Development of an Unstable Slope Management System

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16. ABSTRACT

This report presents a prototype of an Unstable Slope Management System (USMS) and corresponding user's guide. The USMS is a computer program that prioritizes unstable slopes. The system is composed of two parts: a database, and priority programs. The database was developed using dBASE III Plus, Ashton-Tate. The priority programs were developed using the expert shell system CLIPS, a NASA developed language. The resulting USMS, at this point, is not an expert system; it is a management system. The USMS was developed by the aid of conversations with Washington State Department of Transportation (WSDOT) personnel. In addition, a questionnaire was sent to WSDOT personnel concerned with unstable slope maintenance. From the conversations and responses to the questionnaire, the factors concerned with site importance were identified. Also, a method to determine the total importance was proposed. The USMS identifies factors that determine the importance of a failure site. These factors pertain to the cause of instability, cost of repair, use of road, and safety to motorists. Data pertaining to these factors is collected for each failure site and stored in the database. Priority ratings are assigned by the priority rating programs to the data for each site. The priority ratings are multiplied by a weight. The sum of the products represents the total priority. The total priority is a number from 0 to 100, 100 indicates the highest importance. The total priority represents the importance of the failure site based on the factors identified in the USMS. The total priority of a failure site is independent of all other failure sites.

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DEVELOPMENT OF AN UNSTABLE SLOPE MANAGEMENT SYSTEM

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SUMMARY

A prototype of an Unstable Slope Management System (USMS) and corresponding user's guide was developed. The USMS is a computer program that prioritizes unstable slopes. The system is composed of two parts: a database and priority programs. The database was developed using dBASE III Plus, Ashton-Tate. The priority programs were developed using the expert shell system CLIPS, a NASA developed language. The resulting USMS, at this point, is not an expert system; it is a management system.

The USMS identifies factors that determine the importance of a failure site. These factors pertain to the cause of instability, cost of repair, use of road, and safety to motorists. Data pertaining to these factors are collected for each failure site and stored in the database. Priority ratings are assigned by the priority rating programs to the data for each site. The priority ratings are multiplied by a weight. The sum of the products represents the total priority. The total priority is a number from 0 to 100, 100 indicates the highest importance. The total priority represents the importance of the failure site based on the factors identified in the USMS. The total priority of a failure site is independent of all other failure sites.

INTRODUCTION

Slope Stability has been a concern for the Washington State Department of Transportation (WSDOT) for many years. Unstable slopes can cause millions of dollars of damage to state roads and can endanger the lives of motorists. Of all natural catastrophes, such as hurricanes, tornadoes, or floods, slope failures are usually the least spectacular and least costly. Yet, they are more wide spread over the country and, cumulatively, may cause more loss of life and property damage than any other hazard (1). In 1978, it was thought that a reasonable estimate of the annual cost of slope failures in the United States was one billion dollars. This estimate included the costs of damage to buildings and their sites, and corresponding indirect costs (2).

BACKGROUND

The Washington State Department of Transportation spends millions of dollars each year to repair damage caused by slope failures. These slope failures vary from a few rocks falling on to the highway, which only requires a work crew a few minutes to remove, to a major landslide, that may require months of work and millions of dollars to correct. Some slopes fail year after year; others fail once in 50 years. Since slope instability is a significant problem, the quest for a systematic and logical approach to determine a cost efficient repair schedule of the failures began.

PROBLEM STATEMENT

In order to determine a cost efficient repair schedule and strategy, WSDOT decided to develop an Unstable Slope Management System (USMS). The intent of this system is to collect data on each slope that fails within the state, then assign a *priority rating* to that failure site. In order for the USMS to be useful, the *priority ratings* for each slope must be determined in a systematic manner based upon consistent *factors* for each slope. This *priority rating* will then represent the importance of that particular site. By use of *priority ratings* and repair costs a systematic, knowledge based maintenance program can be developed.

RESEARCH APPROACH

The intent of this project was to develop a prototype USMS. The main focus of this project was concerned with the methodology of developing the USMS. In order to accomplish this task, the *factors* that influence a failure sites importance were identified. The relative importance of these *factors* had to be determined as well.

