Landslide Hazard Rating Matrix and Database

Vol. 2 of 2
A Manual for Landslide Inventory

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for the
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RESEARCH & DEVELOPMENT

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A Manual for Landslide Inventory

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CHAPTER I

INTRODUCTION

1.1 INTRODUCTION

The rehabilitation decision for highway slope failure is one of the many important tasks to be tackled by Ohio Department of Transportation (ODOT). A rational approach to manage the unsafe or failed slopes/embankments should ideally include a systematic process for collecting the information needed for decision making. This involves the database management by recording the descriptive inventory and risk assessment of the failure slope. Essentially, this manual provides the information about the following: 1) procedure for landslide data collection, 2) landside hazard assessment using ODOT rating matrix, and 3) guidance on the use of a global positioning system (GPS) and an internet website for ODOT landslide database.

1.2 OBJECTIVES OF THIS MANUAL

The objective of this user manual is three-fold 1) to provide definitions of terms used in the Landslide Field Reconnaissance Form, 2) to provide guidance on the use of ODOT landslide hazard rating procedure, and 3) to provide explanation and guidance on how to use the ODOT landslide database website. The intention of the manual is not for design of slope stabilization scheme or forecasting which landslide will fail first. It is also not applicable for the risk assessment of rockfall.

1.3 BENEFITS OF THE SYSTTEM

The implementation of the system provides the users with a proactive and systematic approach in gathering the unstable and/or failed slope information to support the decision-making in allocating limited fund for slope remediation. The benefits of the GIS internet database lies in the following: 1) Minimal paper work, 2) Real time monitoring, 3) Centralized information, 4) Uniform data collection, 5) Shortened office works, 6) Interchangeable information, 7) Searching and sorting ability, 8) Scheduling and reporting, 9) Effective management of limited resources and assets.

1.4 IMPLEMENTATION

The success of the system depends upon cooperations among various constituents of potential users. Full implementation of the system needs the properly trained staffs and landslide inventory. Once the database is established then different remedial approaches together with the benefit and cost comparisons can lead ODOT personnel to make rational and data-driven decision about fund allocations.

1.5 LIMITATIONS

The system provides ODOT a decision support system to prioritize failed slopes by providing relative hazard rating scores. Since the assessment is partially subjective, the use of the subjective factors may cause a user to over state the slope failure risk. However, researchers have tried to make the assessment of risk score of each factor as straightforward as possible. Thus, the potential hazard score of a landslide site should ideally be about the same when it is assessed by different people. Furthermore, it is

recommended that ODOT conduct training workshop to develop a uniform and well-trained work group who would be undertaking landslide inventory and hazard assessment. A separate set of power point presentation files are developed to aid ODOT to conduct training workshops.

CHAPTER II

LANDSLIDE INVENTORY

2.1 LANDSLIDE FIELD RECONNAISSANCE FORM

The Landslide Field Reconnaissance Form is developed for ODOT personnel or designated ODOT consultants to collect pertinent information of the landslide site in a consistent manner. The forms are divided into four parts according to different user groups assigned to different tasks in collecting information. The forms can be completed in a paper format, or on a laptop computer, or on a handheld GPS unit. Information collected in the field using a laptop computer or GPS unit can be conveniently uploaded to the Landslide GIS Database system through an internet website. The detailed instructions on the use of the Landslide GIS Database are presented in Chapter V. The use of the GPS handheld unit or a portable computer for collecting filed data for landslide inventory is explained in Chapter VI.

2.2 COMPONENTS OF LANDSLIDE RECONNAISANCE FORM

The Landslide Field Reconnaissance Form is divided into 4 parts: a Landslide observation Report and Parts A, B, and C. A copy of Landslide Field Reconnaissance Form is provided in Appendix A. The flow chart in Figure 2.1 depicts the process of data collection and the corresponding data to be collected by different user groups.

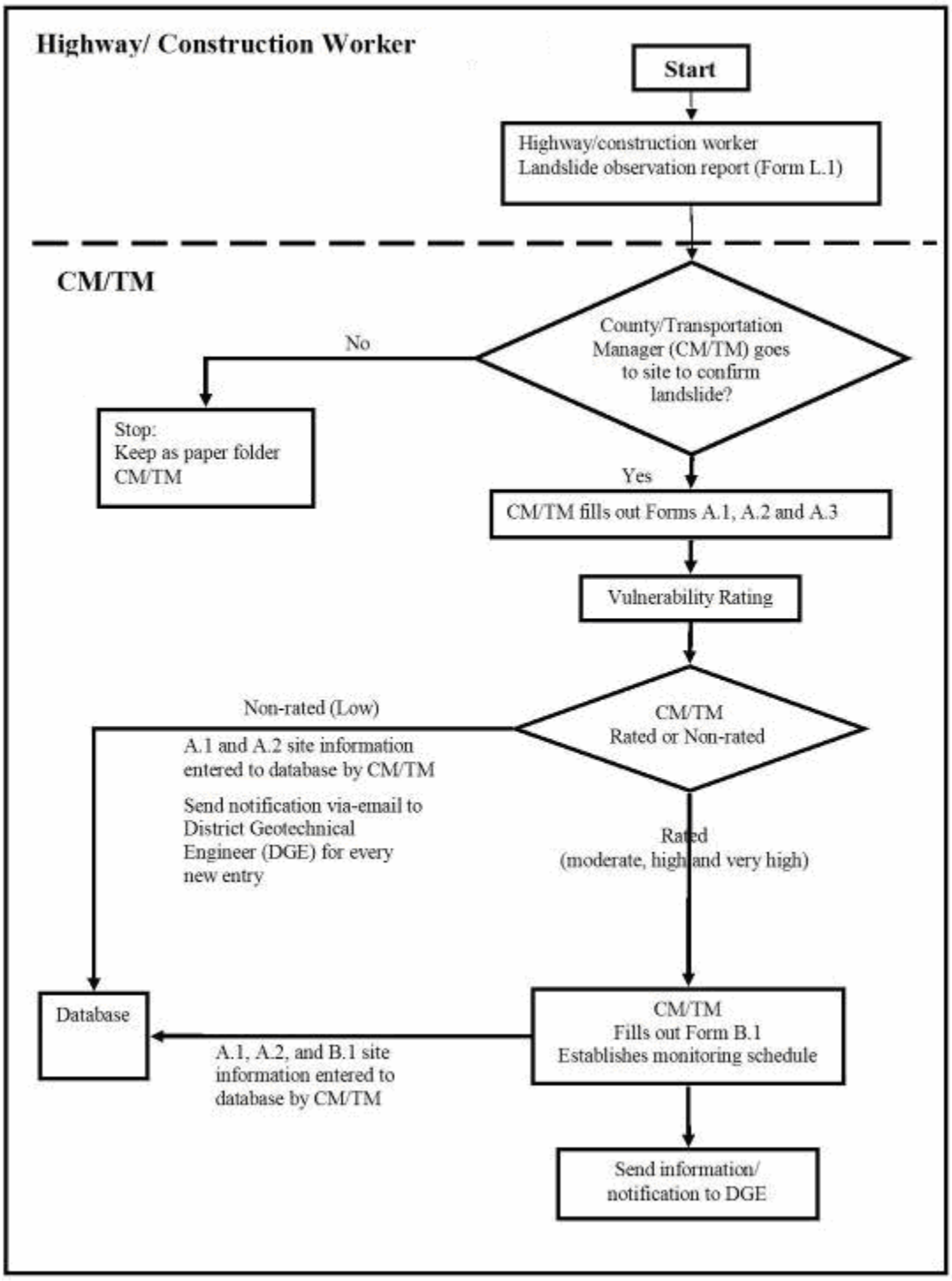


Figure 2.1 Landslide reconnaissance processes

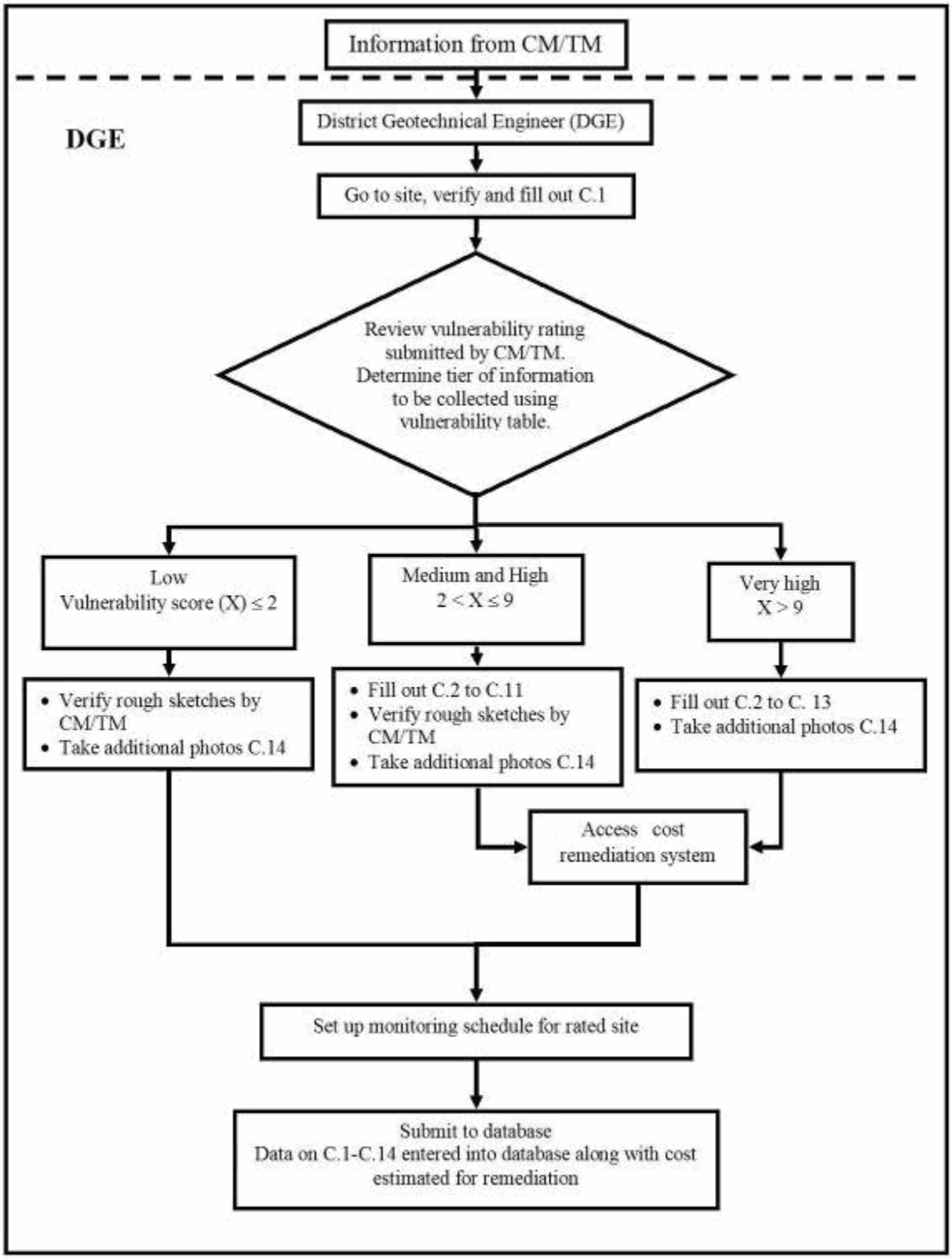


Figure 2.1 Landslide reconnaissance process (continued)

2.2.1 LANDSLIDE OBSERVATION REPORT

Reporting of a potential landslide site is triggered by a highway maintenance crew member, a construction worker, or a crew member from county office, who fills out the Landslide Observation Report. This form can only be completed in a paper format and has to be submitted to County Manager (CM) or Transportation Manager (TM) of the respective county.

2.2.2 LANDSLIDE RECONNAISANCE FORM PART A

After receiving the Landslide Observation Report, CM/TM makes a trip to the site to verify the reported information. CM/TM needs to confirm if indeed it is a landslide. If CM/TM determines that it is not a landslide; there is no need to have any other follow-up activities. CM/TM simply keeps the Landslide Observation Report in a folder for future reference. If, on the other hand, CM/TM determines that the site is indeed a landslide site, then part A (Form A.1 to A.3) needs to be completed. CM/TM determines whether the site is to be "rated" or "non-rated" according to the vulnerability table provided in Form A.2. CM/TM submits data in Part A into database via internet. If the site is classified as rated, CM/TM continues to complete Part B. Then CM/TM submits data into database via internet. Again, for every new landslide entry into database, CM/TM should send alert via e-mail to District Geotechnical Engineer (DGE).

Preparation for the field work

The equipment needed for field work is shown in Table 2.1. Since physical measurement of distance may be needed, it is recommended that at least a two-person team is formed for each site visit.

Table 2.1 Field Equipments

No.	Equipment
1.	Trimble GeoXT or GeoXH GPS unit or equivalent (Window CE installed with ESRI ArcPad® Application)
2.	300-ft measuring tape
3.	Laser based distance measuring device
4.	16 or 25-ft personal measuring tape
5.	Clinometer (A surveying instrument used for measuring the inclination of a slope; it is usually equipped with a compass as well)
6.	Two-way radio
7.	Geologist hammer
8.	Reflecting vest
9.	Grid paper for landslide sketch
10.	Write-in-rain paper
12.	Hard hat
13.	Field shovel

Landslide identification

The first task of CM/TM is to verify whether the reported site in the Landslide Observation Report is indeed a landslide. The highway worker could mistakenly report a site that is not related to landslide. The signs of landslide related ground movements are evident by the formation of tension cracks, hummocky surface on the slope, misalignment of drainage pipe, guardrail, or power lines, tilting of trees, cracking of surface drainage channel, expansion and closing of the bridge joints, loss of alignment of building foundation, etc. The series of pictures presented from Figure 2.2 to Figure 2.7 illustrate the telltale signs of slope movement.

