | 29.58 | 23 |
| 140776 | 1 | 24.32 | 29.50 | 24 |
| 140521 | 1 | 24.18 | 28.93 | 25 |

**Table II** Comparison of Original and Revised Scaling Factors (continued)

| Site ID | Failure Number | Original | Revised | Rank |
|---|---|---|---|---|
| 40211 | 1 | 24.16 | 28.85 | 26 |
| 1010615 | 1 | 23.79 | 27.40 | 27 |
| 140271 | 1 | 23.47 | 26.21 | 28 |
| 5040168 | 1 | 22.74 | 23.68 | 29 |
| 1050124 | 1 | 22.53 | 22.99 | 30 |
| 60209 | 1 | 22.47 | 22.80 | 31 |
| 121487 | 1 | 22.47 | 22.80 | 32 |
| 1010109 | 1 | 22.47 | 22.80 | 33 |
| 140913 | 1 | 22.45 | 22.74 | 34 |
| 5050104 | 1 | 22.16 | 21.84 | 35 |
| 60197 | 1 | 22.11 | 21.69 | 36 |
| 4030054 | 1 | 22.11 | 21.69 | 37 |
| 40088 | 1 | 20.33 | 16.93 | 38 |
| 1050069 | 1 | 19.95 | 16.06 | 39 |
| 40094 | 1 | 19.26 | 14.59 | 40 |

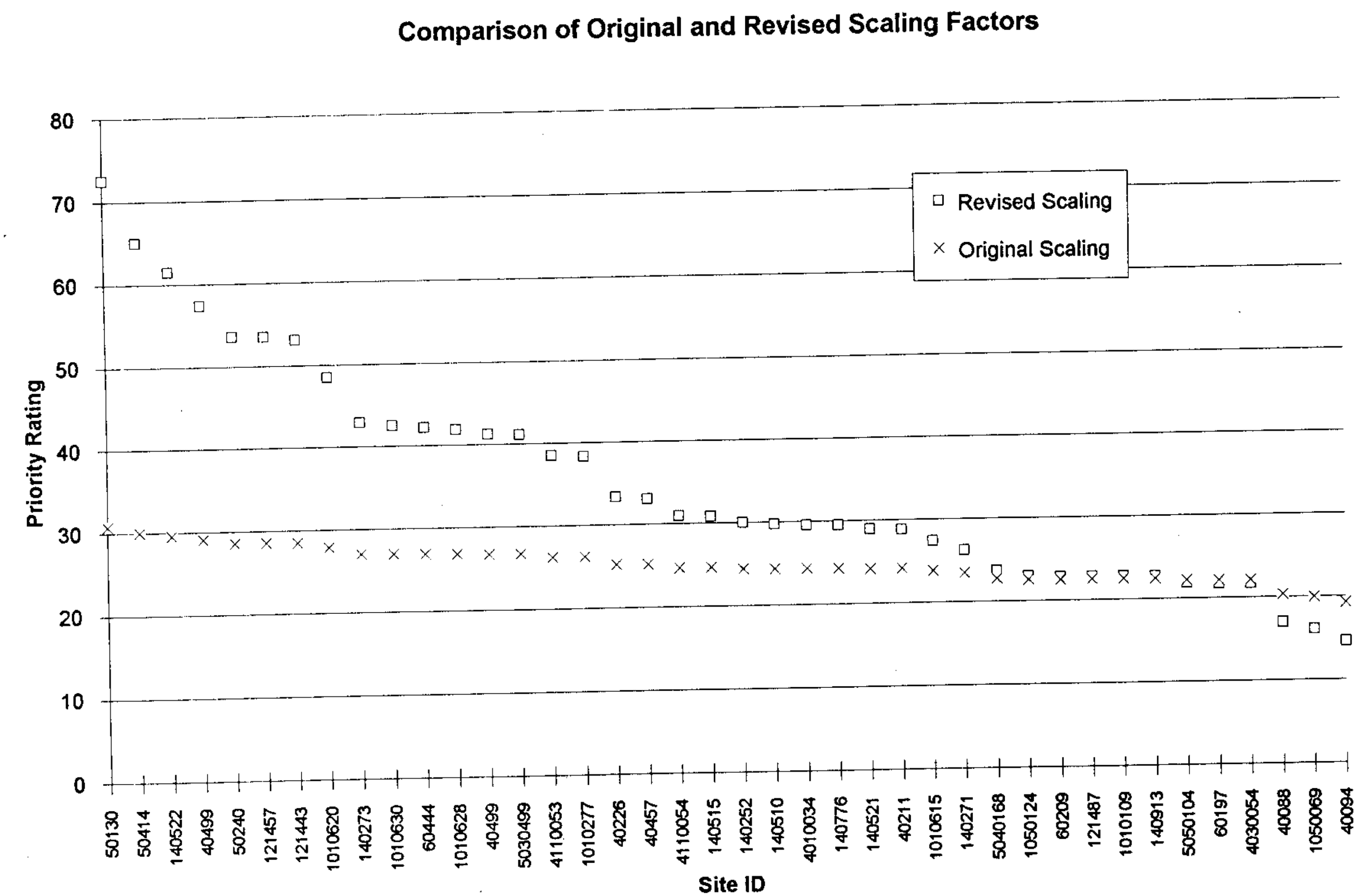


**Figure 1** Comparison of Original and Revised Scaling Factors

**Table III** Original Weighting Values

| Factor Type | Description | Factor | Weight |
|---|---|---|---|
| Permanent | Average Daily Traffic | ADT | 12 |
| | Economic Impact | ECON | 3 |
| | Geographic Hazards | GEOHAZ | 2 |
| | Permanent Loads | PLOAD | 3 |
| | Road Type | ROADTYPE | 10 |
| | Rock Jointing & Layering | ROCK | 4 |
| | Seismic | SEISMIC | 3 |
| | Soil Type & Layering | SOIL | 4 |
| Temporary | Repair Cost | COST | 15 |
| | Failure Date | DATE | 1 |
| | Failure Frequency | FAILFREQ | 8 |
| | Traffic Impedance | IMPEDE | 5 |
| | Pavement Damage | PAVEDAM | 3 |
| | Problem Type | PROBTYPE | 6 |
| | Public Risk Potential | PUBRISK | 1 |
| | Failure Size | SIZE | 2 |
| | Structure Type & Damage | STRUCT | 5 |
| | Temporary Loads | TLOAD | 3 |
| | Failure Water Level | WATER | 10 |
| TOTAL | | | 100 |

desirable to examine the effect of changing the values by ±50% and ±25%. To accomplish this, each of the nineteen weights were changed individually and the rest of the weights adjusted to maintain the total of 100 for the weights to allow for a comparison with the original results.