The USMS is composed of two main parts: the database and the *priority rating* programs. The database was created using dBASE III Plus (3). The *priority rating* programs were created using the expert system shell CLIPS version 4.3 (4). In order to run the system, the user enters the main program in the database program so that data can be entered. Once the data are entered, the information is converted into several DOS text files, which are the input files for the CLIPS programs. After this step is completed, the user leaves the database program and then executes the main CLIPS program to calculate priorities for the individual *factors* considered in the rating of slopes. Once all of the priorities are calculated, the user reenters the main database program, converts the CLIPS output files to dBASE files, and then calculates the *total priority rating*. The *total priority rating* is a number from 0 to 100, 100 being the highest priority. This rating is independent of all other failure sites.

DEVELOPMENT OF USMS

The development phase of the Unstable Slope Management System involved two parts. One part was to determine the *factors* that influence the importance of the slope. The next part was to determine the computer software programs that the USMS would use. WSDOT wished to have a system that would allow them to store and organize data on each site. This information would then be used to determine the importance of the sites and the order in which the sites should be repaired. In order to accomplish this task it was decided that an expert system shell and a database system should be employed to create the system.

METHODOLOGY OF DETERMINING THE IMPORTANCE *FACTORS*

Before any actual programming could begin it was necessary to determine what *factors* are involved in the determination of the importance of a slope. This was quite a difficult task because practically none of the personnel at WSDOT involved in slope maintenance had ever thought about it before.

In order to determine these *factors*, a questionnaire (Appendix CC) was developed and sent to various WSDOT personnel to answer. The purpose of the questionnaire was to confirm the role of previously chosen *factors* and to identify additional *factors*. The questionnaire asked that the identified *factors* be rated. The proper responses to these *factors*, also, had to be identified and rated. The rating system was based from 1 to 10, where 10 represents the most important or critical case.

The questionnaires were sent to over fifty people that were thought to be involved in slope maintenance and repair. Eighteen responses were received. The low response numbers were probably because the questionnaire was too long and too complicated for most to answer. As a result the questionnaire proved to be quite ineffective as a technique to determine the *priority rating* values for *factors* and their responses. The cumbersomeness of the questionnaire, and the resulting responses did not enable the researchers to glean *factors* and corresponding *priority ratings* to be used in, or an approach to, the development of a management system. The most useful aspect of the questionnaire was the process of its development. During the creation of the questionnaire, several conversations were conducted with WSDOT personnel: Alan Kilian (Chief Geotechnical Engineer), Steven Lowell (Cheif Engineering Geologist), and Keith Anderson (Federal Programs Manager). From these conversations some of the *factors* that were deemed to be important to the decision making process were identified. Many ideas on the *factors* concerned with cost and safety were taken from Washington State's pavement management system. See the Slope Importance Decision *Factors* section for further information about these *factors*.

After the importance *factors* were determined, a quantitative and consistent method for determining the importance of each unstable slope had to be determined. The method decided upon uses a numeric rating system. *Priority ratings* are assigned to each *factor* response. These *priority ratings* are then multiplied by a corresponding weighting factor. The resulting numbers are then added. This final number is referred to as the *total priority rating*. The *total priority rating* represents the importance of the slope and is independent of the other slopes.

The *factors* are discussed in greater detail in the Slope Importance Decision *Factors* section. The weights were determined subjectively and are listed in Appendices

W and X. The sum of the weights equals 100.

SOFTWARE CHOICE

After the *factors* and the rating method had been determined, it was possible to begin programming. At this stage it was necessary to determine which programming techniques and software were to be used. At the initial stages of the development of this project it was decided that, eventually, the final system should be an expert system. It was felt that an expert system would be a flexible and appropriate solution. Also the problem of developing an USMS was a task well suited for an expert system to solve. Unstable slope management is a problem that is not too difficult to solve. It deals with a relatively small specialty area. It can, with time, be clearly defined. Also WSDOT has made quite a strong commitment to this project and will be able to continually improve the system. Therefore the problem meets the criteria for the use of an expert system.

In order to develop the system, a building framework or *shell* was used. Choosing a specific *shell* to use was a difficult task because the specific size and required capabilities of the final system were not known. In fact, it is still not known what the final program will consist of; it may take several revisions to achieve the desired system.