Figure 2.2 Misalignment of power line

Figure 2.3 Misalignment of drainage channel

Figure 2.4 Separation of slope and bridge structure

Figure 2.5 Tension cracks on road

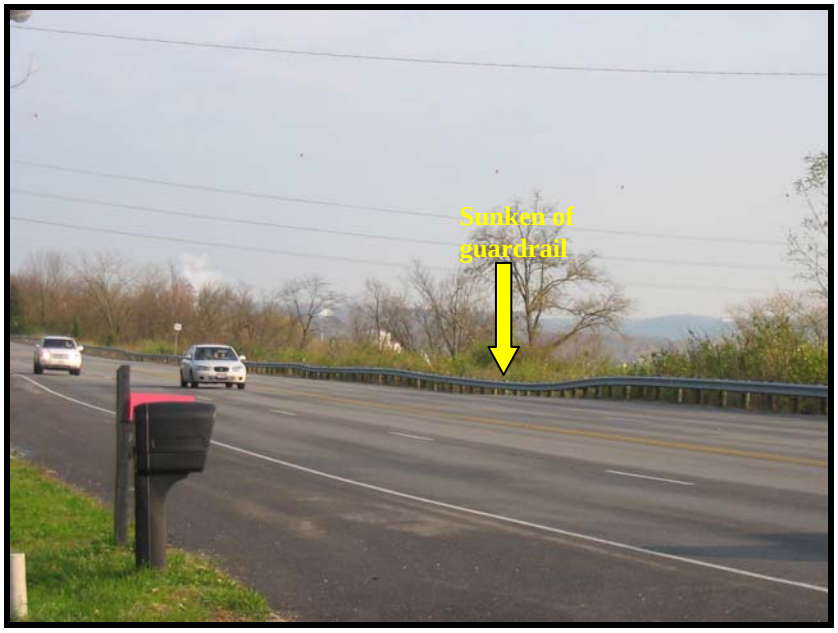


Figure 2.6 Sunken guardrail

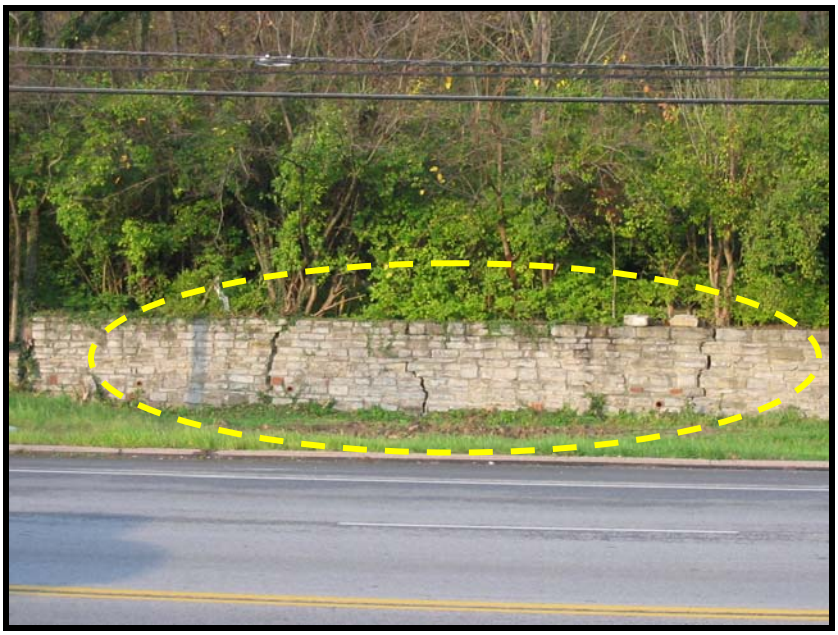


Figure 2.7 Failure of earth retaining structure

Site location

If the site is confirmed as a landslide site, CM/TM proceeds to complete Part A. The recording of landslide location is important because it can be used for future site spatial reference in the database. Some of fields needed to be completed in Part A are explained in the following section.

Network Linear Feature Identification (NLFID)

The NLFID is the 14-character code designation consisting of the components shown in Figure 2.8.

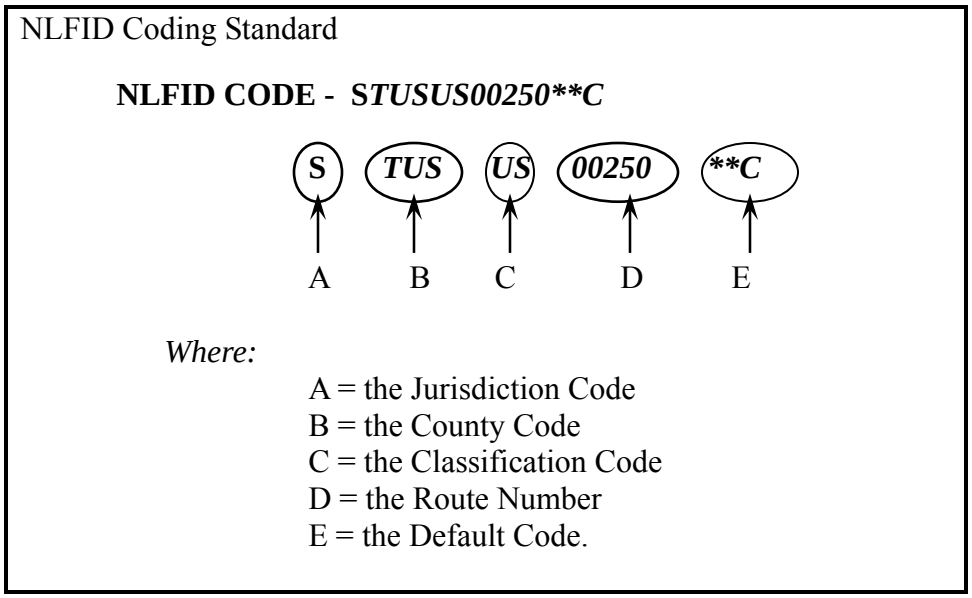


Figure 2.8 Determination of the NLFID code

Beginning Mile Point (BMP)

The BMP should be determined based upon the Digital Mileage Indicator (DMI) reading recorded at the beginning point of the site. The BMP should always be the lowest Straight Line Mileage (SLM) point of the Site. If the DMI reading at the BMP starts at SLM 0.00, then the BMP is the adjusted DMI reading. However, if the DMI reading recorded at the BMP starts at a location other than SLM 0.00, the BMP needs to be calculated by adding the starting point SLM and the adjusted DMI reading. The adjusted DMI reading is the true log mile reading adjusted for the station equations to calculate the

SLM. It is recommended that for future reference purpose that a letter "B" be painted at the shoulder of the site to physically mark the BMP at the site.

Ending Mile Point (EMP)

First, the measured length (ft) of the landslide is divided by 5280 ft/mile to determine the site length in miles. Add the calculated site length in miles to the BMP to obtain EMP. Again, it is recommended that the letter "E" be painted on the shoulder for physically marking the location of EMP at the site.

Centroid

After calculating the EMP, the crew member needs to determine the center position, or centroid, for the site by dividing the calculated length by 2 and adding to the BMP. The location of centroid should be marked on the right shoulder by placing a "*" using surveyor's paint. The location of BMP, EMP and Centroid points are illustrated in Figure 2.9.

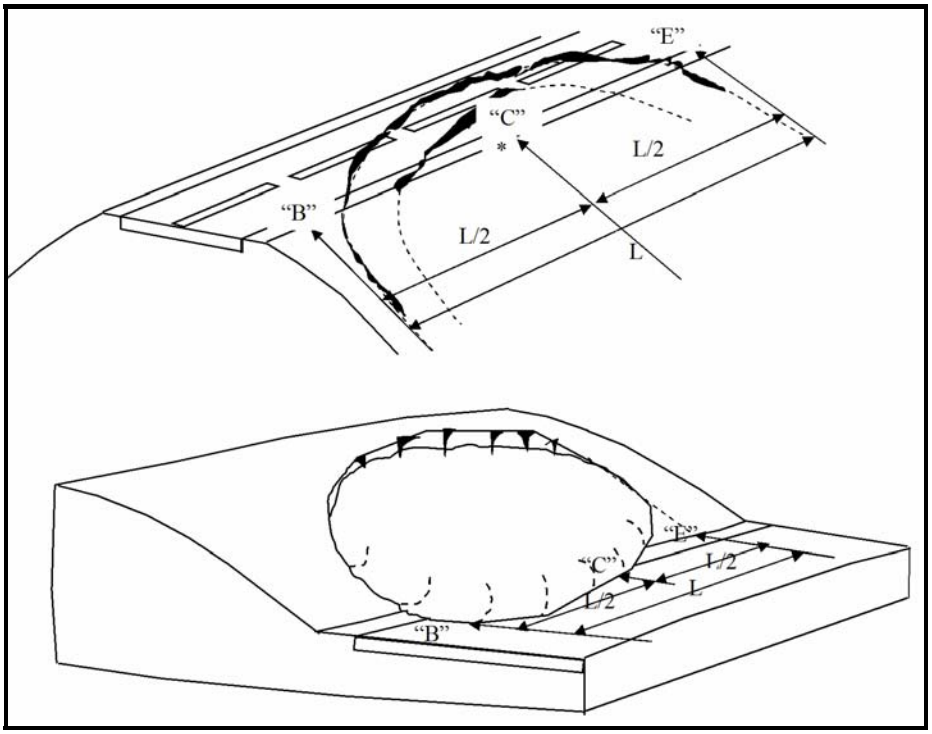


Figure 2.9 BMP, EMP and Centroid of a landslide site

GPS

The GPS coordinates should be collected at the centroid, BMP and EMP by using a Trimble GeoXT or GeoXH GPS unit or equivalent. The GPS coordinates are based on the WGS 1984 datum collected as **latitude**, **longitude,** and **elevation** in feet**,** respectively. The site centroid coordinates are used to identify the location of the landslide on the GIS map. The state coordinates as well as the USGS Quad name and number are auto-generated based on the GPS coordinates of the site centroid.

If a GPS reading can not be taken on the shoulder of the roadway at the landslide site due to poor satellite signal, the investigator should measure the offset distance and bearing of location where strong satellite signal can be received. After recording the GPS

coordinates at the offset location, the investigator also collects and records a bearing and the offset distance. The bearing should be obtained in degrees from north (azimuth coordinate), and the offset distance should be recorded to the nearest foot. If there is an elevation change from the centroid position to the offset point, this change can be determined by the use of any of the following means: a hand level, an abney level, a clinometer and a tape. The offset distance, bearing, and elevation changes are used to calculate the coordinates of the center from the offset point.

General dimensions of landslides

The general features and definitions of the dimensions of a landslide site are provided in Appendix C. The length of the landslide is determined as the minimum distance from the toe of the landslide to its crown. The width of a landslide is the maximum breadth of the displaced mass perpendicular to the length. The measuring tape or a laser based distance measuring device is used to measure the dimensions.

The depth to the slip surface is estimated by an engineer's or geologist's experience and judgment. If no other field evidences suggested otherwise, the depth to the slip surface could be estimated as the distance from the edge of the crest of a slope to the surface of the scarp (see dimension w in Figure 2.10). For the failure beyond the toe of a slope as also shown in Figure 2.10, the depth of the slip surface at the toe is usually about one-third of the distance from the toe to the edge of mud wave (see dimension t in Figure 2.10) (McGuffy, 1991). If the mud wave exits on the slope, the outlet of the failure surface is usually near the top of the visible mud wave.

The depth of the slip surface could also be estimated from the tilting of trees on slope. As seen in Figure 2.11, the depth of the slip surface may be estimated from the tree root, which is approximately less than 10 feet. If the depth of the slip surface is less than 10 feet, the trees on the sliding mass usually tilt down slope. Breaks in the buried utilities, such as culverts and sewer pipes, can give a direct visual identification of where the slip surface exists.

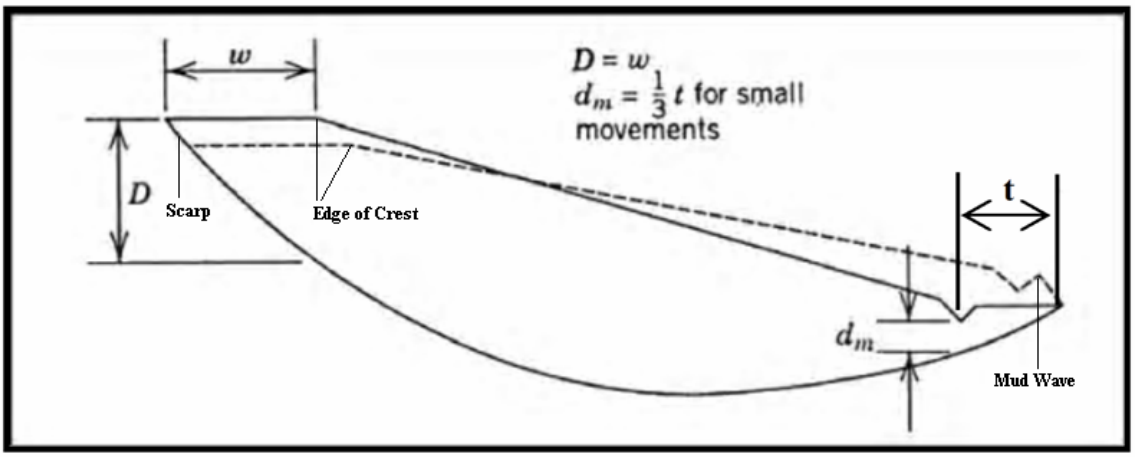


Figure 2.10 Distance from the toe to the edge of mud wave (McGuffy, 1991)

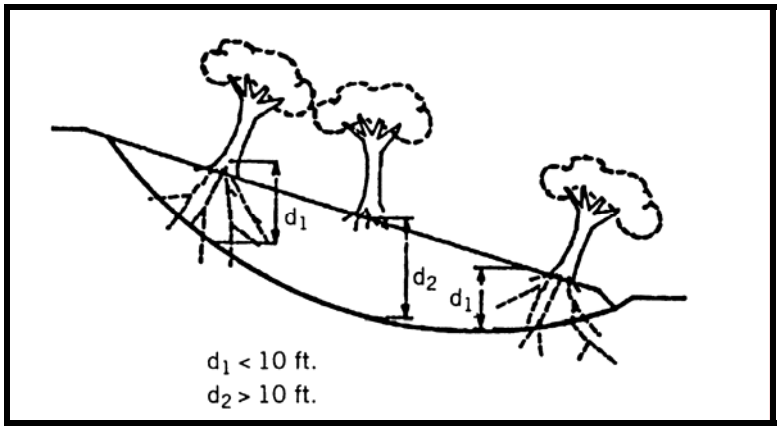


Figure 2.11 Depth of the slip surface estimated from trees with deep roots (McGuffy, 1991)

Preliminary rating and inspection frequency

The CM/TM determines the preliminary rating by visual evaluation as to whether the landslide should be “rated” or “non-rated”. The landslide vulnerability table shown in Table 2.2 should be used to derive the subjective decision. The empirical scale used to estimate the hazard in terms of probability of impact on structures and additional movements are as follows: very high, high, moderate, and low. If the intersection of the subjective rating of these two categories is “low”, the site is classified as “non-rated”; otherwise, it is classified as “rated”.

An example of “non-rated” landslide site is shown in Figure 2.12. The probability of additional movement was judged to be “low”. The distance from the toe of the slope to the roadway is large. If slope movement continues, it is unlikely to reach the roadway. There is no facility or building existing on the upslope side. Therefore, the probability of significant impact to the roadway, structures, and adjacent property or features was judged to be “low”.

A “rated” landslide is a slope with potential to affect the safety of the public and may cause future failure to the roadway. Several examples of “rated” landslide sites are shown in Figures 2.13 and 2.14. A landslide site in Figure 2.13 has a direct effect on the pavement shoulder. Significant horizontal and vertical displacements were observed which could continue to develop into the traffic lanes. Another picture of this landslide site was taken at the retaining structure down the slope. As seen in Figure 2.14, the

landslide has caused movement of the retaining wall. The standing water behind the wall could induce additional pressure on the retaining structure.

The decision regarding the landslide site shown in Figures 2.13 and 2.14 based on the landslide vulnerability criteria was reached as follows. The probability of additional movement was rated as "very high" because the pavement surface and the retaining structure were highly affected by slope movement. Moreover, the existing standing water may exert the additional pressure to the wall. The probability of the impact to the roadway, structure, adjacent properties or features was rated as "high" because of the surrounding bridge, the railroad, and retaining structures. As a result, this site is rated as "very high" according to the vulnerability table and therefore should be "rated".