The weights were separated into temporary and permanent categories and varied, maintaining a total value of 59 for the temporary weights and 41 for the permanent weights. When a weight was raised, the rest of the weights were reduced in proportion to their original value divided by the total of the weights minus the value of the changed weight. Conversely, when a weight was reduced, the rest of the weights were increased in the same fashion.

For example consider the case of varying the permanent weight for the Average Daily Traffic Count, ADT (Table IV). The original value of ADT was 12. Varying ADT by ±50% and ±25% produced values of 6, 9, 15, and 18. In order to maintain the total of forty-one, each of the other weights needed to be adjusted. Reducing the value of ADT by -50% meant that the difference (-6) needed to be distributed among the other values. ROADTYPE was increased by 2.07 to 12.07, which is the value of the change (-6) multiplied by the percentage (10 ÷ 29) of the remaining weights subtracted from the original value of the weight. This process can be defined by Equation 3:

$$W_N = W_O - \Delta \frac{W_O}{W_\Sigma - W_V} \tag{3}$$

where $W_N$ = adjusted weight value, $W_O$ = original weight value, $\Delta$ = change in weight, $W_\Sigma$

**Table IV** Modified Values of ADT

| VARYING ADT | -50% | -25% | Original | +25% | +50% |
|---|---|---|---|---|---|
| ADT | 6 | 9 | 12 | 15 | 18 |
| ECON | 3.62 | 3.31 | 3 | 2.69 | 2.38 |
| GEOHAZ | 2.41 | 2.21 | 2 | 1.79 | 1.59 |
| PLOAD | 3.62 | 3.31 | 3 | 2.69 | 2.38 |
| ROADTYPE | 12.07 | 11.03 | 10 | 8.97 | 7.93 |
| ROCK | 4.83 | 4.41 | 4 | 3.59 | 3.17 |
| SEISMIC | 3.62 | 3.31 | 3 | 2.69 | 2.38 |
| SOIL | 4.83 | 4.41 | 4 | 3.59 | 3.17 |
| SUM | 41 | 40.99 | 41 | 41.01 | 41 |
| Per Cent of Original | 100 | 99.975 | | 100.024 | 100 |

= sum of weights, and $W_V$ = weight being changed (i. e. ADT). For this example substitute $W_O = 10$, $\Delta = -6$, $W_\Sigma = 41$, $W_V = 12$. Using these values, $W_N = 12.07$.

These new weight values were then used to determine a new set of priority ratings. This process was repeated 76 times (nineteen weights and four variations each). A program was written in the dBASE programming language to apply the new values of the weights to TEMPWT.PRG and PERMWT.PRG. The results were output to spreadsheet files and the results ordered by their rank for each changed factor.

The method originally tried to evaluated the effect of the changes was to look at the priority ratings directly. This method was unsuccessful. Trends were developed from the results, but it was difficult to attribute the change to any one factor. Viewing the data by the changes in rank from the original gave a better idea of how the changes affected the results. To determine effects of the change, the average change of the ranks in each categories of the access to the road (ACCESSTYPE), the problem type (PROBTYPE), and the type of road (ROADTYPE) were calculated. The changes that were sorted by ROADTYPE were divided into groups based on the responses obtained, Frontage Roads, Interstates, and Two Lane Primary Roads. PROBTYPE was divided into Erosion, Rockfall, Settlement, Slow Debris Flow, and Slow Landslide. ACCESSTYPE was divided into Long Detours, No Detours Required, and Sole Access. These results were then analyzed to find any trends caused by changing the weighting factors listed in Table V.

A trend was identified if the values showed a monotonic variation from the original rank. A zero change in the rating was also noted. Any other variations encountered were defined as no trend. The monotonic variations were identified by the direction of their

**Table V** Trends from parametric study; sorted by ACCESSTYPE.

| FACTOR | LD | NDR | SA |
|---|---|---|---|
| Average Daily Traffic | + | + | - |
| Repair Cost | N | + | - |
| Failure Date | - | 0 | + |
| Economic Impact | - | N | + |
| Failure Frequency | - | 0 | + |
| Geographic Hazard | + | 0 | - |
| Traffic Impedance | N | - | + |
| Pavement Damage | - | 0 | + |
| Permanent Loads | + | 0 | - |
| Problem Type | N | 0 | N |
| Public Risk Potential | - | 0 | + |
| Road Type | N | 0 | N |
| Rock Jointing & Layering | + | N | - |
| Seismic | N | 0 | N |
| Failure Size | N | 0 | N |
| Soil Type & Layering | + | N | - |
| Structure Type & Damage | N | 0 | N |
| Temporary Loads | - | 0 | + |
| Failure Water Level | + | 0 | - |

KEY: + = upward change LD = Long Detours
- = downward change NDR = No Detours Required
N = no trend SA = Sole Access
0 = no change

NOTE: Not enough data points to draw conclusions about NDR.

change. If the average change in rank for the category increased and decreased with the respective increase and decrease of the weight, the trend was taken to be positive. If the change was opposite of the change in the weight, the trend was negative. The results are summarized in Tables V, VI, and VII.

In all of the results there were slight changes as a result of the effect of changing both DATE and FAILFREQ, even though there were no data for these factors. These changes result from the changes applied to the other factors to maintain a consistent total for the sum of the priority ratings. There were also slight changes caused by varying PLOAD and TLOAD, the additional temporary and permanent loads placed on a site, although there were no additional loads from the initial collection of data. Varying these factors caused changes for the same reasons as DATE and FAILFREQ.