Even though many specifics of the USMS were not initially known, there were a few requirements that were known. First of all, it was known that the system would have to be IBM PC compatible and would have to be able to interact with other software programs. Since the scope of project was not known, it was assumed that the *shell* would also need to have a large rule capacity. The cost of the *shell* was also a constraint. Finally, it was assumed that the system would eventually be able to suggest a repair schedule.

There are many expert *shell* packages on the market today that would have satisfied the known criteria, (5). In the end, a *shell* developed by NASA called CLIPS (4) was chosen. CLIPS was recommended by a computer science professor at the University of New Mexico, Dr. George F. Luger, who was at the time assisting in the creation a pavement management system for the State of New Mexico. CLIPS is written in the computer programming language C. This gives the user the option to write additional programs or modify the existing code in the system, if it is so desired. Another advantage of CLIPS is the fact that it was developed and is maintained by NASA, suggesting that there will be future support and revisions of the program. NASA also offers a good support system, including a help line, for CLIPS. A big advantage of CLIPS over other systems is the cost. CLIPS is free to all government agencies and has no royalty fees.

In addition to an expert system, a database system had to be chosen. The database system that was used was dBASE III Plus. This software was chosen because of existing familiarity with the system. It is also a fairly popular and commonly used system. dBASE is a user friendly system that is fairly easy to learn to use and to create programs in. It has the capability to sort data in many ways and offers a convenient way to enter and store data. dBASE also has the capability to convert its data files to DOS text files, which can then be used as input files for CLIPS. Likewise, dBASE can convert DOS text files to dBASE files.

The USMS as it exists now is not an expert system and could have been created using only dBASE. CLIPS, however, was used because it is anticipated that the final USMS will be an expert system. This will mean that the system will provide an explanation facility and allow the user to interact with the system during the decision making process. It is hoped that future versions of the USMS will resemble human thought more closely and will be able to respond to user questions.

SLOPE IMPORTANCE DECISION *FACTORS*

A major portion of the development of the USMS was the determination of the *factors* that should be involved in the rating process. The principal *factors* that were considered were the causes of instability, cost of all damage, use of the road, and safety to the motorists. For an explanation of these factors, where appropriate, see Appendices B through Q.

The physical causes of instability obviously had to be identified. This lead to *factors* that dealt with the site geology (see Appendices K, M, and P), water conditions (see Appendix D), and load conditions (see Appendices I and O). Once the causes of the instability are determined a method to prevent future failures may be apparent.

Cost is another important category. It is necessary to know what the direct and indirect costs will be. The indirect costs are the more difficult of the two to quantify because there are probably no actual figures on these costs. For example, what will be the economic burden to the surrounding area and can this hardship be represented by a dollar value? Would a failure severely disrupt the major economic means, such as agriculture or logging, of the area? See Appendices E, L, and Q. Direct costs are less ambiguous for they relate to repair costs to damaged property, such as roads and buildings, which can be quantified. See Appendices B, F, and H.

The safety of motorists is the most important consideration. The *factors* that deal with safety are not obvious. For example, geographical hazards (a hazard resluting from geometry or placement of the failure, e.g. impaired line of site, adjacent bodies of water) are not an obvious consideration in slope safety. Yet it should be known if a site is located between two blind curves, a potentially dangerous situation (see Appendix N). Another obscure consideration is the failure speed of the site. Does the speed of the failure have very much influence on safety and, if so, how much influence? See Appendices G and C. The importance of these *factors* is not easily quantified.

Another category that influences the importance of the failure site specifically deals with the road that the site affects. The type of road, i.e. interstate, and the average daily traffic, ADT, are important *factors* to know (see Appendix J). The type of road and the ADT of the road indicate the importance of the road to the community. The population of the area that the road affects and whether or not the road is the sole means of access is also important to know (see Appendix L).

SUMMARY

The creation of the USMS required the determination of the *factors* that influence slope importance. This was accomplished through the development of a questionnaire and conversations with WSDOT personnel. A method to rate the importance of each failure site then had to be determined. The rating system developed assigns a *priority rating* to each *factor* response. The *priority rating* can range from 1 to 10, 10 being the highest rating. Weights are then applied to the priority ratings. The products would then be added and the sum represents the *total priority rating* for the failure site.