Figure 2.15 presents the second example of a "rated" landslide site. The failure was localized on the roadway slope. The slope was speculated to be triggered by rainfall. When this unstable slope experiences more rainfall, a larger failure could ensue and eventually affect the roadway. The probability of additional movement was considered "high" and potential impact to roadway was also considered "high".

More detailed instructions on how to use the GIS database are presented in Chapter V. If the landslide is "rated", CM/TM should send alert e-mail to the District Geotechnical Engineer (DGE) for follow up action. The rough sketches and digital photos of the slope should be taken. All information is submitted via internet and stored in the GIS database.

Table 2.2 Landslide Vulnerability Table

Probability of additional movement	Probability of significant impacts to the roadway, structures, adjacent property or features			
	Very High	*High*	*Moderate*	*Low*
Very High	Very High	Very High	High	Moderate
High	Very High	High	High	Moderate
Moderate	High	High	Moderate	Low
Low	Moderate	Moderate	Low	Low

Figure 2.12 "Non-rated" slope

Figure 2.13 “Rated” slope

Figure 2.14 Displacement of retaining wall and standing water behind the wall

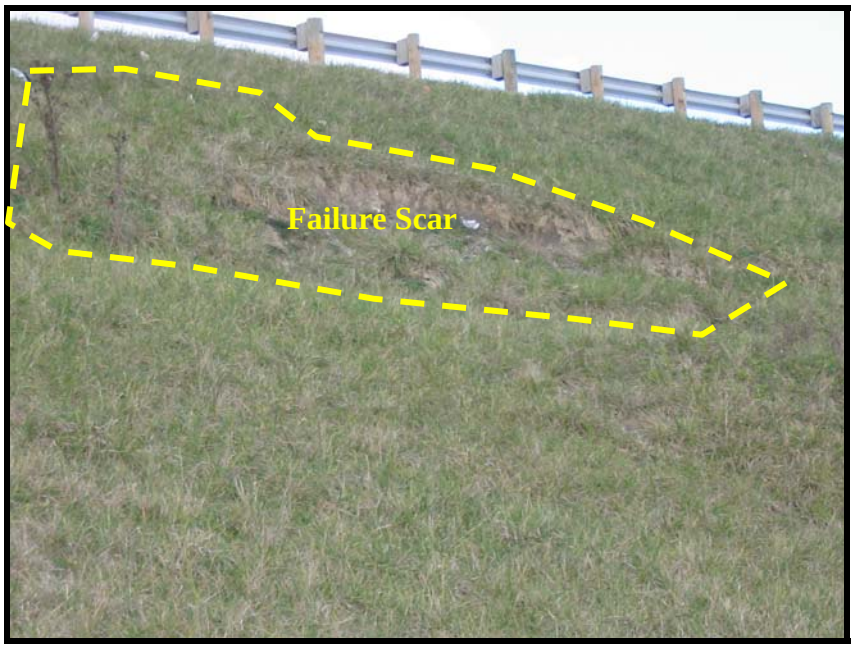


Figure 2.15 Another example of "rated" slope

2.2.3 LANDSLIDE FIELD RECONNAISSANCE FORM PART B

Part B is intended mainly for the collection of site history and traffic information of the site. The site history, such as the date of original construction, the date of alignment modification, the date of remediation activities, past and existing remediation activities, annual maintenance frequency and cost, and maintenance response should be obtained in office.

The traffic information, including the average daily traffic (ADT), the number of accidents in past ten years, posted speed limit, estimation of detour length, and estimated traveling time of detour for both passenger vehicles and trucks can be obtained from the source listed in Appendix F. The compiled information is uploaded by CM/TM to the database.

2.2.4 LANDSLIDE RECONNAISANCE FORM PART **C**

Once the CM/TM identifies a "rated" site, he/she sends a notification to a District Geotechnical Engineer (DGE). The DGE schedules his/her time to conduct site visit and to complete part C of the Landslide Field Reconnaissance Form. DGE also verifies data collected by CM/TM in Parts A and B.

The team for site reconnaissance ideally should include at lease two people. One would be the DGE and the other is a highway maintenance person or a CM/TM who knows the site history and activities well. The field equipment used in the detailed site reconnaissance is the same as previously mentioned.

Required information for data collection

The amount of information to be collected for Part C is based on the criteria set in Table 2.3. The tiered approach in information collection is to facilitate more expeditious completion of landslide database buildup. The detailed information to be collected in each of the three tiers is given in Table 2.4.

Table 2.3 Landslide Vulnerability Table (numerical score shown in parenthesis)

Probability of additional movement (A)	Probability of significant impacts to the roadway, structures, adjacent property or features (B)			
	Very High(4)	*High(3)*	*Moderate(2)*	*Low(1)*
Very High(4)	Very High (16)	Very High (12)	High (8)	Moderate (4)
High(3)	Very High (12)	High (9)	High (6)	Moderate (3)
Moderate(2)	High (8)	High (6)	Moderate (4)	Low (2)
Low(1)	Moderate (4)	Moderate (3)	Low (2)	Low (1)

Vulnerability score (X) = A× B

Table 2.4 Information to be collected in each tier

Low (0< X ≤ 2 points)	Moderate and High (2< X ≤ 9 points)	Very high (X > 9 points)
• Verify and fill out C.1 • Verify rough sketches by CM/TM • Take additional photos C.14	• Verify and fill out C.1 • Fill out C.2 to C.11 • Verify rough sketches by CM/TM • Take additional pictures C.14	• Verify and fill out C.1 • Fill out C.2 to C.13 • Take additional photos C.14

The information in Part C includes the following categories: slope characteristics, slope materials, landslide characteristics, observed remediation, preliminary determination of causes of landslide, observed traffic information, impact assessment, adjacent structures and areas, information for estimation of landslide remediation cost, initial suggested remediation measures, sources of supplemented information, landslide hazard assessment, photographs, and sketches. Explanations of the definitions and terms used in Part C are provided in Appendix C.

Digital photographs should be taken and sketches of plan and cross-section of the landslide site should be drawn in scale by using the grid paper. The photos and sketches

are important as they serve as a reference for planning future slope monitoring or possible slope remediation. The sketches and photographs include locations of crown, toe, edges, spring, water sources, cracks, toe bulge, sloughing, scarps, guardrail distortions, linear deflections, stream deflections, toe erosion, hydrophilic vegetation, slanted poles /trees, etc. There is no limit on how many photos that needs to be taken. As a minimum, it is recommended that at least 2 photos taken each at BMP, EMP, and centroid. The landslide hazard rating is assessed by using the rating matrix described in Chapter III.

2.3 ADDITIONAL RECOMMENDATIONS FOR SLOPE FAILURE RECONNAISSANCE

To conduct field reconnaissance, it is recommended that two persons are assigned to each team. In the beginning, site reconnaissance may seem to be tedious. The reconnaissance should start from identifying visible features, such as cracks on the pavement, broken utility lines, movement of guardrail, etc. Useful tips for landslide site reconnaissance are provided in Appendix B.

The historical information of a landslide site such as maintenance history and accident history, is required as part of the inventory documentation. The historical information often may not be easy to obtain due to poor documentation or simply missing records. One could search for supplemental sources by conducting interviews with local people. ODOT has implemented a “Geo” work type to track maintenance operations. Accident reports are available through databases maintained by Department of Safety and are available as GIS layers.

Taking photographs and sketching plan and cross-section of the landslide site constitute one of the most important tasks in a site reconnaissance. These photos and sketches provide detailed chronicle information of the site, from which more accurate assessment of landslide hazard potential can be made. Some of the information needed for Part C is further explained below.

- Location of landslide activity is recorded by Global Positioning System (GPS) and highway mile markers. The GPS positions can be determined by using a GPS hand held unit, with latitude, longitude, and elevation.
- Type of movement of landslide is determined by visual inspection of evidences on the slope.
- Physical characteristics of landslide materials are determined by visual inspection.
- The estimated dimensions of a landslide site, particularly "depth to slip surface" are difficult to ascertain. The engineer or geologist needs to exercise reasonable judgment in estimating the dimensions.
- Previous site works and past remediation are determined by visual inspection.
- Accident history could be obtained from Department of Safety or from an interview with local people.
- The landslide causes are determined by judgment.
- The frequency of a landslide activity can be determined by consulting county maintenance record provided by CM/TM.
- Take effort to capture features of a landslide site in photographs and sketches.

CHAPTER III

LANDSLIDE HAZARD RATING SYSTEM

3.1 OVERVIEW

This chapter provides a detailed explanation of a set of factors used in the landslide hazard rating matrix. The landslide hazard is assessed based on the total numerical hazard score, which is calculated as sum of each numerical score of each factor. At the present time, all the factors used in the landslide hazard rating system are equally weighted. However, it may be likely that upon expansion of landslide database and completion of additional analysis that a weighting system could be adopted in the future.

3.2 LANDSLIDE HAZARD POTENTIAL ASSESSMENT

Six factors are used for assessing the hazard potential of a landslide site. Each factor has four scoring scales, with the degree of hazard increasing from left to right in Table 3.1. The numerical scores of 3, 9, 27 and 81 are used to represent the increasing hazard of each factor. The use of a scoring system in a form of x^3 , where x is a non-negative integer, is intended to heighten and differentiate the hazard potential of several thousand landslide sites eventually to be built into the database.

The six factors used for assessing the hazard potential of a landslide site are as follows: 1) Movement Location and Impact, 2) Hazard to Traveling Public, 3) Decision Sight Distance (DSD), 4) Average Daily Traffic (ADT), 5) Maintenance Frequency and Maintenance Response, and 6) Accident History. The landslide hazard numerical rating matrix is presented in Table 3.1.

Table 3.1 Landslide Hazard Rating Matrix

CATEGORY		RATING CRITERIA and SCORE			
		Points 3	Points 9	Points 27	Points 81
Movement location/ impact (select higher score)	Current and potential impact of landslide on roadway	On slope with a low potential to affect shoulder	On slope with a low potential to affect roadway	On shoulder, or on slope with a moderate potential to affect roadway	On roadway, or On slope with a high potential to affect roadway or structure
	Current and potential impact of landslide on area beyond right of way	On slope with a low potential to impact area beyond right of way (A)	On slope with moderate potential to impact area beyond right of way (B)	On slope with high potential to impact area beyond right of way (C)	On slope with high potential to impact structure beyond right of way (D)
Hazard to traveling public (Select higher score)	Rate of displacement in roadway if known	<1-inch/year	1 to 3-inches/year No single event ≥1-inch	3 to 6-inches/year No single event ≥3-inches	>6-inches/year Single event ≥3-inches
	Evidence of total displacement on roadway	Visible crack without vertical drop (E)	≤1-inch of displacement (F)	1 to 3-inches of displacement (G)	≥ 3-inches of displacement (H)
Maintenance (Select higher score)	Maintenance frequency	None to rare	Annually (one time/year)	Seasonal (1 to 3 times/ year)	Continuous throughout year (> 3 times/year)
	Maintenance response	No response (I)	Requires observation with periodic maintenance (J)	Requires routine maintenance response to preserve roadway (K)	Requires immediate response for safe travel or to protect adjacent structure (L)
ADT		<2000 (M)	2001-5000 (N)	5001-15000 (O)	>15001 (P)
%Decision Sight Distance (DSD)		≥ 90 (Q)	89 -50 (R)	49-35 (S)	< 34 (T)
Accident history		No accident (U)	Vehicle or property damage (V)	Injury (W)	Fatality (X)

3.2.1 MOVEMENT LOCATION AND ITS IMPACT

The location and impact of the slope movement are broken down into two subcategories: 1) impact of landslide on roadway, and 2) impact of landslide beyond right of way. Figure 3.1 illustrates the concept of the impact of a landslide on both roadway and beyond the right of way. The higher score from these two categories is used to represent the hazard score associated with this factor.

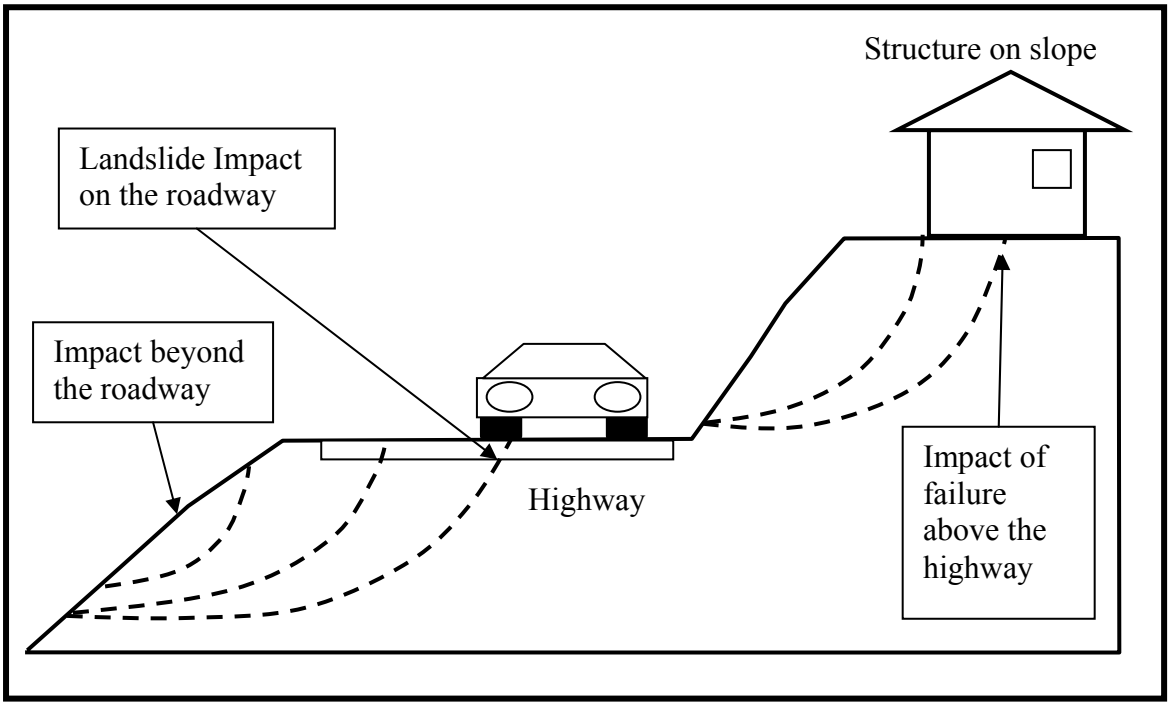


Figure 3.1 The slope failure above and below the roadway

Current and potential impact of landslide on roadway

- 3 points: on **SLOPE** with a **LOW** potential to affect **SHOULDER**
- 9 points: on **SLOPE** with a **LOW** potential to affect **ROADWAY**
- 27 points: on **SHOULDER**, or on slope with a **MODERATE** potential to affect **ROADWAY**
- 81 points: on **ROADWAY**, or on slope with a **HIGH** potential to affect **ROADWAY** or **STRUCTURE**

Current and potential impact of landslide on area beyond right of way

- 3 points: on **SLOPE** with a **LOW** potential to impact area beyond right of way
- 9 points: on **SLOPE** with **MODERATE** potential to impact area beyond right of way
- 27 points: on **SLOPE** with **HIGH** potential to impact area beyond right of way
- 81 points: on **SLOPE** with **HIGH** potential to impact structure beyond right of way

An example of high potential to affect roadway is shown in Figure 3.2. The cause of failure is the Lake Erie waves near the toe of the slope. Dips and cracks are not found on the pavement. However, this site was judged to have a "high" potential because the failure slope has a head that is relatively close to the roadway as shown in Figure 3.3.