The results sorted by ACCESSTYPE included a category for No Detours Required (NDR). There were only two sites that received this response and this category should be disregarded until more data points are acquired. Sites with an ACCESSTYPE of Sole Access should be influenced by factors relating to an economic impact

caused by the failure. Increasing the weights for ECON, FAILFREQ, and IMPEDE all caused a positive change in the priority rating for the Sole Access sites. The same changes should also be seen by the Long Detour sites. Because the majority of the sites were either Sole Access or Long Detour, the Long Detour sites were reduced in rank because of to the

**Table VI** Trends from parametric study; sorted by ROADTYPE.

| FACTOR | F | I | TLP |
|---|---|---|---|
| Average Daily Traffic | N | - | - |
| Repair Cost | + | - | N |
| Failure Date | 0 | + | - |
| Economic Impact | N | - | N |
| Failure Frequency | - | + | N |
| Geographic Hazard | + | - | - |
| Traffic Impedance | + | N | - |
| Pavement Damage | - | N | N |
| Permanent Loads | N | - | N |
| Problem Type | - | + | + |
| Public Risk Potential | 0 | + | - |
| Road Type | - | + | - |
| Rock Jointing & Layering | + | - | N |
| Seismic | 0 | - | + |
| Failure Size | 0 | - | + |
| Soil Type & Layering | + | - | N |
| Structure Type & Damage | - | N | N |
| Temporary Loads | N | + | N |
| Failure Water Level | N | N | N |

KEY: + = upward change F = Frontage Road
- = downward change I = Interstate
N = no trend TLP = Two Lane Primary Road
0 = no change

**Table VII** Trends from parametric study; sorted by PROBTYPE.

| FACTOR | E | R | S | SDF | SL |
|---|---|---|---|---|---|
| Average Daily Traffic | - | N | + | N | N |
| Repair Cost | N | - | - | N | + |
| Failure Date | + | N | - | 0 | 0 |
| Economic Impact | + | N | - | + | - |
| Failure Frequency | + | + | - | + | - |
| Geographical Hazard | N | - | N | - | + |
| Traffic Impedance | + | + | N | N | - |
| Pavement Damage | + | N | + | N | - |
| Permanent Loads | - | - | + | + | N |
| Problem Type | - | + | - | - | - |
| Public Risk Potential | N | + | - | - | N |
| Road Type | - | N | + | N | N |
| Rock Jointing & Layering | N | - | N | - | + |
| Seismic | N | - | N | 0 | N |
| Failure Size | + | N | - | N | N |
| Soil Type & Layering | N | - | N | - | + |
| Structure Type & Damage | N | + | + | + | - |
| Temporary Loads | + | + | - | N | - |
| Failure Water Level | - | N | + | + | N |

KEY:
+ = upward change
- = downward change
N = no trend
0 = no change

E = Erosion
R = Rockfall
S = Settlement
SDF = Slow Debris Flow
SL = Slow Landslide

upward trend of the Sole Access sites.

The results that were sorted by the type of problem (erosion, rockfall, settlement, slow debris flow, or slow landslide) also behaved much as expected. When the weight for PROBTYPE was increased, the sites that had a rockfall showed an upward trend. All of the other sites showed downward trends. The sites with a PROBTYPE of slow debris flow exhibited a downward trend instead of the upward trend expected. This was attributed to having only four data points, two of which did not change rank. None of the other factors caused a discernable trend.

The factors sorted by roadtype were inconclusive due to the lack of variation of the sites. Thirty-five of the sites used for the study were two lane primaries, three were interstate highway, and only two were frontage roads. The sites with a ROADTYPE of interstate showed an upward trend with the when ROADTYPE was changed as expected. When the factor GEOHAZ was changed the trend for frontage roads increased. GEOHAZ is the factor that relating to geographical hazards such as limited sight distances. Frontage roads will generally have more problems like this than will the more heavily travelled interstates and primary roads.

# CONCLUSIONS AND RECOMMENDATIONS

## CONCLUSIONS

The principal objectives of this project were to test and modify the existing USMS. A secondary objective of the project was to make the system easier to use. A pilot study was conducted by collecting the data required for the USMS and using the data to test the system. Errors encountered while operating the system were addressed and corrected. The structure of the programs and databases were changed to accomplish these goals. A study of the weighting factors and their effect on the results of the system was also undertaken.

The major areas of effort in this project were the overall improvements to the system, the collection of data, and the analysis of the results. The improvements to the system included modifying the existing user interface and altering file and program access structure. Error checking was included in both the dBASE and CLIPS programs. Now the system only permits the entry of responses that are recognizable to the CLIPS part of the system. File and program access were modified to expedite execution and to prevent accidental corruption of the source files.

The data collection process was modified from the original method. The original intent of the system was to use the WSDOT's Unstable Slope Inventory (USI) to collect much of the data for the USMS. This information was determined to be insufficient for the USMS. It was thought that all information required for the USMS would be available in the field or in construction and repair documents for each site. To the contrary, many of the sites are in areas lacking extensive geotechnical information. This information was gathered using the geologic maps compiled and published by the Washington State Department of Natural Resources [11]. The information contained in these maps is intended primarily for geologists and do not provide engineering properties for the soils or information about rock jointing and layering. The soil types were determined by correlating the geologic description to the Unified Soil Classification System (USCS). The geologic maps only provide the surficial geology, there is no information on soil layering conditions which can affect the stability of a slope. Because this was the initial collection of data there is no information on actual failures. Therefore, the effects of the failure frequency and the failure date on the results have not been tested.

District 4 was selected to be the site of the Pilot Study due to the wide variety of conditions available. Potential failure sites were identified for many of the conditions the USMS is designed to use. From the results of this study the USMS performed well. Changes made to the data entry part of the system facilitated easier input. As a result, the CLIPS part of the system operated properly. The results showed that the sites with the highest cost and the greatest impact to the public received the highest priority ratings. The sites with the least cost and public impact received the lowest priority ratings.

Change of the weighting factors did not greatly alter the results but instead provided a means of fine tuning them. The sites with the highest or lowest priority ratings were not affected by the change of the weights. Those sites that priority ratings in between these extremes showed changes with the variation of the weights because no one factor greatly influenced their rank. Generally, the changes in rank for the intermediate sites were limited to only a few places up or down.