In order to perform these tasks and manage the data involved, the database system dBASE III Plus and the expert system *shell* CLIPS were chosen. These programs were integrated to develop the USMS. The existing USMS is a management system, not an expert system.

FINDINGS

The USMS is composed of two parts, the database and the CLIPS programs. The USMS works by alternating between these parts. To begin, the user enters into a main program (see Appendix R) that is written in dBASE. This program will allow the user to add, edit, display, and delete the data for failure sites, to create the input files for CLIPS, and to calculate the *total priority rating* of the failure site. Once all the data have been entered into the database and the files have been converted to text files, the CLIPS programs can be executed. In order to do this, the user must exit dBASE and enter CLIPS. The user can then execute a control program (see Appendix A) that will execute all of the individual CLIPS programs (see Appendices B through Q). Once the programs have been executed, the user reenters dBASE. The output files from CLIPS are then converted from text files into dBASE files. After this, the weights can be applied and the *total priority rating* can be determined for each site.

In order to understand how the USMS operates, the terms *temporary* and *permanent* data need to be defined. *Temporary* data are the information that will most likely vary each time the slope fails, such as the size and the type of failure. *Permanent* data are the information that will probably not change over several years, such as the geology of the site. See Tables 1 and 2 for a specific list of *temporary* data variables and *permanent* data variables.

There are corresponding *permanent* and *temporary* programs and databases.

Table 1 *Temporary* **Data** *Factors*

Variable Description	Variable Name in CLIPS Prog.
Road Impedance	ROAD-IMPEDE
Availability of Paved Detours	DETOURS
Public Risk	DAMAGE-TYPE
Failure Type	PROBLEM-TYPE
Pavement Damage	PAVEMENT-DAMAGE
Structure Type	STRUCTURE-TYPE
Structure Damage	STRUCTURE-DAMAGE
Presence of Static Load	STATIC-LOAD
Location of Static Load	STATIC-LOAD-LOCATION
Presence of Dynamic Load	DYNAMIC-LOAD
Location of Dynamic Load	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 2 *Permanent* Data *Factors*

Description	**Variable Name in CLIPS Prog.**
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
Presence of Soil Layering	LAYERS
Top Layer, Soil Type	TOP-SOIL
Bottom Layer, Soil Type	LOWER-LAYER
SPT	SPT
Presence of Loose Rock	LOOSE
Presence of Intact Rock	HOMOGENEOUS-INTACT
Presence of Joints	JOINTS
Presence of Layers	LAYERS
Access Type	PROBLEM-TYPE
Population	POPULATION
Presence of Static Load	STATIC-LOAD
Location of Static Load	STATIC-LOAD-LOCATION
Time Static Load Applied	STATIC-LOAD-TIME
Presence of Dynamic Load	DYNAMIC-LOAD
Location of Dynamic Load	DYNAMIC-LOAD-LOCATION
Time Dynamic Load Applied	DYNAMIC-LOAD-TIME
Geographical Hazard	GEOGRAPHY-HAZARD

Permanent programs determine *permanent* priorities. The data used in these programs are considered *permanent* data. These data are stored and manipulated in *permanent* databases. The same situation exists for *temporary* programs and databases. See Tables 3 through 6 for a list of the *permanent* and *temporary* databases and programs.

GENERAL EXPLANATION OF CLIPS PROGRAMS

All of the CLIPS programs work in the same general manner. A program reads the input data for a particular failure site, assigns *priority ratings* to this data, stores the information in an output file, and then reads the input data for the next failure site. These steps are repeated until the end of the file is reached.