Furthermore, there are evidences of roadway alignments from its old position several times in the past. This landslide site receives 81 points for this hazard factor.

Figure 3.2 Slope with high potential to affect the roadway

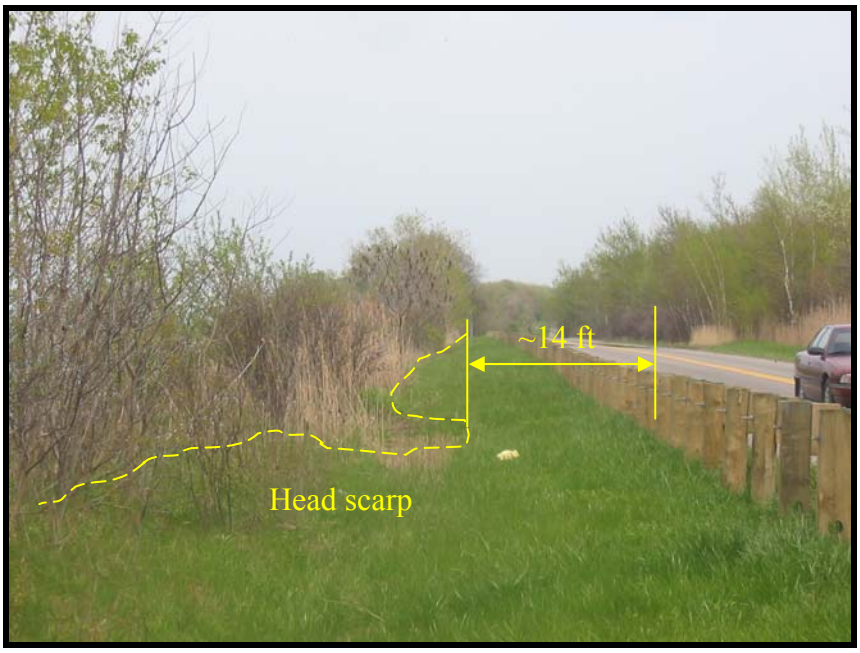


Figure 3.3 Distance from head scarp to roadway

Figure 3.4 shows a photograph of a slope failure on the roadway shoulder. This landslide site is judged to have a moderate potential to cause a larger slope movement. The risk score of 27 points is assigned.

Figure 3.5 shows an example of a cut-through highway slope. This landslide site only needs debris clean up. Since there is no structure on the top of slope, the risk score of 9 points is assigned. Figure 3.6 shows the cracking of a retaining wall due to the slope movement. Since the retaining wall is right adjacent to the roadway, a risk score of 81 point is assigned.

Figure 3.4 Impact on roadway shoulder with potential to affect roadway

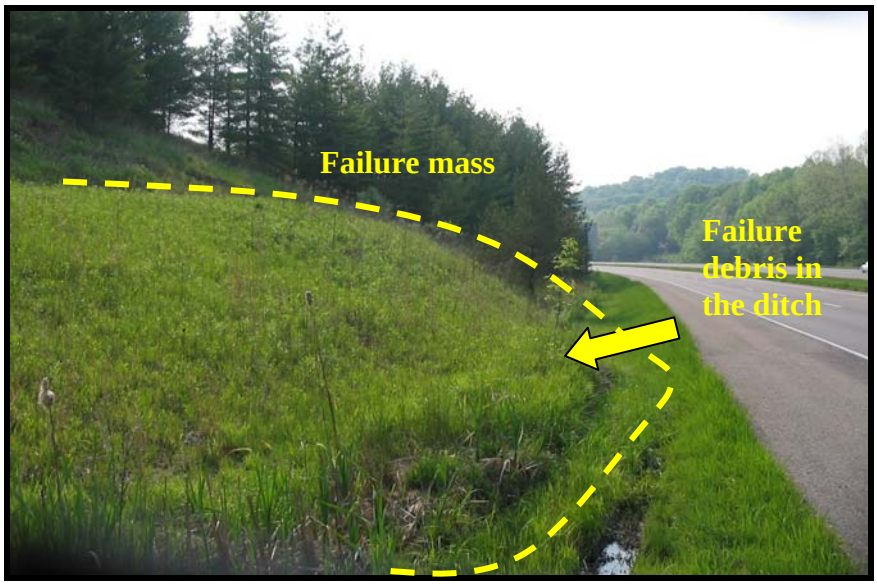


Figure 3.5 Landslide with low potential to impact shoulder

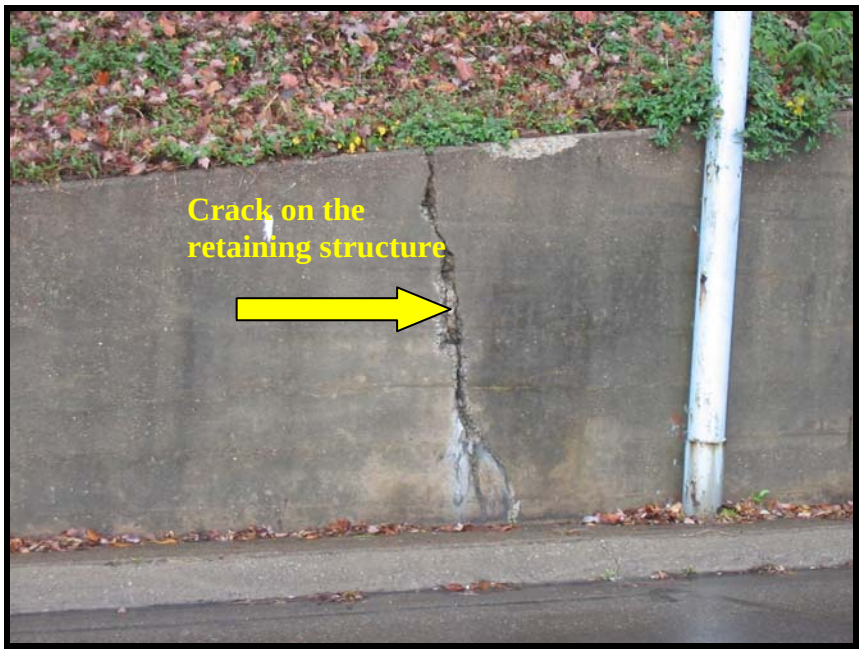


Figure 3.6 Impact of slope movement to a structure

3.2.2 HAZARD TO TRAVELING PUBLIC

Hazard to the traveling public is assessed by the slope movement rate or the amount of total movement of a slope. The movement rate of a slope can only be quantified by using a slope monitoring device such as inclinometers. Since the quantitative data on the rate of slope movement may not be available at the time of site reconnaissance, an alternative approach is to estimate the total movement in terms of vertical and horizontal displacement of visible cracks and dips on the roadway or structure.

Cracks and dips are the telltale signs of a slope moment. Dips or cracks on a roadway affect the safety of traveling public. The larger the displacements on a road, the higher the risk to the moving vehicles will be. The following criteria are used for assessing the hazard according to the rate of movement or the total movement. The higher numerical score from those two subcategories is used to represent the hazard to traveling public according to slope movement.

Rate of displacement in roadway if known

- 3 points: <1-inch/year
- 9 points: 1 to 3-inches/year, no single event ≥1-inch
- 27 points: 3 to 6 inches/year, No single event ≥3-inches
- 81 points >6-inches/year, single event ≥3-inches

Evidence of total displacement in roadway

- 3 points: Visible crack without vertical drop
- 9 points: ≤1-inch of displacement
- 27 points: 1 to 3-inches of displacement
- 81 points: ≥ 3-inches of displacement

Figure 3.7 shows a displacement greater than 3 inches. Since this poses a high potential for causing an accident when the vehicles are traveling at high speed, a risk score of 81 points is assigned.

Figure 3.8 shows minor cracks, with a displacement less than 1 inch. Based on Table 3.1, the corresponding risk score is judged to be 9 points. The investigator must also consider both short term and potential long term risks in assigning scores.

Figure 3.9 and 3.10 show the undulation of a roadway. This type of roadway surface is sometimes difficult to be noticed when motorists are driving at a high speed. The vehicles may lose control and suffer a serious accident due to roadway unevenness. The risk score of 81 points is assigned for this case.

Figure 3.7 Displacement or cracks more than 3”, receiving a risk score of 81

Figure 3.8 Displacement less than 1”, receiving a risk score of 9 points

Figure 3.9 Roadway undulation/dip, receiving a risk score of 81

Figure 3.10 Roadway undulation/dip, receiving a risk score of 81

3.2.3 MAINTENANCE

Maintenance frequency is used to reflect the intensity/frequency of the past maintenance activity of a landslide site. The site with a high maintenance frequency indicates that the slope movement at that location is persistent. Therefore, as maintenance frequency increases, a sense of urgency to mitigate the problem becomes heightened.

If the maintenance frequency is not known, the investigator should determine the appropriate maintenance response. Figure 3.11 and 3.12 show a failing slope that affects the stability of a bridge. By best professional judgment, this slope requires an immediate response to preserve the stability of the bridge structure and the roadway. Thus, a hazard score of 81 points is assigned based on the consideration of maintenance response.

If feasible, the investigator should attempt to obtain maintenance history of the site. At a recently repaved roadway, the past failure histories may be hidden from visual inspection. An example of a newly paved site is shown in Figure 3.13. Without checking into maintenance history, an investigator may fail to notice the distress, thus underestimating the need for maintenance response. The criteria for determining numerical scores for the maintenance factor are as presented below.

Maintenance frequency

- 3 points: None to rare
- 9 points: Annually (one time/year)
- 27 points: Seasonal (1 to 3 times/ year)
- 81 points: Continuous throughout year (> 3 times/year)

Maintenance response

- 3 points: No response needed
- 9 points: Requires observation with periodic maintenance
- 27 points: Requires routine maintenance to preserve roadway
- 81 points: Requires immediate response for safe travel or to protect adjacent structure

Figure 3.11 Separation of the slope and a bridge structure

Figure 3.12 Effect of a slope failure to the stability of a bridge structure that requires immediate response

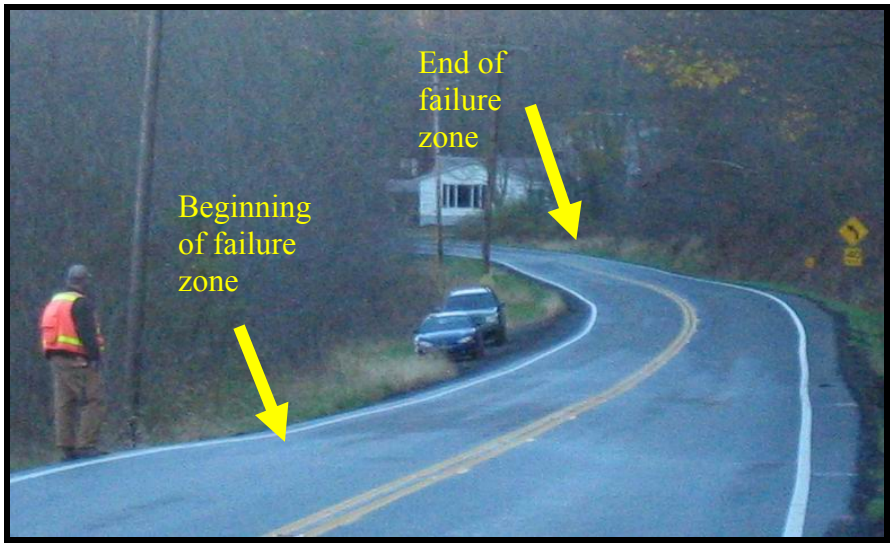


Figure 3.13 Newly paved roadway surface with evidence of failure that may not be obvious to the investigator

3.2.4 DECISION SIGHT DISTANCE (DSD)

The decision sight distance (DSD) is a comparison between the actual sight distance and the standard sight distance recommended by AASHTO (Table 3.2). Sight distance is the shortest distance along highway, at which an object of 6 inches high is continuously visible to a driver.

Calculating DSD

The actual sight distance is measured by placing a six-inch object at both BMP and EMP. The shortest distance that this object disappears from eye sight at the height of 3.5 ft above the road surface is the actual sight distance. The investigator needs to consider both traffic directions.

In some cases, the view of the landslide site may be obstructed by the vertical and horizontal curves. The actual sight distance is determined from the distance that a driver emerges from the curve and sees the six-inch object. Figures 3.14 through 3.161 show the measurement of the actual sight distance of a straight, vertically curved, and horizontally curved highway, respectively.

When the roadway is straight and flat, the actual sight distance can be measured by using the maximum distance that the six-inch object disappears from the driver's sight. In case of the vertical or horizontal curve (see Figure 3.17 and Figure 3.18 as an example), the actual sight distance is the furthest distance that a six-inch object can not be seen from the

driver's sight. After the actual sight distance is determined, the DSD can be calculated by using Equation 3.1.