## RECOMMENDATIONS

### Improvements to the CLIPS Programs

This study did not point out the need for many improvements in the CLIPS programs. Minor improvements might be to incorporate the new features of Version 5.0 of the CLIPS language such as object oriented programming. Object oriented programming allows the programs to "reuse" code. This would allow the CLIPS programs to share common functions such as opening, reading and writing to the input and output files. This would have the effect of reducing the overall size of the programs and allow easier changes to the programs. Currently each program contains the code to for these functions. Another improvement would be to allow the path for the program files to be declared externally to the programs. As the programs now exist, the paths are included in the program code and any changes must be made to the program itself.

The only major improvement to the CLIPS programs may not be possible in the current operating environment (PC-DOS). That would be to compile the programs to an executable form, one that would not require the use of the CLIPS shell. Because of operating system constraints it has not been possible to do this so far.

### Improvements to the Databases

Many of the improvements suggested in the development stage have been accomplished [3]. The system is more user friendly. The USMS now prevents errors by not allowing invalid responses when entering the data. On some computer configurations the system can be run from within dBASE. The only recommendation that was not met was to have the permanent data already stored in the system. This information could contain many of the permanent data factors that are currently entered with the first failure at a site. Information such as ADT, Site Geology, and Road Type for all roads could be entered from existing sources thus eliminating the need for the user to collect and enter that data.

### Improvements to the Overall System

An improvement that can be made to the system is to continue to use it. As more data is collected, the values of the weights can be continued to be refined. Although a total of thirty-nine sites (and forty failure conditions) were used in the pilot study not all of the possible permutations of data were explored. With more variations of data it can be determined if the values for the weights need to be adjusted, if new responses need to be added to the system, or if existing responses need to be deleted from the system.

A major improvement to the system would be to incorporate it with a Geographic Information System (GIS). A GIS is a system that uses data that has been referenced to geographical coordinates to produce spatial relationships [11]. This would allow the USMS to produce maps indicating failures sites. The GIS allows the user to look at the data in a variety of ways. For example the user could sort data based on failure type, priority rating, or within a certain radius of a point. The user could also display only those sites that meet any or all of those conditions. The conditions are only limited by the data available. Using a GIS would also automate much of the permanent data entry. Permanent data such as the geologic maps, seismic zonation maps, and road location maps could be stored in the GIS. When a site is entered, the user would only need to enter the highway number and the mile post. The maps could then be automatically overlaid and the permanent data collected.

Incorporating a GIS would require a change in computer platform from the personal computers now used to an engineering workstation to achieve best performance. However, this would eliminate the constraints imposed on the CLIPS programs by the PC-DOS operating system. Most work stations operate under the UNIX operating system for which the CLIPS software was originally developed. The programs would be able to be compiled to executable form. There are versions of dBASE available for the UNIX system as well. All of the dBASE programs would need to modified. The conversion to a new system would be fairly easy. Before any change occurs a analysis of the costs and the benefits of such a change should be weighed carefully.

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# APPENDIX A: USER'S GUIDE

## INTRODUCTION

The USMS is comprised of two parts: the database; and the CLIPS programs. The database part of the system contains the programs that allow data entry and manipulation and the databases themselves. The CLIPS part of the system contains the programs that determine the priority ratings. The USMS works by alternating between these two parts. The entire system is controlled through the dBASE programs.

The USMS operates by the use of permanent and temporary data types. Permanent data are defined as data that will most likely not change over time, such as soil types or geology. Temporary data are data that will be unique for each failure occurrence, such as failure size or failure date. These data type variables are listed in Tables A.I and A.II. These data are stored in the temporary and permanent databases TEMPORAR.DBF and PERMANEN.DBF. The CLIPS programs process the data according to the data type. These programs are listed in Tables A.III and A.IV.

## INSTALLATION

### System Requirements

The USMS is designed to be run on an IBM compatible Personal Computer with a hard disk of at least 20 megabytes of storage. The USMS also requires dBASE IV loaded into the system. To run the CLIPS programs from within the dBASE part of the program, MS-DOS version 5.0, the computers operating system, is strongly recommended for use of the system. At least 2 megabytes of Random Access Memory (RAM) is recommended.

**Table A.I** Temporary Data Variables

| Description | Variable Name in CLIPS Program |
|---|---|
| Road Impedance | ROAD-IMPEDE |
| Paved Detours Available? | DETOURS |
| Public Risk Potential | DAMAGE-TYPE |
| Failure Type | PROBLEM-TYPE |
| Pavement Damage | PAVEMENT-DAMAGE |
| Structure Type | STRUCTURE-TYPE |
| Structure Damage | STRUCTURE-DAMAGE |
| Static Loads? | STATIC-LOAD |
| Static Loads Location | STATIC-LOAD-LOCATION |
| Dynamic Loads? | DYNAMIC-LOAD |
| Dynamic Loads Location | DYNAMIC-LOAD-LOCATION |
| Current Date | CURRENT-MONTH |
| | CURRENT-DAY |
| | CURRENT-YEAR |
| Failure Date | FAILURE-MONTH |
| | FAILURE-DAY |
| | FAILURE-YEAR |
| Repair Cost | COST |
| Failure Volume | FAIL-SIZE |
| Failure Water Level | WATER-LEVEL |

**Table A.II** Permanent Data Variables

| **Description** | **Variable Name in CLIPS Program** |
|---|---|
| Acceleration Coefficient | ACCELERATION-COEFFICIENT |
| Road Type | ROAD-TYPE |
| ADT | ADT |
| General Soil Composition | COMPOSITION |
| Major Soil Type | PRIME-SOIL-TYPE |
| Minor Soil Type | SECOND-SOIL-TYPE |
| Soil Layering? | LAYERS |
| Top Layer Soil Type | TOP-SOIL |
| Lower Layer Soil Type | LOWER-LAYER |
| SPT | SPT |
| Loose Rock? | LOOSE |
| Intact Rock? | HOMOGENEOUS-INTACT |
| Rock Joints? | JOINTS |
| Rock Layers? | LAYERS |
| Access Type | PROBLEM TYPE |
| Population | POPULATION |
| Static Load? | STATIC-LOAD |
| Static Load Location | STATIC-LOAD-LOCATION |
| Time Static Load Applied | STATIC-LOAD-TIME |
| Static Load? | STATIC-LOAD |
| Static Load Location | STATIC-LOAD-LOCATION |
| Time Static Load Applied | STATIC-LOAD-TIME |
| Geographical Hazard | GEOGRAPHY-HAZARD |