The CLIPS programs are composed of several *defrule* statements. A *defrule* statement, a rule, is basically an IF THEN statement. For each condition considered within a program there is a corresponding *defrule* statement. For example, the PROBTYPE.CLP program (Appendix G) consists of sixteen *defrule* statements. Five are concerned with reading the input data, which are the site ID, failure number, and problem type, for a failure site. There are nine *defrule* statements concerned with the determination of the problem type *priority rating* for the failure site. A *defrule* statement exists for each valid response to the problem type *factor*. There are nine valid responses; therefore there are nine rules. Once the appropriate rule has been fired (or implemented) and the *priority rating* determined, the site ID, failure number and the problem type *priority rating* are stored in the output file RATPROB.TXT. At this point the program can read the input data for the next failure site and repeat the entire process. When the

Table 3 *Temporary* Databases

Description	**File Name**
Repair Cost	COST.DBF
Failure Conditions	FAILCOND.DBF
Damage	DAMAGE.DBF
Temporary Loads	TEMPLOAD.DBF

Table 4 *Permanent* **Databases**

Description	File Name
Identification	IDENTITY.DBF
Geology	GEOLOGY.DBF
Permanent Loads	PERMLOAD.DBF

Table 5 *Temporary* **CLIPS Programs**

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

Table 6 *Permanent* CLIPS Programs

Description	**File Name**
ADT & Road Type	ADTROADT.CLP
Economic Importance	ECONIMPO.CLP
Geographical Hazards	GEOHAZ.CLP
Geology: Soil Classification	DIRT.CLP
Geology: Rock Classification	ROCK.CLP
Geology: Seismicity	EQUAKE.CLP
Permanent Loads	PERMLOAD.CLP

program has reached the end of the input file, all files are closed and the program terminates. All CLIPS programs function in this manner. They continue the loop process when the required priority ratings have been determined and terminate when the end of the input file has been reached or when the program is unable to fire any more rules.

INTERPRETATION, APPRAISAL, AND APPLICATION

The existing USMS provides a logical and systematic approach to determine the importance of an unstable slope with respect to several defined factors. The USMS is the first version attempted and is by no means a perfect solution. The USMS, as it exists now, is quite limited in its capabilities. It can only calculate the importance of a slope and store information. It can not determine a cost efficient repair strategy for the slope. It is hoped that future versions will have this capability. It also can not suggest to WSDOT a repair schedule for the failed sites. In order to accomplish this task more information about the actual management of slopes is required.

The USMS is a functioning program and can be applied to actual failure sites. It was created with the state of Washington in mind and therefore is biased towards the conditions existing in Washington. The USMS should be tested with actual data from a certain area and its output should be evaluated for reasonability. It is known that many of the *priority ratings* are inaccurate and should be adjusted. Testing the system should enable the user to be able to suggest more accurate *priority ratings*.

Even though the system is limited in its capabilities and accuracy, it should be emphasized that it is the first of its kind. Most of the energy and time attributed to this project were spent trying to develop a reasonable method to rate sites and to determine the factors that should be involved in the rating process. Future versions of the system should be able to concentrate on expanding the capabilities and increasing the accuracy of the USMS.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The primary purpose of this project was to develop a prototype of an Unstable Slope Management System. The main focus of this project was to determine a methodology for developing a USMS, not to produce a numerically accurate system. In order to determine how the system should work and what it should include, several conversations with WSDOT personnel were conducted. In addition, a questionnaire was developed and sent to WSDOT personnel. The questionnaire was intended to obtain actual *priority rating* values for the USMS and determine what is important in the decision making process. However the questionnaire was not effective in this area because people had never thought of an USMS before and were not sure how to go about it. The development of the questionnaire was its most useful aspect.

Since no one knew what the system should include or how it should work, it was not possible to develop a numerically accurate system. Instead the main concentration of the project was to determine the *factors* involved in the decision making process.

This system is composed of a database and *priority rating* programs. The database was developed using the software system dBASE III Plus. The *priority rating* programs were created using the expert *shell* system CLIPS. The database stores and manipulates information for each failure site. The dBASE programs allow the user to append, delete, or edit information. The dBASE programs also create the input files for the *priority* *rating* programs. The *priority rating* programs calculate the *priority ratings* for each failure site. The dBASE programs then use these *priority ratings* to calculate the *total priority rating*. The *total priority rating* represents the importance of the site. It is a number between 0 and 100, where 100 represents a site that needs immediate attention.

The USMS that was developed is by no means the best solution. However, it does determine a *total priority rating* using a reproducible, logical, and supportable method. It is therefore felt that this is a reasonable first attempt at an Unstable Slope Management System.