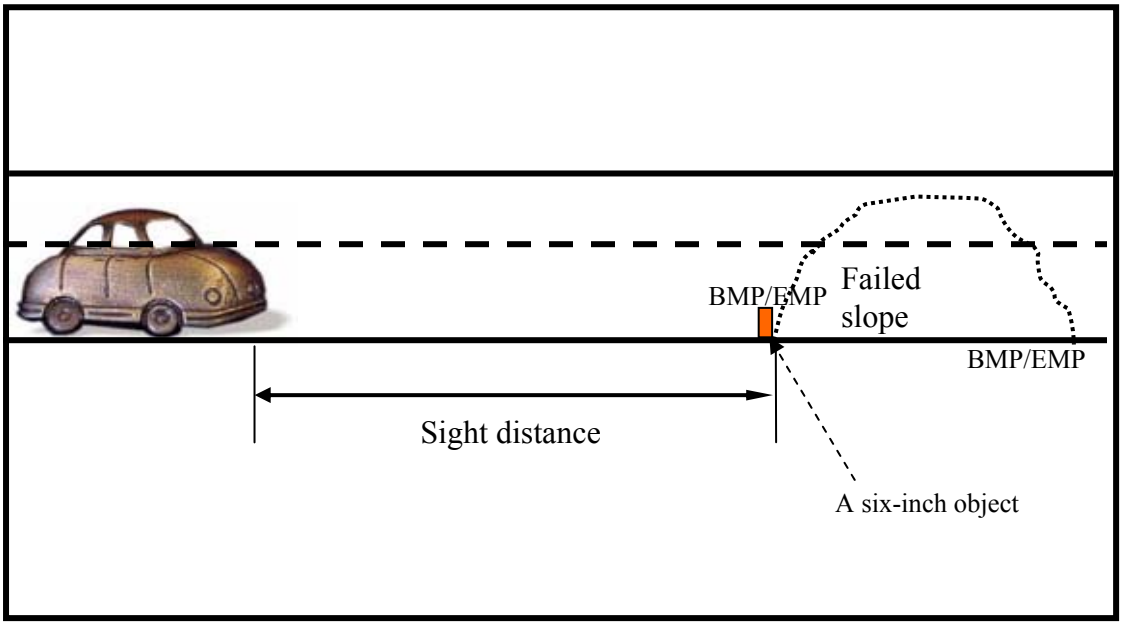


Figure 3.14 Sight distance measurement (straight roadway)

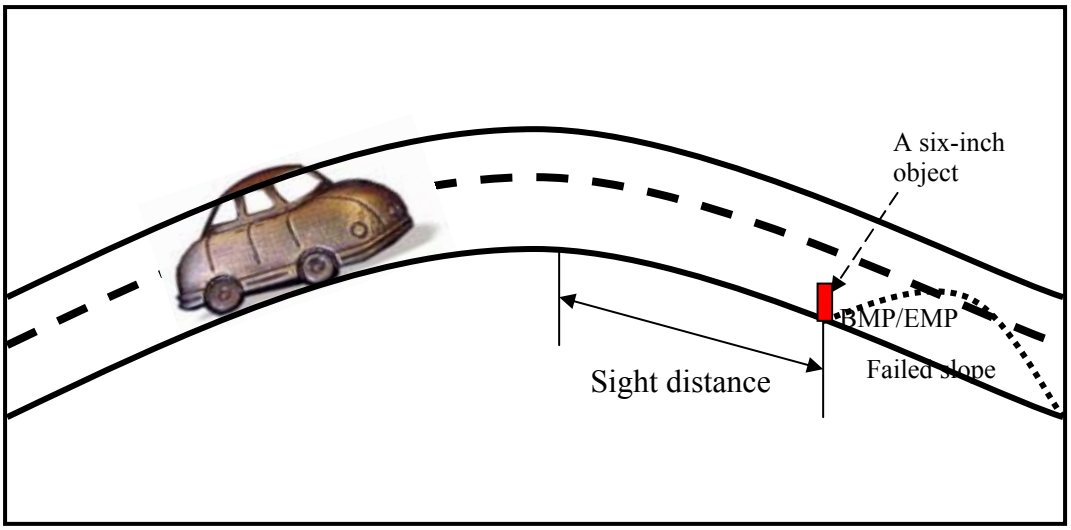


Figure 3.15 Sight distance measurement (vertical curve roadway)

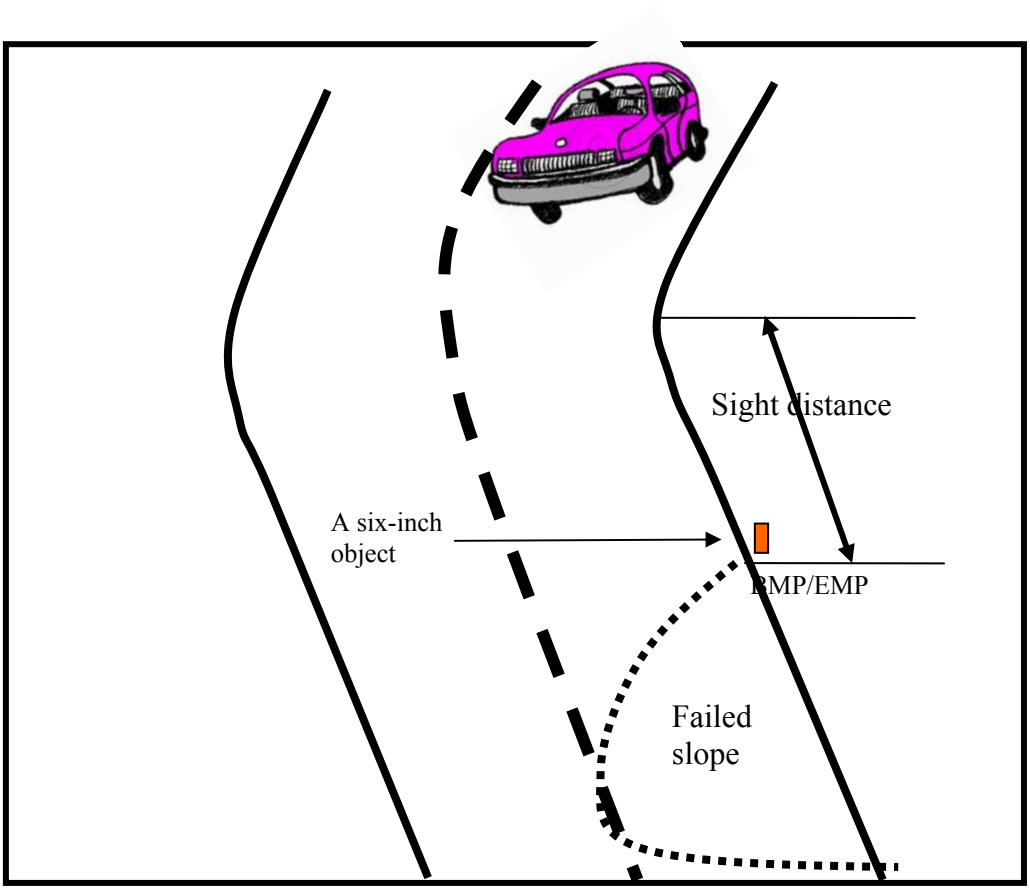


Figure 3.16 Sight distance measurement (horizontal curve roadway)

$$\frac{\text{Measured Sight Distance}}{\text{AASHTO Decision Sight Distance}} \times 100 = \text{Decision Sight Distance} \qquad (3.1)$$

Table 3.2 AASHTO Standard Decision Sight Distance

Posted speed limit (mph)	Decision sight distance (ft)
25	375
30	450
35	525
40	600
45	675
50	750
55	865
60	990
65	1050
70	1105
75	1180

The numerical scoring based on the decision sight distance follows the following criteria.

Decision Sight Distance (DSD) (%)

- 3 points: ≥ 90
- 9 points: 89 -50
- 27 points: 49-35
- 81 points: < 34

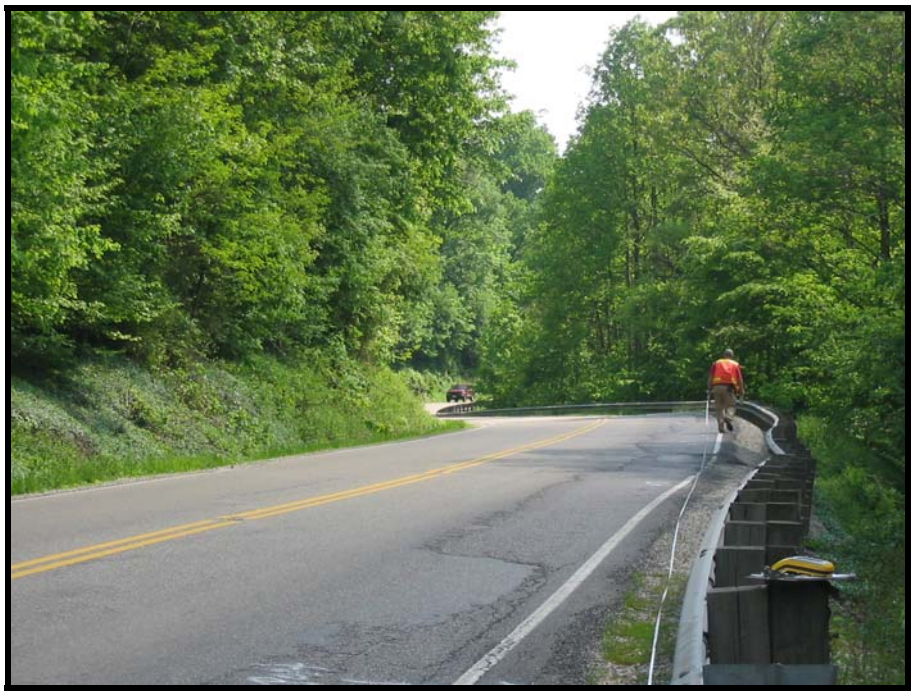


Figure 3.17 Example of a horizontal curve that could hide the slope hazard on the road ahead

Figure 3.18 A restricted sight distance due to vertical curve

3.2.5 AVERAGE DAILY TRAFFIC (ADT)

ADT is an average number of vehicles passing a landslide location per day. A landslide site with a high ADT number may imply that a higher number of accidents could occur due to landslide related hazards. ADT number also indicates the importance of the highway. Closing the highway for remediation may affect the regional economy. Therefore, with high ADT, earlier remediation of a landslide should be considered as a priority, thus a higher numerical score. The traffic number can be obtained from the web link provided in the Appendix F. An example of an ADT map is shown in Figure 3.19. The scoring criteria for taking ADT into account are specified as follows.

ADT

- 3 points: <2000 cars/day
- 9 points: 2001-5000 cars/day
- 27 points: 5001-15000 cars/day
- 81 points: >15001 cars/day

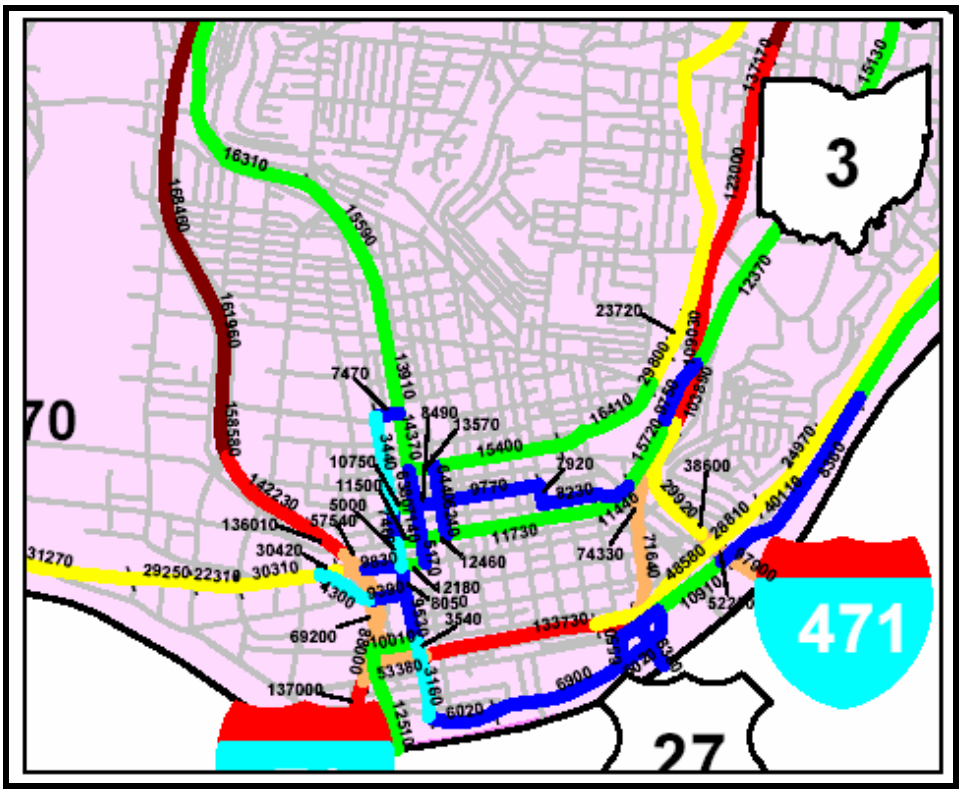


Figure 3.19 ADT map

3.2.6 ACCIDENT HISTORY

The accident history can be obtained from a highway traffic database if it is available. Alternative sources of information can be obtained from local organizations, such as local police office, highway patrol office, or sheriff department. The accident history is important in the landslide hazard assessment. In the case that a landslide location has shown records of injury or fatality due to landslide, the landslide site should receive high priority for remediation. The scoring criteria for the accident history factor are shown as follows.

Accident history

- 3 points: No Accident
- 9 points: Vehicle or Property Damage
- 27 points: Injury
- 81 points: Fatality

CHAPTER IV

LANDSLIDE RISK ASSESSMENT EXAMPLES

4.1 OBJECTIVE OF LANDSLIDE RATING EXERCISE

This chapter provides three examples of rating a landslide site by using the developed rating matrix. The site sketches and collected data using the Landslide Field Reconnaissance Form are provided as well. The exercise of going through the three examples should help demonstrate the proper application of rating factors in determining numerical scores.

4.2 EXAMPLE 1

4.2.1 SITE DESCRIPTION

The slope was mainly constructed with the fill material. The fill material on the existing natural slope consisted of a combination of gravel, clayey silt, silty clay, rock fragment, and shale. The embankment was constructed for a bridge approach. During the time of investigation, pavement patching was noticed. Dips and drops of the pavement were noticeable. Multiple cracks were observed on both traffic directions.

The slope failure was speculated to be a translational slide. There was a stream located at the toe of the slope, which may have caused erosion and aggravated the slope instability. The degradation of the fill material may also have caused the instability of the slope. The investigator also considered that the fill material may be compacted directly on the existing slope without benching or without elimination of vegetation. The failure was speculated to occur along the interface between the original ground and the fill material.

Figure 4.1 Northbound lane direction

Figure 4.2 Southbound lane direction

4.2.2 RISK ASSESSMENT

Movement Location and Impact

The slope failure may have impacted on both traffic lanes, as shown in Figure 4.1 and 4.2. Dips and cracks on pavement surface were noticeable on both traffic directions as well. Significant drops and separation between the fill material and bridge structure as well as misalignment of guardrail were noticeable as shown in Figure 4.3. There were multiple cracks on the bridge abutment, as shown in Figure 4.4. A hazard score of 81 points was assigned for this factor.