**Table A.III** Temporary CLIPS Programs

| **Description** | File Name |
|---|---|
| Failure Type | PROBTYPE.CLP |
| Traffic Impedance | TRIMPEDE.CLP |
| Public Risk | PUBRISK.CLP |
| Pavement Damage | PAVEDAM.CLP |
| Structure Type and Damage | STRUCTUR.CLP |
| Temporary Loads | TEMPLOAD.CLP |
| Failure Frequency | FAILFREQ.CLP |
| Repair Cost | COST.CLP |
| Failure Size, Water Level, and Date | FSIZE.CLP |

**Table A.IV** Permanent CLIPS Programs

| Description | **File Name** |
| --- | --- |
| ADT and Road Type | ADTROADT.CLP |
| Economic Impact | ECONIMPO.CLP |
| Geographical Hazards | GEOHAZ.CLP |
| Soil Classification | DIRT.CLP |
| Rock Classification | ROCK.CLP |
| Seismicity | EQUAKE.CLP |
| Permanent Loads | PERMLOAD.CLP |

Both the dBASE and CLIPS programs require large amounts of memory to run. Under previous versions of MS-DOS, some of the memory is required for the operating system. MS-DOS 5.0 with extra RAM allows the operating system to be loaded into upper memory, freeing up extra memory for the USMS. For further information see the operating system manuals for your system.

**Installation of dBASE IV**

dBASE IV must be installed for the USMS to run. To install dBASE, follow the instructions in the software manuals. It is recommended that some form of *disk caching* be used. This will speed up the operation of the system greatly. dBASE comes with its own disk cache that should be installed if you are not using DOS 5.0. DOS 5.0 also provides a disk cache, SMARTDRIVE, that yields much better performance than the one supplied with dBASE. It is recommended that SMARTDRIVE be used in place of the dBASE disk cache.

To install dBASE follow the instructions in the installation program. You do not need the tutorial programs unless you wish to learn more about dBASE itself. Make sure that you modify your AUTOEXEC.BAT file to place the directory where you installed dBASE into the path statement. This is necessary to be able to run dBASE from the directory where the USMS files are located. If there are any problems loading dBASE, refer to the dBASE or DOS manuals.

**Installation of the CLIPS Program**

To install the CLIPS programs, insert the CLIPS program disk 1 into the floppy disk drive of your computer (either A: or B:). At the DOS command line type:

A:install (or B:install) <RETURN>

This will start the CLIPS installation program. The CLIPS programs are compressed to take less space on the distribution disks, so you cannot copy the programs directly. The installation program will display a screen asking what part of the program you wish to install. The USMS requires only the command line executable. Using the arrow keys, move the highlight to *Install Command Line Executable*. The program will ask for the directory the program is to be installed. At the *Enter Destination* prompt type

C:\CLIPS <RETURN>.

If you wish to install the CLIPS programs to another drive or directory you will have to make changes to two of the dBASE programs and to all of the CLIPS programs. This is discussed in the following section. A path statement is not required for the CLIPS programs.

**Installation of the USMS**

To install the USMS programs onto the computer you must first create two new directories, USMS and CLIPSFIL. To do this from the DOS prompt (C:\>) type:

md usms <RETURN>

md clipsfil <RETURN>

<RETURN> indicates pressing the enter key on the keyboard. Also note that DOS does not care if you enter the command in uppercase or lowercase. This creates the directories where

the USMS programs will be located. For help on creating the directories consult your DOS manuals.

To install the dBASE part of the program you must copy the files from the USMS disk "USMS dBASE Files". Assuming you are using disk drive A:, insert this disk into the floppy disk drive in your computer. If you are using drive B: substitute B: for A: below. Change to the USMS directory by typing

cd\usms <RETURN>

and copy the files

copy a:*.* <RETURN>

Now change to the CLIPSFIL directory by typing

cd\clipsfil <RETURN>

Insert the disk labeled "USMS CLIPS Files" into the floppy disk drive. Type

copy a:*.* <RETURN>

The USMS files are now installed.

**Installing to a Different Drive or Directory**

If the USMS was installed on a different drive than recommended, you must change several files. This is necessary because the CLIPS programs look for their data in the directory C:\CLIPSFIL\. The dBASE programs INPUT.PRG and OUTPUT.PRG also read and write data to this directory. To change these programs you need to open each of the clips programs listed in Tables A.III and A.IV and change the drive specification. Using a text editor or word processor, search for any occurrences of c:\\clipsfil\\...

change this to the drive and/or directory that you have installed the system to. It is **very** important that the format of these statements remains **exactly** as shown above. For example if you loaded the CLIPS programs into *d:\otherdir* you must change the CLIPS programs to read *d:\\otherdir* or else the programs will not run. Also make sure that these commands are typed in **lowercase**.

To change the dBASE programs INPUT.PRG and OUTPUT.PRG change to the USMS directory and open these files with a text editor or word processor. Change all occurrences of *c:\clipsfil\...* with the correct drive and directory. Also open the file CLIPS.BAT and change the lines *cd\clips* to the directory where CLIPS is installed.

**NOTE:** **If using a word processor, the files must be saved in ASCII format, not in the word processor's format!**

Now that the files have been updated they must be reformatted for the CLIPS shell. To do this, from the DOS prompt type the following

cd\clips <RETURN>

clips <RETURN>

there will now appear a new prompt on the screen.

CLIPS>

This prompt indicates that you are in the CLIPS shell. Type the following **exactly** in lowercase:

(batch "d:\\otherdir\\clp2bin.clp") <RETURN>

if an error message appears, type this again. If the program seems to do nothing, try entering a parenthesis or double quote and pressing enter. This program converts the files to a format that runs faster in the CLIPS shell. When this program is completed, type

(exit) <RETURN>

You should now see the DOS prompt again. You are now ready to enter the USMS.