A major portion of this project was involved with determining what should be included in the USMS. This search is still continuing. It is hoped that with the use of this system, more people will think about how the importance of slopes should be determined and will voice their opinions. With each revision this system should improve in its efficiency and its scope. As more information and thought is put into the system the reasonability of the answers should increase.

It should be emphasized that the USMS as it exists now is not an expert system; it is a management system. The decision process resembles a black box approach. There is no interaction between the user and the decision making process. There is also no explanation facility. It is thought that future versions of this system will incorporate these features.

RECOMMENDATIONS

Numerous improvements to the system have become apparent as the development of the USMS progressed. These changes pertain to all components of the system, the CLIPS programs, the database, and the overall system.

Improvements to CLIPS Programs

The recommended improvements to individual CLIPS programs are discussed in Appendices A to Q. Improvements that all of the CLIPS programs have in common deal with the *priority rating* values. All of these values were estimated and should be reviewed and adjusted as necessary.

Improvements to Database

The database portion of the program should be made more user friendly. A very useful feature that would reduce the number of user errors in the USMS, when it is executed, would be a response check for each database. This would mean that each time the user appended or edited a record within a database, the program would check the responses with a list of valid responses and would notify the user of any invalid data entered in the database.

Another feature that would be helpful to the user would be to have all or most *permanent* data already stored in the database. For example, the ADT and Road Type information within the Identity database could be stored in another database by the corresponding road number and mile post. This information could then be input by dBASE into the Identity database. The same could be done with the Geology database. This could be very useful and would save time and the chance of inconsistencies within the program.

A very useful improvement that would decrease the run time of the USMS and decrease the complexity of the system to the user would be to execute the CLIPS programs from within dBASE. However, this may not be possible. If this is the case, it might be advantageous to choose a different database software system, expert system *shell* system, or both. These items are being studied during the implementation phase of the project.

Improvements to Overall System

There are many changes and additions that can be made to the overall system in order to improve its performance. One such improvement to the overall system would be to change the weighting system of the *priority ratings*. As the system exist now, the weights are arbitrary and, due to lack of information, are not based on any specific data. The weights are subjective. A program such as WARP (6) could be used to determine the optimal weights. WARP is a computer program designed to optimize cost weighting parameters for ranking investment goals.

Another improvement would be to determine default values for certain types of failures. These default values would then supply data for sites where data could not be obtained. Data *factors* that could use default values would be the geologic data, failure type and the corresponding failure size, water level, and date.

A helpful improvement to the system would be the identification of failure patterns. The identification of recurring patterns could enable the system to possibly predict the probable failure date and size of the next failure of a particular site.

It would also be useful to have programs that would search the database for failure sites with similar features. This program could be used to provide data from an existing site to a site in which data are not available.

Ultimately, the system should be able to determine the optimal repair schedule. It should decide which slopes should be permanently fixed or if it is more economical to allow the site to fail each year. In accomplishing this task it should also meet the budgeting constraints of the department.

IMPLEMENTATION

The implementation of the USMS will be conducted as part of a subsequent research task. It was the original intention to use the Unstable Slope Inventory (USI), developed by WSDOT, as the initial database for the USMS. The information contained in the USI was found to be insufficient for the reliable operation of the USMS.

Information on the seismic, geological, geotechnical, and usage needs to be added to the database. The seismic data can be based upon the seismic zonation recommendations of Higgins, et al. (7). Geological data can be extracted from geologic maps and guide descriptions. A catalog of these maps has been complied by Manson (8) for the State of Washington Department of Natural Resources (DNR). Also, DNR has compiled a geologic guidebook for the state (9). Geotechnical data can be based upon WSDOT records design and construction records. Usage data can be extracted from the WSDOT Average Daily Traffic (ADT) data base. Land use and adjacent structures can be determined from as built records.

A pilot study of the USMS will be conducted using data from one district of WSDOT. The district selected for the study must have a variety of unstable slopes affecting the highways. The goal is to utilize the data collected from the pilot study to evaluate the performance of the USMS, and to implement the USMS in a district. During the study, the USMS will be modified as necessary. Some work will be done to determine appropriate weighting factors for the various parameters of the USMS.

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Appendix References

Appendix G

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Appendix M

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Appendix A (WA-RD 270.2) to this report is available through the Research Office.