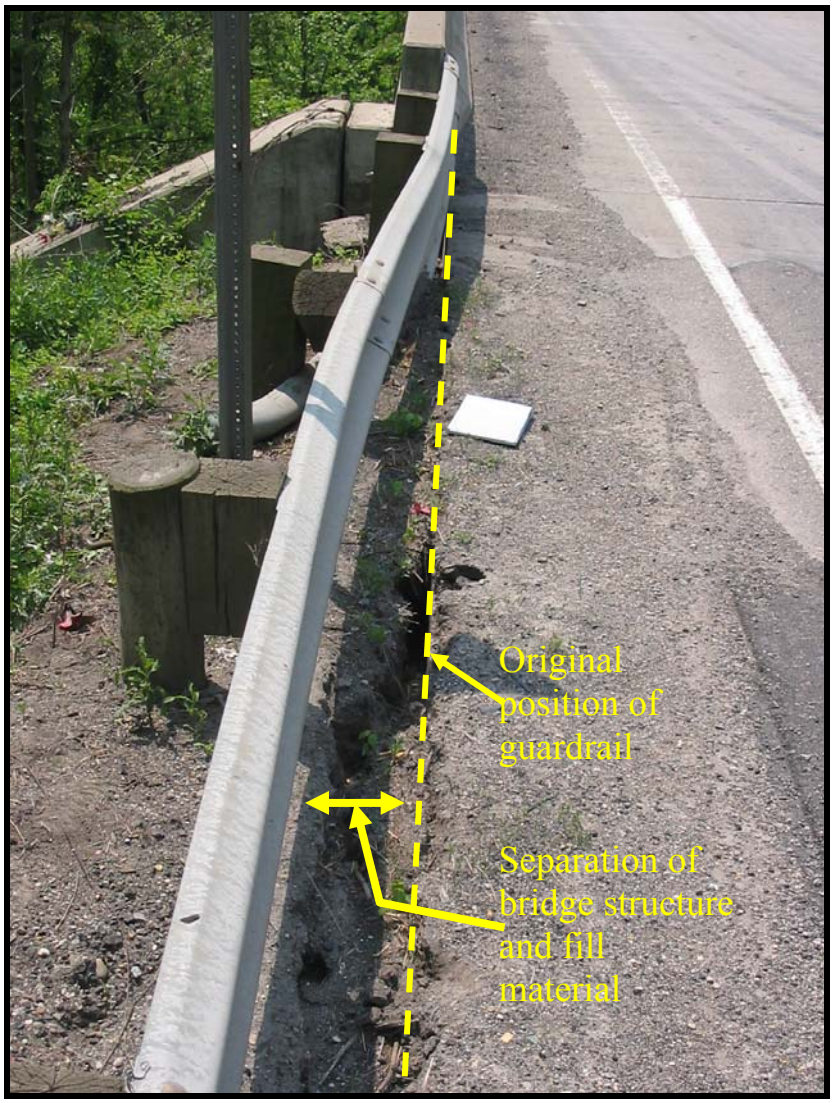


Figure 4.3 Separation between embankment and bridge structure

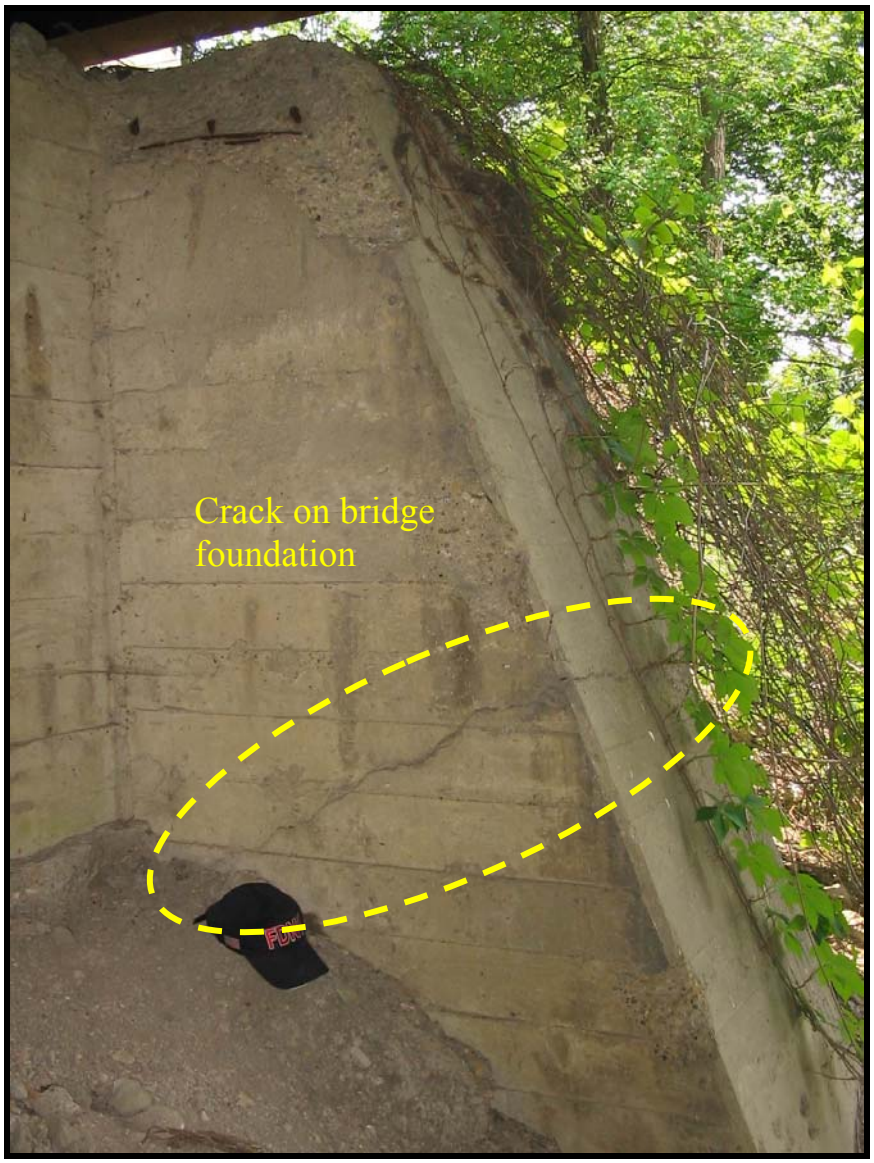


Figure 4.4 Cracks at the bridge foundation

Hazard to Traveling Public

The rate of movement was not available at the time of site investigation. The displacement observed on the roadway was used to assign the numerical score for this risk factor. As seen in Figure 4.3, there was approximately a foot of separation between the bridge structure and the fill material. Due to recently paved roadway surface, the displacement on the pavement surface was not visible at the time of investigation. The hazard score of 81 points was assigned to this risk factor.

Maintenance

Maintenance history was not available at the time of site investigation. However, some cracks on the bridge substructure and separation between the fill material and the bridge structure were observed. Therefore, the response for maintenance required immediate response for safety of vehicles and stability of the bridge structure. The hazard score of 81 points was assigned to this risk factor.

Decision sight distance (DSD)

The posted speed limit at the site location is 55 miles/hr. A six-inch object was placed on the edge of pavement closest to where the failure has started as shown in Figure 4.5. The sight distances were measured in both traffic directions. The shortest sight distance of 300 ft was taken, which is the distance that the six-inch object disappeared from the sight at the height of 3.5 ft above the road surface. According to ASSHTO standard, at the speed limit of 55 mph, the standard sight distance is 875 feet. Therefore, the DSD is calculated as 34%. The hazard score of 81 points was assigned to this risk factor.

Figure 4.5 Location of six-inch object

Average Daily Traffic

The traffic count was obtained from ODOT traffic map as shown in Figure 4.6. The traffic volume at the site is 10,110 vehicles per day. Therefore, the hazard score of 27 points was assigned to this risk factor.

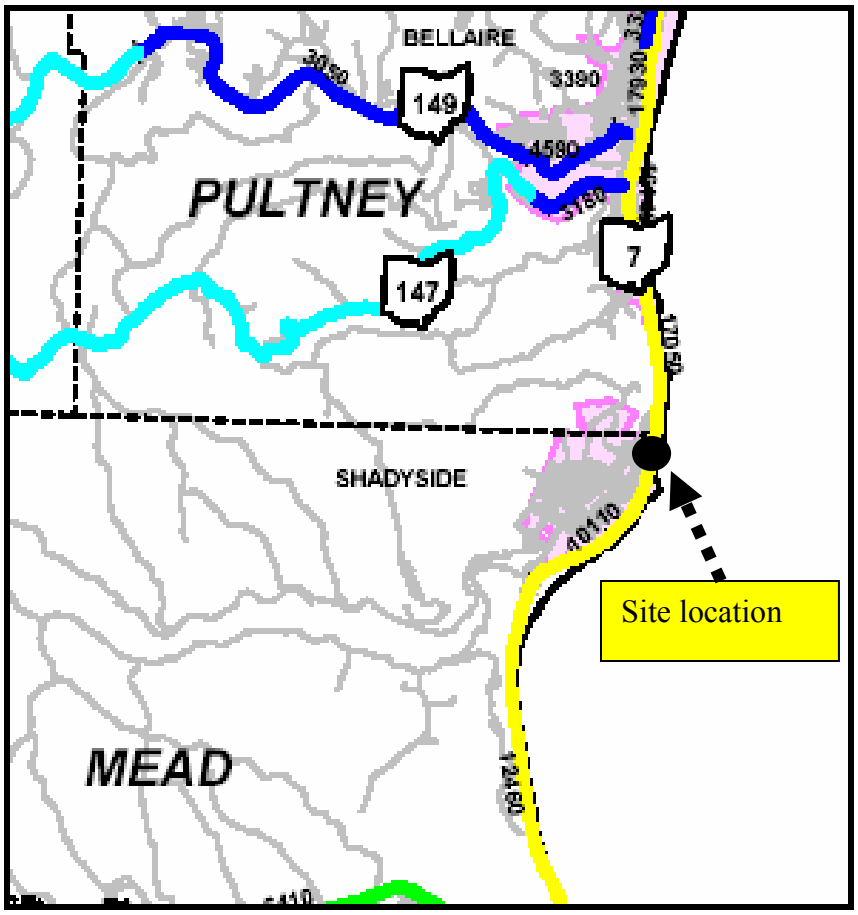


Figure 4.6 A traffic map for example 1

Accident History

Accident history can be obtained from the ODOT district office and the website link provided in Appendix F. Sometimes, accident history related to the landslide site may not be well documented. Interviewing local people could be an alternative approach to obtain accident history. This accident history at the site was classified to be “injury”. The hazard score of 27 points was assigned to this category.

Total Risk/Hazard Score

The total hazard score of this site is tabulated in Table 4.1. The numerical hazard score of 378 indicates that this landslide site is in the category of high hazard potential.

Table 4.1 Total risk/hazard score potential of example 1

Parameter	**Risk/Hazard Score**
Movement Location and Impact	81
Hazard to Traveling Public	81
Maintenance	81
Decision sight distance (DSD)	81
Average Daily Traffic	27
Accident History	27
Total	378

4.3 EXAMPLE 2

4.3.1 SITE DESCRIPTION

The slope failure is located at the roadway shoulder of a state route highway. The cracks, shown in Figure 4.7, were approximately 1 to 5 inches wide. Also, as shown in Figures 4.7 and 4.8, the guardrail was moved from the original location. The area in the middle of the failed slope was very wet, where cattails can be seen. The evidence of this type of vegetation suggests perhaps the pipes connected to the catch basin upslope were leaking. The type of movement is judged to be rotational slide. The materials of the slope are combinations of silty clay with trace of gravel. The drainage ditch connected to the lake is at the toe of slope as shown in Figure 4.9. The fluctuation of water level in the lake may have triggered the slope instability. The toe out area may be located in the drainage ditch or beyond.

4.3.2 RISK ASSESSMENT

Movement Location and Impact

The impact of the landslide is on the roadway shoulder. Based on judgment, the hazard to the roadway was considered as moderate. The hazard score of 27 points was assigned to this risk factor.

Hazard to traveling public

The displacement on the pavement shoulder was more than 3 inches. Therefore, the hazard score of 81 was assigned to the risk factor.

Maintenance

The maintenance response for this site was classified as "requires routine maintenance response to preserve roadway" as the cracks on the roadway shoulder were significant, and somewhat close to the traffic lane. Thus, the hazard score of 27 points was assigned to this risk factor.

Decision sight distance (DSD)

The post speed limit was 55 mile/hr. The actual sight distance was longer than 1,000 feet. The decision sight distance was 100%, which is greater than 90%. Therefore, the hazard score of 3 points was assigned to this risk factor.

ADT

Based on the traffic map shown in Figure 4.10, there are about 16,330 vehicles/day. Thus, the hazard score of 81 was assigned to this risk factor.

Accident history

There is no accident history for this landslide site. The hazard score of 3 points was assigned to this risk factor.