## OPERATING THE USMS

To run the USMS, switch to the directory containing the dBASE programs (c:\usms) by typing

cd\usms <RETURN>.

Type

usms <RETURN>

from the DOS prompt. This enters you into dBASE and calls up the main program, MAINMENU.PRG. A screen appears with the dBASE license agreement. Press return. You should now see a screen like Figure A.1. The main menu gives access to the functions of the USMS.

```
USMS                     MAIN MENU               12 August 1992

     1            User Instructions

     2            Temporary Database Menu

     3            Permanent Database Menu

     4            Add a New Site

     5            Create Input Files for the CLIPS Program s

     6            Run CLIPS Programs

     7            List/Print the Priority Ratings (Menu)

     Q            Quit
```

**Figure A.1** USMS Main Menu

## 1 User Instructions

The User Instructions for the USMS can be seen if number 1 is selected from the Mainmenu. These instructions are a description of the USMS and a guide to the operation and are not intended to replace the User Guide. Pressing any key allows the user to view the instructions. After the instructions have been shown, the user is returned to the Main Menu.

## 2 Working with the Temporary Database

This option leads to another menu (Figure A.2) and allows the user to add or delete a new failure to a site that already exists or edit temporary failure information (Repair Cost, Damage, Failure Conditions, or Temporary Loads). Using this option assumes that the site already has permanent data stored for that SITE ID.

## 3 Working with the Permanent Database

This selection also leads to another menu (Figure A.3) and allows the user to edit permanent data for a site or delete a site entirely. A site can also be added through this option, although there will be no temporary data associated with it.

## 4 Add a New Site

This option adds a new site to the USMS. Both the temporary and permanent data are entered with this option. This option should not be used to enter new failure data to and existing site. That should be accomplished using the Working with the

```
TEMPORARY DATA MENU

A    Add a New Failure
D    Delete a Record from the Temporary Datab ase
E    Edit a Record in All Categories
1    Edit the Repair Cost Information
2    Edit the Damage Information
3    Edit the Failure Condition Information
4    Edit the Temporary Load Information
R    Return to the Main Menu
```

**Figure A.2** Temporary Database Menu

| PERMANENT DATA MENU | |
|---|---|
| A | Add a New Site |
| D | Delete a Record from the Permanent Datab ase |
| E | Edit a Record in All Categories |
| 1 | Edit Site Identity Information |
| 2 | Edit Site Geology Information |
| 3 | Edit Permanent Load Information |
| R | Return to the Main Menu |

**Figure A.3** Permanent Database Menu

Temporary Database.

**5 Create Input Files for the CLIPS programs.**

This selection creates the files necessary for the CLIPS programs to run. This option first performs a routine to cleanup the databases of records with a SITE ID that is less than or equal to zero. Since the SITE ID is based on the Sign Route Number and the Mile Post, this should remove any unwanted "data" that may appear in the database files. The data could create errors when importing the data and calculating the Total Priority Rating. The program then exports the data as ASCII files for use by the CLIPS programs.

All data that was previously exported to the CLIPS programs will be over written with the current data. Once the data has been exported, the CLIPS programs can be run.

**6 Run CLIPS Programs**

This option runs the CLIPS programs, using the data exported in option 5. This option will shell out of the dBASE programs and run the CLIPS programs. When this option is selected, a message will appear on screen informing the user that "this will take a while!". The screen will then blank and the CLIPS programs will run. During this stage, do not interrupt the system as the results could be unpredictable. Depending on the speed of the computer and the size of the databases, this could take ten minutes or longer. To inform the user when the programs are complete, the computer should "beep". The user will be returned to a screen that has a period (.) in the lower left corner. Press any key to be returned to the Main Menu.

There may be problems with this option. If the screen blanks and lines appear saying

MEMORY ERROR

DEALLOCATING MEMORY

there are several things that can be tried. Exit the USMS by typing Q. This returns you to the dBASE Dot Prompt. Type

quit <RETURN>.

This brings you back to DOS. Re-enter the USMS and try option 6 again. If this error message still occurs, there is not enough memory available to dBASE and CLIPS for both to run at once. Try to release as much memory as possible by temporarily removing any Terminate and Stay Resident (TSR) programs loaded. You can also remove the mouse driver (if available) by typing

mouse off <RETURN>

at the DOS prompt before entering the USMS.

If all of these options fail, the CLIPS programs can be run from outside dBASE. To do this exit the USMS and dBASE. From the DOS prompt in the USMS directory type

clips <RETURN>.

This invokes the same batch file that dBASE uses to run the CLIPS programs. This will take as long to run as before (ten minutes or more). The system will "beep' to let the user know when the CLIPS programs are completed. Re-enter dBASE by typing

usms <RETURN>

from the DOS prompt.

**7 List/Print the Priority Ratings**

This selection allows the user to import the output from the CLIPS programs and calculate the priority ratings for the sites. This option leads the user to another menu (Figure A.4)

**Q Quit**

This selection quits the USMS program, returning the user to the dBASE dot prompt. To exit dBASE from the dot prompt, type

quit <RETURN>.

This returns the user to the operating system.

## TEMPORARY DATABASE MENU

The Temporary Database Menu (selection 2) allows the user to add, edit, or delete data in the temporary database. Data may be edited for each site by groups of repair cost, damage, failure conditions, or loads. Data may also be edited in all of the categories at once.

**A Add a New Failure**

OUTPUT (PRIORITY RATINGS)MENU

| | |
|---|---|
| D | Delete Old Data to Import New Data |
| F | Import the Data from CLIPS Files |
| 1 | Display/Print Temporary Priority Ratings |
| 2 | Display/Print Permanent Priority Ratings |
| 3 | Calculate & Print the Total Priority Rat ings |
| R | Return to the Main Menu |

**Figure A.4** Output Menu

By selecting Add a New Failure, the user can enter information for a failure at an established site. This assumes that the site has a previous failure that was entered into the USMS. Use of this option will not detect the absence of corresponding permanent data for a previous failure. There will be no harm the system in any way but when the Total Priority Rating is calculated, there will be errors because of the lack of permanent data.

**D Delete a Record from the Temporary Database**

This option allows the user to delete a failure from the temporary database. Use this option to delete a failure for a site with multiple failures. To delete a site entirely, delete all sites with the same Site ID from both the temporary and permanent databases.

**E Edit a Record in all Categories**

This option edits records in all categories listed below, stepping through each of the editing screens. This is useful for really big mistakes.

**1 Edit Repair Cost Information**

This option edits the repair cost information for a site. The only information required for this category is the total repair cost, the other categories are optional. The information for man hours, repaving cost, etc. are included in case that information is available and assists in tracking the costs associated with that failure.

**2 Edit Damage Information**

This selection allows editing the Damage Information for a site. This includes the problem type, pavement damage, road impedance, if detours are available, structure type and damage, and public risk information.

**3 Edit the Failure Condition Information**

This option edits the Failure Condition information for a site. Failure conditions include water levels, failure date, and failure size for each failure.

**4 Edit the Temporary Load Information**

Allows editing of the information supplied for temporary static and dynamic loads for each site. Temporary loads are those static and/or dynamic loads that are applied on or near the site

**R Return to Main Menu**

This option returns the user to the main menu.

## PERMANENT DATABASE MENU

This menu accesses the information contained in the permanent database. Permanent data can be entered, edited, or deleted in the same way as for the temporary databases.

**A Add a New Site**

This allows the user to add a new site without entering any temporary data. This option should be used with caution. If the system is run, the sites with no temporary data will have erroneous priority ratings. This can be checked by looking for priority ratings with no failure number.

**D Delete a Record from the Permanent Database**

Deletes a site from the permanent database. Should only be used in conjunction with deleting record from the temporary database to remove a site.

**E Edit a Record in all Categories**

This option lets the user edits records in all of the categories listed below.

**1 Edit Site Identity Information**

This option allows the editing of the information that defines a site. This includes the Road Number, Mile Post, Side of Road, District, County, Road Type, ADT, and the Access Importance of the Road.

**2 Edit the Geology Information**

This selection allows the editing of the information for the geology of the site including the Soil Type and Layering, Rock Classification, Seismic Acceleration Coefficient, and Geographical Hazards. Geographical hazards are hazards related to the geography of the site.

**3 Edit Permanent Load Information**

This option lets the user edit the permanent static and dynamic load information for the site. The permanent loads are those static and dynamic loads that are on or near the failure site and their time of application.

**R Return to Main Menu**

Selecting this option returns the user to the Main Menu.

## EXAMPLE OF ADDING A NEW SITE

To add a new site from within the USMS follow the following procedure. From the Main Menu, select *4 Add a New Site*. A form appears on screen asking for information relating to the cost information for the site. First, enter the Site ID and the Failure Number. Generally the Site ID is a Sign Route number and the milepost. A site on SR-6 at milepost 43.2 would have a Site ID of 60432, a site on SR-101 at milepost 102.0 would have a Site ID of 1011020. Next the information for the repair cost is requested. The fields for the man-, equipment-, earthwork-, and replacement- hours and cost are optional. If that information is not available press the enter key until the cursor is on the field for the Total Cost. Enter an estimate, in dollars, for the total repair cost for the site. This information is mandatory in order for the system to calculate a priority rating for that site. Press enter to continue to the next screen.

The next screen asks for information related to the damage at the site. The first field asks for the problem type. Press the space bar to cycle through the selections. See Table A.V for valid responses for the Damage information. On reaching the desired selection, press enter. The choices available to the system are limited to those listed, due to the constraints of the CLIPS part of the system.

The rest of the fields on this screen are selected in a similar fashion (Tables A.VI and A.VII). The next field is for the pavement damage. This field can only be selected if the choice for the problem type is settlement or erosion. The default value is *NONE*. The user then can select the type of road impedance that the failure has caused . The response *Three Quarter-Half* refers to a road that is three quarters to one half closed, and so on for the other responses. The structure type fields are similarly filled in using the responses in Table A.VII. All of these responses are selected by pressing the space bar until the proper response

**Table A.V** Valid Responses for Problem Type

| **Field** | **Valid Responses** |
|---|---|
| Problem Type | Erosion |
| | Slow Debris Flow |
| | Fast Debris flow |
| | Slow Landslide |
| | Fast Landslide |
| | Piping |
| | Rockfall |
| | Wave Action |

**Table A.VI** Valid Responses for Road Information

| **Field** | **Valid Responses** |
| --- | --- |
| Pavement Damage | None |
| | Low |
| | Moderate |
| | Severe |
| Road Impedance | None |
| | Road Closed |
| | One Way Traffic |
| | Three Quarters-Half Closed |
| | Half-Shoulder Closed |
| | Shoulder Closed |
| Paved Detours Available? | Yes |
| | None |

**Table A.VII** Valid Responses for Structure Damage and Public Risk

| **Field** | **Valid Responses** |
|---|---|
| Structure Type | Bridge |
| | Commercial |
| | Home |
| | Railroad |
| | Toxins |
| | Utilities |
| | None |
| Structure Damage | None |
| | Differential Settlement |
| | Unusable |
| | Unusable 1 Month |
| | Unusable 1 to 3 Months |
| | Unusable more than 3 Months |
| | Restrict Use |
| Risk Type | High Personal |
| | Low Personal |
| | Toxins |
| | Property |
| | None |

appears and then press the enter key.

The next screen asks for the conditions of the site at failure. The water level is the ground water level at the time of failure. This response is subjective, a response of 0 for a very low level, 10 for a very high level. The failure date is also entered on this screen. An estimated failure volume, in cubic yards, is also entered. This helps determine the magnitude of the failure.

The next screen asks for the Temporary Static and Dynamic Loads. These responses are also entered by pressing the space bar. Each category asks if there is a load and if so the location with respect to the site.