Figure 4.7 Cracks on roadway shoulder and displacements of guardrails

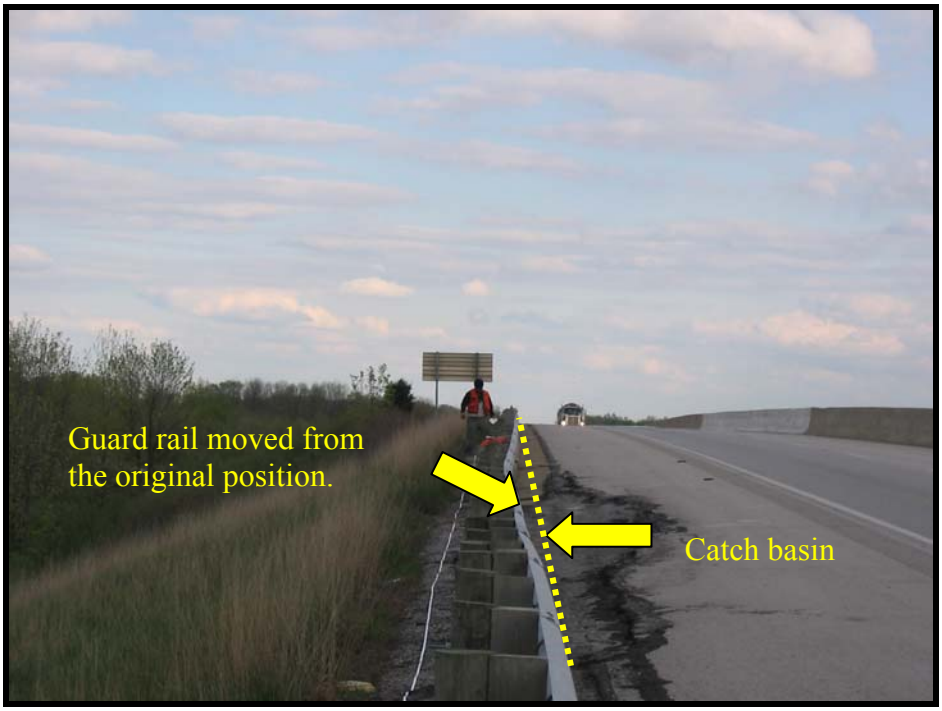


Figure 4.8 Guardrail movement, location of catch basin

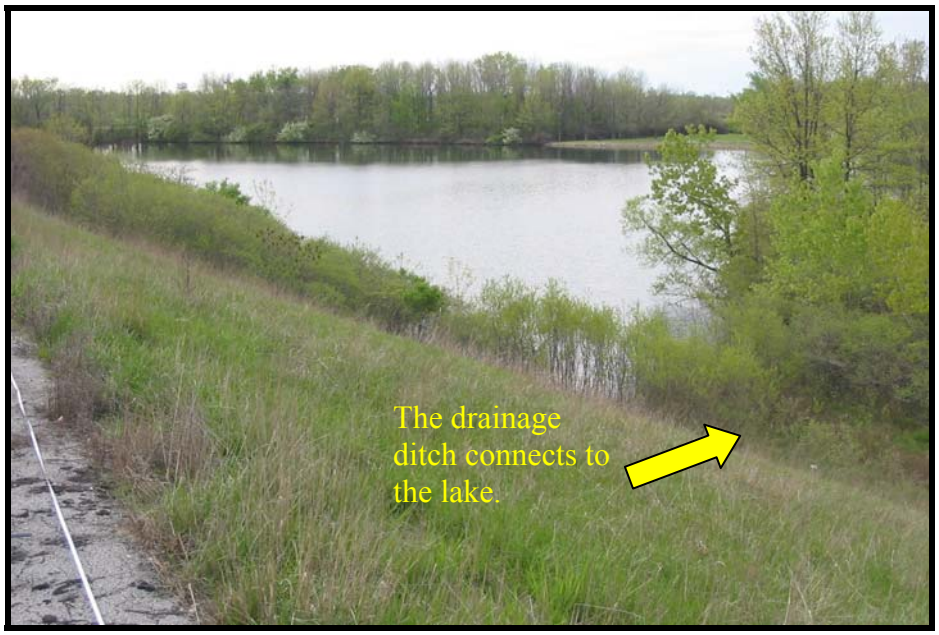


Figure 4.9 Lake at the toe of embankment

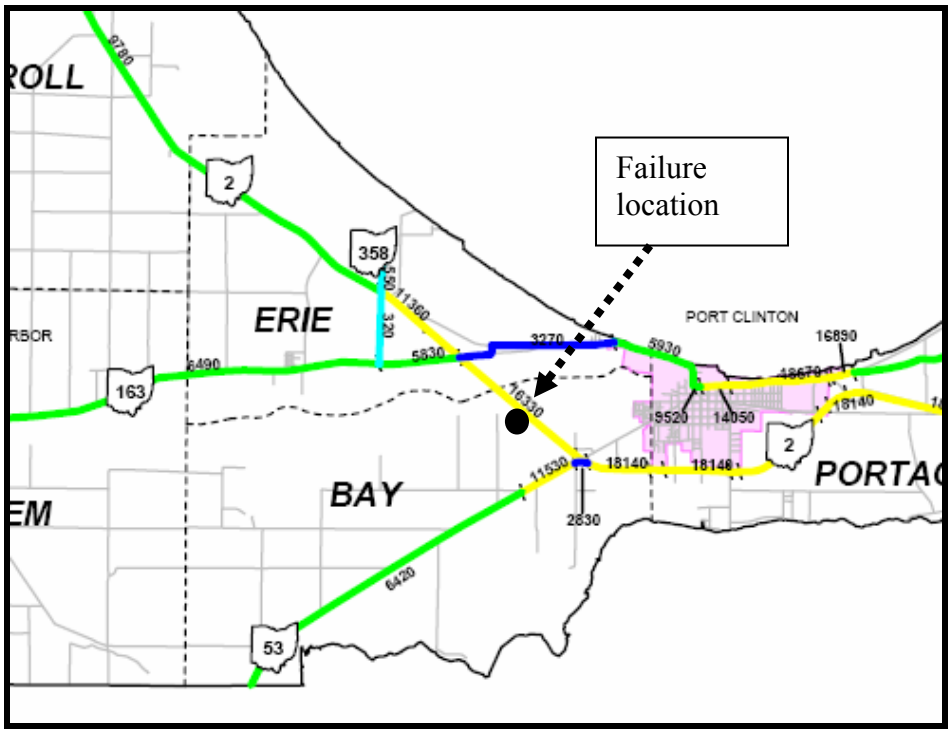


Figure 4.10 A traffic map for example 2

Total Risk/Hazard Potential

The total hazard score of this site is summarized in Table 4.2. The numerical hazard score of 222 points indicates that this site is in the category of "moderate hazard".

Table 4.2 Total risk/hazard score potential of example 2

Parameter	**Risk/Hazard Score**
Movement Location and Impact	27
Hazard to Traveling Public	81
Maintenance	27
Decision sight distance (DSD)	3
Average Daily Traffic	81
Accident History	3
Total	222

4.4 EXAMPLE 3

4.4.1 SITE DESCRIPTION

The site is a side hill fill slope. Cracks and surface patching exist in many places on the pavement as shown in Figures 4.11, and 4.12. The cause of this slope failure may be the result of the deterioration of the fill material and the improper method of construction. The fill material consisted of silty clay and silty sand with trace of rock fragments. Creek at the toe of the fill slope causes erosion and movement. The old riprap found along the toe of the slope indicates either that the site might have experienced failure movement before. However, riprap could also be placed at the time of original construction.

Figure 4.11 Crack line on pavement

Figure 4.12 Surface patching and transverse cracks

4.4.2 RISK ASSESSMENT

Movement Location and Impact

The impact of the landslide is on both directions of the traffic lanes. Based on the professional judgment, the hazard to the roadway was considered as high hazard. The hazard score of 81 points was assigned to this risk factor.

Hazard to traveling public

The hairline cracks were visible on roadway. The horizontal and vertical displacements were not observed. The hazard score of 3 points was assigned for this risk factor.

Maintenance

The investigator determined that the maintenance response for this site was "observation". The hazard score of 9 was assigned to this risk factor.

Decision sight distance (DSD)

According to AASHTO, at the speed limit of 55 mile/hr, the standard decision sight distance is 865 ft. The decision sight distance measured at this landslide site was 300 ft. This is approximately 34% of standard decision sight distance. Thus, the hazard score of 81 points should be given to this category.

ADT

Based on the traffic map shown in Fig. 4.13, there are about 1,610 vehicles /day. Thus, this site should receive the score of 3 points.

Accident history

There is no accident history report at the site. The hazard score of 3 points was assigned to this risk factor.

Total Risk/Hazard Potential

The total of hazard score for this site is summarized in Table 4.3. The numerical hazard score of 180 points indicates that this site should be categorized as "moderate hazard".

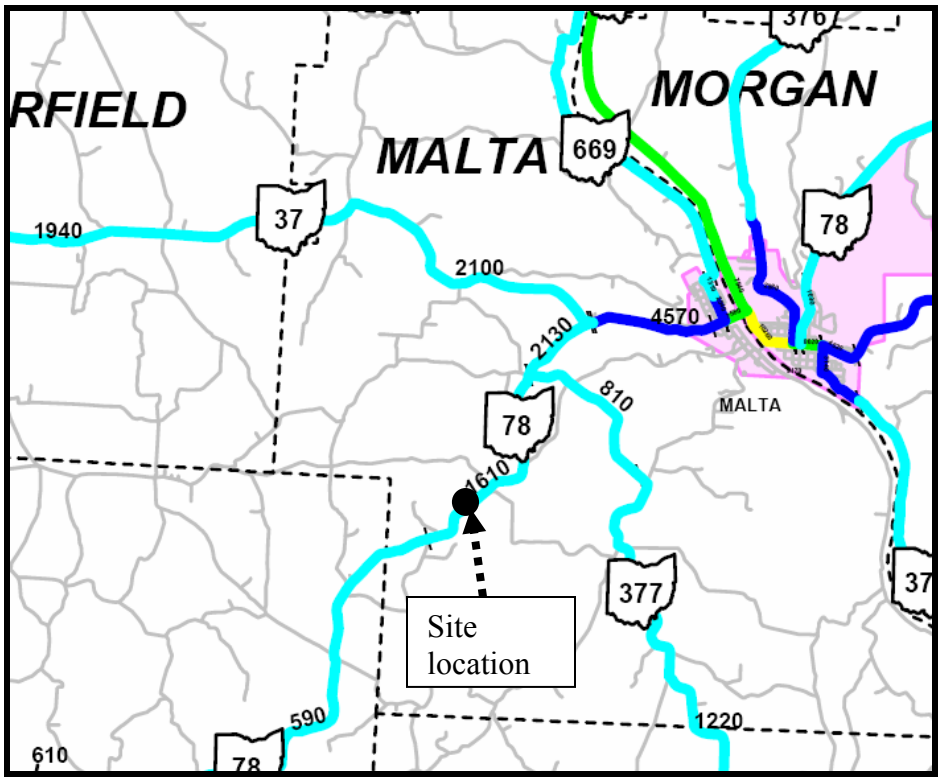


Figure 4.13 A traffic map for example 3

Table 4.3 Total risk/hazard score potential of example 3

Parameter	Risk/Hazard Score
Movement Location and Impact	81
Hazard to Traveling Public	3
Maintenance	9
Decision sight distance (DSD)	81
Average Daily Traffic	3
Accident History	3
Total	180

Note: As the three examples of landslide risk/hazard rating exercises are illustrated in this chapter, we can see that the most important issue is how to consistently assess the parameters that rely on the judgment: (i) Movement Location and Impact, (ii) Hazard to Traveling Public, (iii) Maintenance. More examples are presented in Appendix D to provide more experience and help for the users in assigning numerical scores in a consistent manner.

CHAPTER V

GIS DATABASE AND ACCESS VIA INTERNET

5.1 OVERVIEW

This chapter provides instructions for a user to access via an internet portal and to navigate through the ODOT Landslide Hazard Management Database. A diagram showing functions of each database feature is displayed in Figure 5.1. As can be seen, a total of 5 main database components can be identified: (i) Data Management, (ii) ShapeFile Update, (iii) System Management, (iv) GIS Query, and (v) User Forum.

5.2 USER LOGIN AND PRIVILEGES

A new user should request a new username and password from an administrator. The administrator would register and assign appropriate user group privileges to a new user. Database users are classified into seven groups, each with its associate user privileges. The user groups include: (i) normal users, (ii) county power users (CM/TM), (iii) district power users (DGE), (iv) state power users, (v) system power users, (vi) administrators, and (vii) supervisors. It is recommended that before the new user starts using the system, he/she should check his/her assigned privileges in Table 5.1, so that there will be no mishandling of the system by unintended personnel. Furthermore, the system has a built in function that would automatically match the accessibility of system with the user group designation.

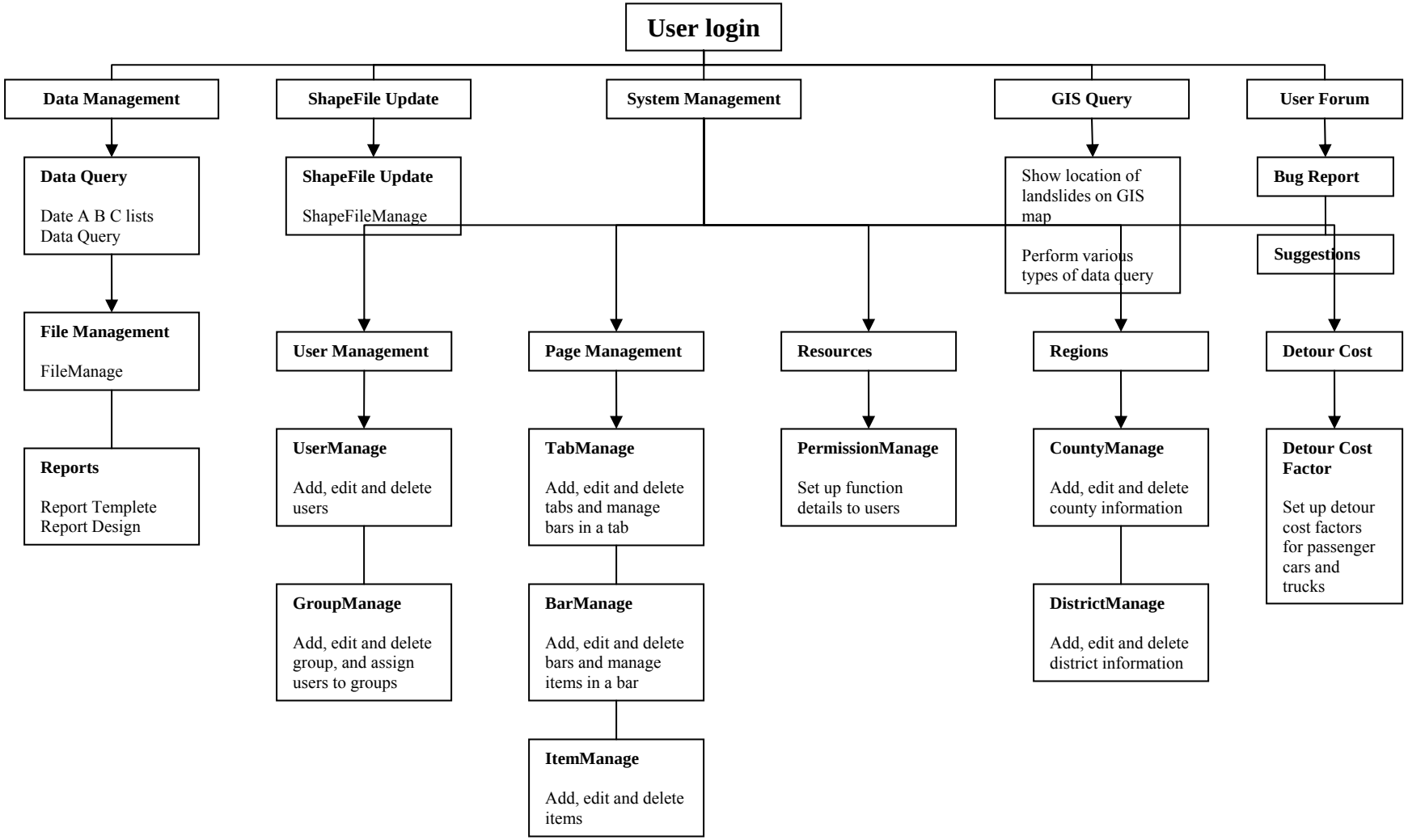


Figure 5.1 Database components

Table 5.1 User privilege

User / Privilege	Normal User	CM/TM	DGE	State Power User	Administrator	System Power User	Supervisor
Download (Section 5.5.1 and 5.5.2)	√	√	√	√	√	√	√
Upload shapefiles and information into database (Section 5.5.1 and 5.5.2)		√	√	√	√	√	√
Data query (Section 5.4.1.4)	√	√	√	√	√	√	√
GIS query (Section 5.7)		√	√	√	√	√	√
Add/Edit Parts A and B (Section 5.4.1.1 and 5.4.1.2)		√	√	√	√	√	√
Add/Edit Part C (Section 5.4.1.3)			√	√	√	√	√
Delete Parts A, B, and C (Section 5.4.1.1, 5.4.1.2 and 5.4.1.3)				√	√	√	√
Manage landslide pictures (Section 5.4.2)		√	√	√	√	√	√
Manage regional information (County and District) (Section 5.6.4)				√	√	√	√
Merge shapefiles in GIS server (Section 5.5.1)				√	√	√	√
Design of webpage configuration (Page Manage) (Section 5.6.3)						√	√
User registration (Use Manage) (Section 5.6.1)					√		√
Set user privileges (Section 5.6.2)							√

5.3 COMPONENTS OF DATABASE AND THEIR FUNCTIONALITIES

This section explains each component and general functions of the ODOT Landslide Hazards Management System (LHMS) as accessed through an internet portal. The website of the ODOT LHMS portal can be reached at http://landslidetest.ascn3.uakron.edu/gisView. The first page of the website is shown in Figure 5.2. The user fills in the *username, password and verify code* and then clicks on the *login* button. It would display a new window as shown in Figure 5.3. Note: a user may not see all database components illustrated in this chapter because each user is limited to access certain functions according to his/her assigned user group designation.

In Figure 5.3, a user can see the five main components that control the functionalities of the database. These components are *Data Management, ShapeFile Update, System Management*, *Gis Query, and User Forum*, which are marked as 1, 2, 3, 4 and 5 respectively in the figure. Clicking on each component would reveal its sub-components, which are shown on the left column in Figure 5.3. Database components and subcomponents are discussed in detail in next sections.