The Site Identification screen asks for information to identify the site. It asks for the Road Number, Mile Post, and the side of the road the failure is on. The Road Type (*Interstate, Multilane, Two Lane Primary, Frontage or Gravel*), ADT, and the access importance of the road to the community. The population of the affected area is also requested.

The next two screens ask for information relating to the geology and geography of the site. First the system needs to know about the soil composition. Is the soil cohesive, cohesionless, of a similar type, or even if there is soil? The soil types are then requested. The primary soil constituent is the type of the majority of the soil, the secondary soil constituent is the rest. These are given in terms of the Unified Soil Classification System (USCS). The orientation to the soil layers (if any) is also requested. If the soil is layered the USCS of the layers is needed. These are all entered by cycling through the list of valid responses by pressing the space bar. The Standard Penetration Test (SPT) blowcount is also requested. If the SPT is not available enter a value of -99. The second screen asks for the same type of information for any rock at the site. Again, cycle through the choices with the space bar. The Seismic Acceleration Coefficient is from the map by Higgins, et. al. [10]. The Geographical Hazards are related to the area of the failure site. See Table A.VIII for a list of these hazards.

The final screen asks for the Permanent Loads. These are very similar to the Temporary Loads, with the addition of the fields for the time that the load has been applied. For both the Static and Dynamic Loads, the valid responses are none, new and old.

After the information has been entered the user is returned to the Main Menu. More data can be entered or the existing data can be output to the CLIPS part of the USMS. To output the data, select *5 Create Input Files for the CLIPS Programs*. This will "clean" the databases of zero records and create the text files for the CLIPS programs. When the files have been created, select *6 Run CLIPS Programs* from the Main Menu. This will run the CLIPS part of the system. When the CLIPS programs are finished (ten minutes or so) the files need to be imported back into dBASE. Select *7 List/Print the Priority Ratings (Menu)* from the Main Menu.

From the Output Menu first select *D Delete old data to import new data*. This removes the data from previous runs of the USMS. To import the files select *F Import the data from the CLIPS files*. This brings the files into a form that dBASE can use. Now you can either list and print the Priority Ratings from the Permanent or Temporary databases or

**Table A.VIII** Valid Responses for Geographical Hazards

| **Field** | **Valid Responses** |
|---|---|
| Geographical Hazards | None |
| | Blind Curve 2 Directions |
| | Blind Curve 1 Way |
| | Water Body Large 1 Side |
| | Water Body Large 2 Sides |
| | Water Body Small 1 Side |
| | Water Body Small 2 Sides |
| | Cliff 1 Side |

calculate the Total Priority Rating. Select the option of your choice. When the Priority ratings are calculated you can return to the Main Menu and exit the USMS. from the Main Menu select *Q Quit*. This brings you to the dBASE "dot prompt". Type

quit <RETURN>

and you are returned to the world of MS-DOS.

## APPENDIX B: INFORMATION REQUIRED FOR USMS

**Information Required for USMS**

Site ID ____________
Failure Number __________

Ground Water Level __________
*(1 = Extremely Low, 10 = Extremely High)*

Failure Date ___________ *(mm/dd/yy)*
Failure volume ____________ *cubic yards*

**Repair Cost**

| | | | |
|---|---|---|---|
| Man Hours | __________ | Cost/Hr | __________ |
| Equipment Hours | __________ | Cost/Hr | __________ |
| Earthwork Hours | __________ | Cost/Hr | __________ |
| Repavement Hours | __________ | Cost/Hr | __________ |

Problem Type ____________________
*(Erosion, slow debris flow, fast debris flow, slow landslide, fast landslide, piping, rockfall, wave action, settlement)*

Pavement Damage ____________________
*(low, moderate, severe, none)*

Road Impedance ____________________
*(none, road closed, one way traffic only, 3/4 to 1/2 road closed, 1/2 to shoulder closed, shoulder closed, none)*

Paved Detours Available? _____________ *(yes, no)*

Structure Type __________________
*(Bridge, Commercial, Home, RR, Toxins, Utilities, None)*

Structure Damage ___________________
*(Demolished, Differential Settlement, Unusable, Unusable 1 month, Unusable 1 to 3 months, Unusable 3 months, Restrict use, None)*

Public Risk ____________________
*(High personal, Low personal, Toxins, Property, None)*

**Temporary Loads**

Static Loads ________ *(yes, no)*

Location ____________________
*(near site, on site, on-near site, none)*

Dynamic Loads ________ *(yes, no)*

Location ____________________
*(near site, on site, on-near site, none)*

Road Number ______

Milepost ______

Side of Road ______ *(N, S, E, W)(L, R)*

District __________

County __________

Road Type ______________
*(Interstate, Multilane, Two-lane Primary, Frontage)*

ADT _________ *(Average Daily Traffic count)*

Access Importance of Road ____________________
*(sole access, long detours, no detours available)*

Population _____________

Site ID __________ Failure Number ______

**Soil Classification**

Overall Soil Composition _______________
*(similar, cohesive, cohesionless, none)*

Primary Soil Constituent _______________
*(Use USCS classifications)*

Secondary Soil Constituent _______________
*(Use USCS classifications)*

Orientation of layers ___________________
*(none, down-slope dip, cross-slope dip, horizontal)*

USCS of top layer ____________
*(none, USCS classification)*

USCS of lower layer ____________
*(none, USCS classification)*

Loose Rock ____________ *(none, gravel, boulders)*

Rock intact? _________ *(yes, no)*
Orientation of rock joints ___________________
*(none, down-slope dip, cross-slope dip, horizontal, vertical)*
Orientation of layers _________________
*(none, down-slope dip, cross-slope dip, horizontal, vertical)*
Seismic Acceleration Coefficient ___________
*(from WSDOT seismicity map)*

Geographical Hazards _____________________
*(none, water body small 1 side, water body small 2 sides, water body large 1 side, water body large 2 sides, cliff 1 side, blind curve 1 direction, blind curve 2 directions)*

**Permanent Loads**
Static _____ *(yes, no)*
Location ________ *(near site, on site, on-near site, none)*
Application time _____ *(new, old, none)*
Dynamic _____ *(yes, no)*
Location ________ *(near site, on site, on-near site, none)*
Application time _____ *(new, old, none)*