Figure 5.2 User login window

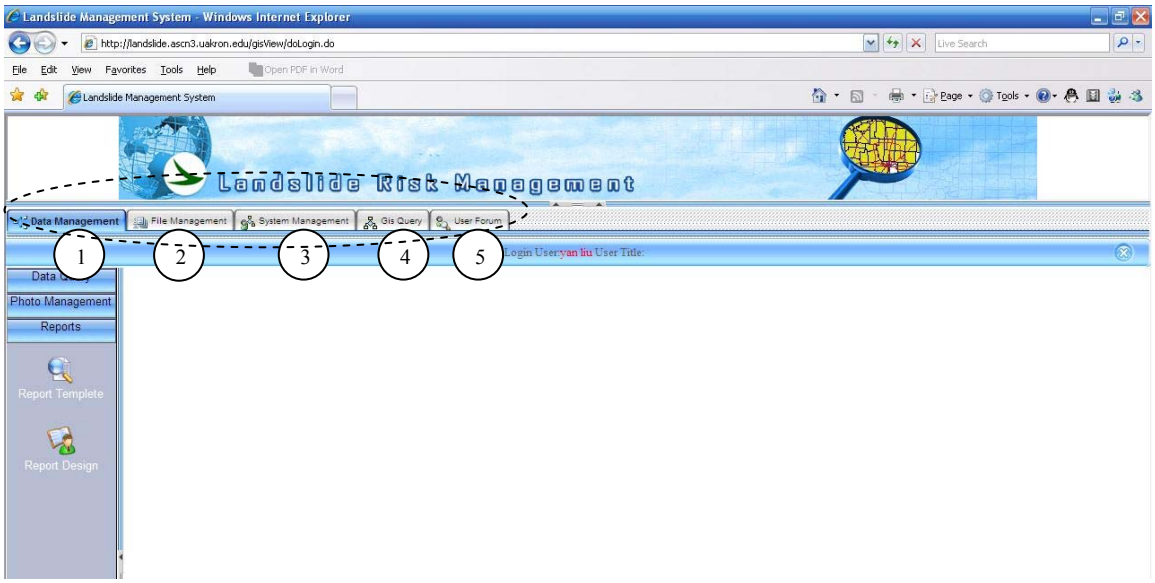


Figure 5.3 Front page

5.4 DATA MANAGEMENT

Data Management provides a mean for a user to dynamically interact with information in the database. A user can view and query the landslide site information. The user can upload and download information and the associated photos and sketches into and from

the database. Once a new landslide site and its associated information are generated in the database, the site location automatically appears on the GIS map. A user can also access each landslide site data via GIS map. Details of navigating through GIS map are provided later in Section 5.7.

Clicking on *Data Management,* marked as 1 in Figure 5.3, the user can see three sub-components, which are *Data Query*, *File Management, and Report Design.* Currently, *Report Design* is under construction.

5.4.1 DATA QUERY

In *Data Query*, there are several components that a user can use to explore and view the landslide site information stored in the database. When a user clicks on the *Data Query,* a bar numbered as 1 in the figure, the sub-components appear as shown in Figure 5.4. A user can view and query the landslide information. Also, a user can upload, download information and pictures. A user can search and view landslide information via Parts A, B, and C List. The Inspection and Data Query provides a search engine allowing a user to input search criteria to sort out information regarding landslide inspection schedule and landslide Forms A, B,C, respectively.

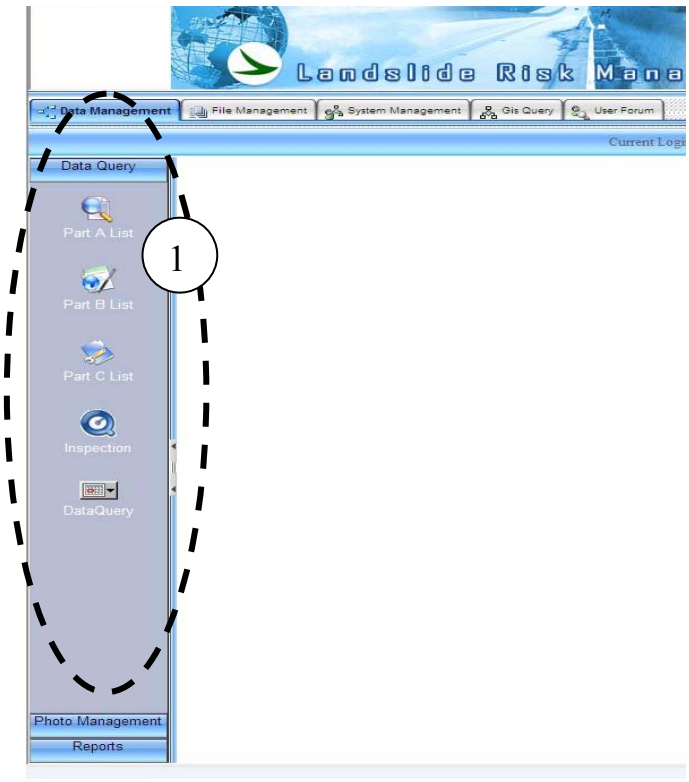


Figure 5.4 Data query

5.4.1.1 PART A LIST

Part A list is used to view Part A information of the Landslide Field Reconnaissance Form. Clicking on the *Part A list* icon, a user can view a list of sites that already had From A stored in the database system. A new window as shown in Figure 5.5 appears. There is a search engine embedded in this section as a pull down menu, which allows the user to select the pertinent information of interest. To use this option, the user simply selects the search criteria embedded in the dropdown boxes and clicks *Go*. It would show a list of Par A relevant to the search option specified by the user.

There are also several functions in the Part A list that would help a user to manage information in the database. These functions are listed on the right top of the window, including *FileManage, Part B Data, Add New, Modify Data, Detail,* and *Delete,* as shown as 2 in Figure 5.5.

Managing pictures

FileManage is used to delete and upload site pictures to *Part A list*. Before a picture can be linked to a site, it should be loaded to database. A process to load pictures into database is explained in Section 5.4.2. A procedure to associate or disassociate a picture with a particular landslide site is as follows:

1. Select a site that you want to associate a picture with (Figure 5.5).
2. Click on *FileManage* on the right top of menu. It pops up a new page as shown in Figure 5.6.
3. Click on *Add File* on the upper left corner of Figure 5.6, a new window appears as shown in Figure 5.7. This window shows a list of pictures that can be associated with the site.
4. Select a picture or a group of pictures to be associated with the site.
5. Click on *Select Pic* on the right top of Figure 5.7. The picture is now associated with the site.
6. To disassociate a picture from a site, select the picture to be disassociated as shown in Figure 5.6.
7. Click on *Delete File*. The picture is disassociated from the site.

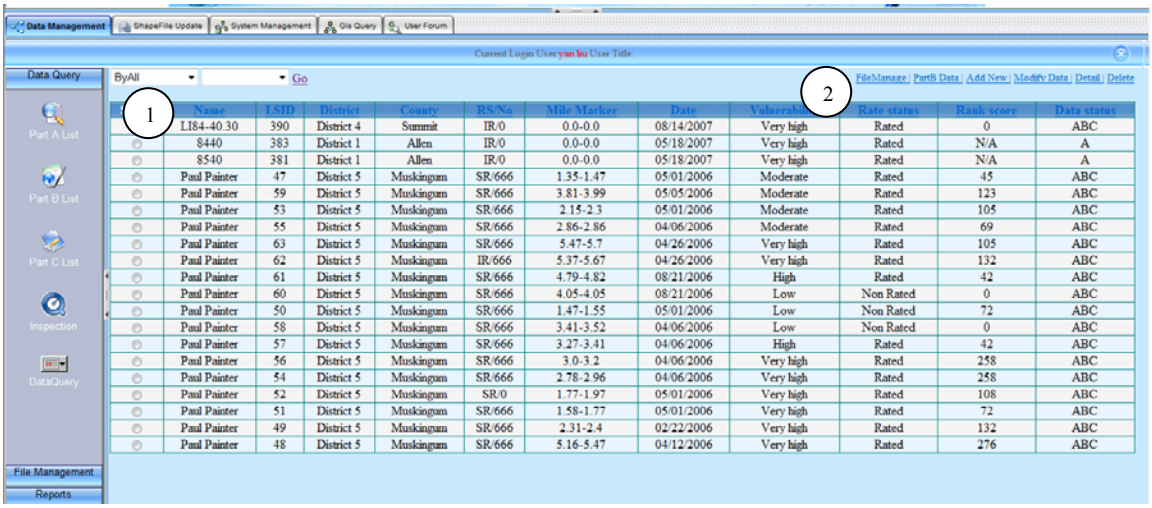


Figure 5.5 Part A list

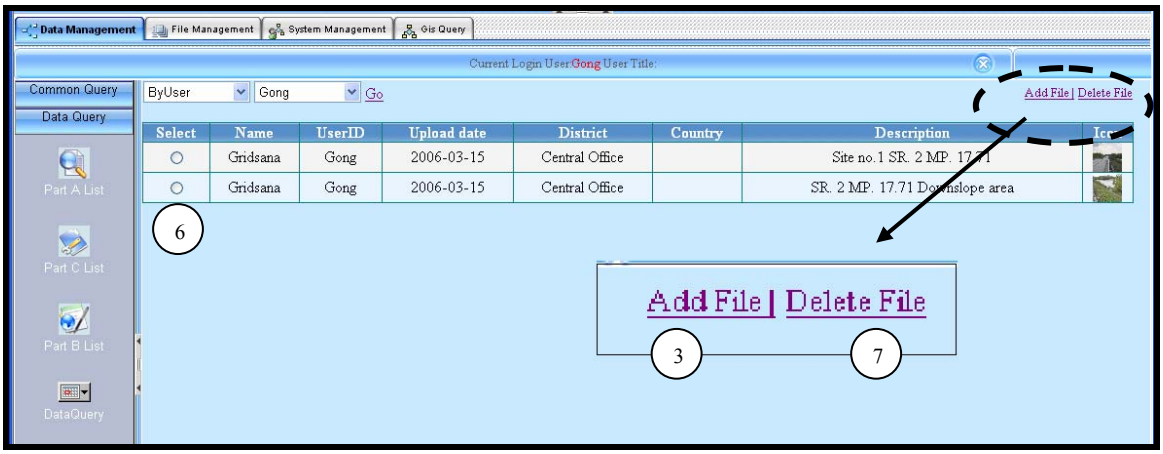


Figure 5.6 Associate and disassociate pictures with a site (1)

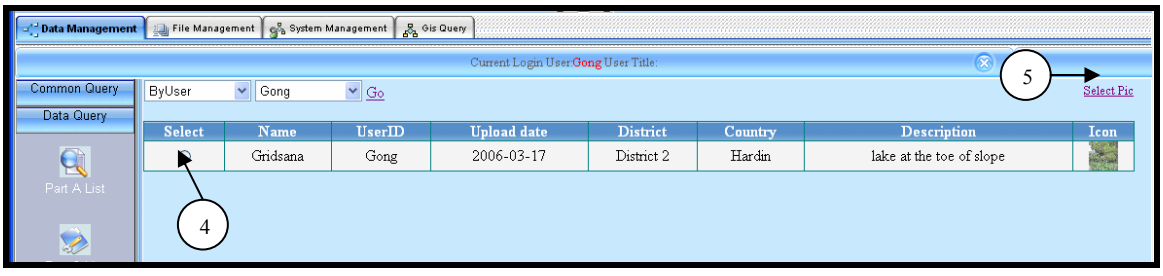
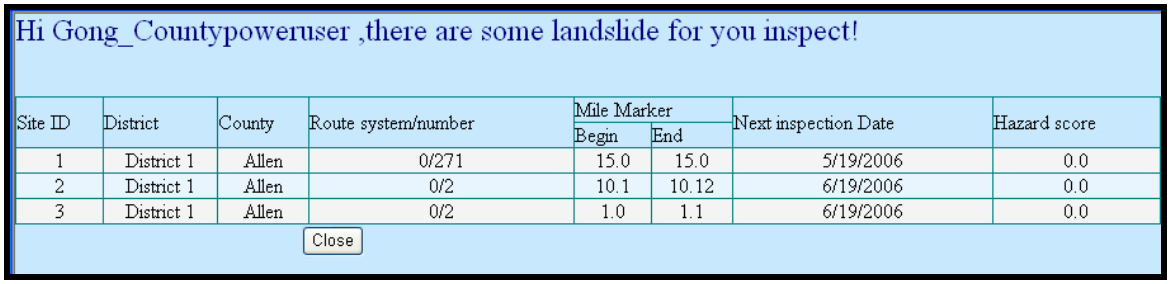


Figure 5.7 Associate and disassociate pictures with a site (2)


Hi Gong_Countypoweruser ,there are some landslide for you inspect!

Site ID	District	County	Route system/number	Mile Marker		Next inspection Date	Hazard score
				Begin	End		
1	District 1	Allen	0/271	15.0	15.0	5/19/2006	0.0
2	District 1	Allen	0/2	10.1	10.12	6/19/2006	0.0
3	District 1	Allen	0/2	1.0	1.1	6/19/2006	0.0

Close

Figure 5.8 Schedule report

Add/Modify/Review information in Part A list

A qualified user (consult Table 5.1 to see which user group can perform this function) can add, modify, or review information of a site by selecting the site and then clicking on *AddNew, Modify Data*, and *Detail*, respectively (see Figure 5.5).

Delete information in Part A list

A qualified user can delete the Part A information in the Part A list by selecting the site and then clicking on *Delete*. The Part A information is deleted from the Part A list. User will be prompted to confirm before "Delete" is taken action.

Part B Data

A user can review, modify, delete, or add the Part B information. To perform these tasks, the user selects the site and then clicks on the *PartB Data*, as shown in Figure 5.5. A list of Part B that has been recorded for the selected site appears as shown in Figure 5.9. The

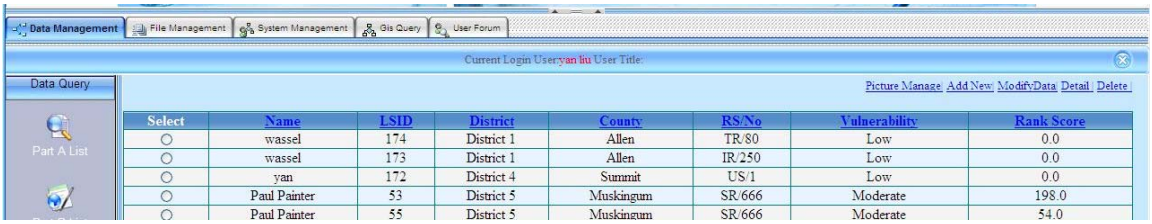
user can add, modify, review, or delete the Part B information by the same procedure as discussed for the *Part A List*.

Part C Data

A user can go to the *Part C Data* by selecting the site and then clicking on *Part C Data*. A new window appears, showing a list of the Part C information of the selected site as demonstrated in Figure 5.10. The procedure to add, modify, review, and delete the Part C information is the same as it is previously discussed in PartA, and PartB Data.

Select	Name	LSID	District	County	RS/No	Mile Marker	Date	ADT	MTFrequency	MTCost	Rank Score	Data Status
○	Wassel	174	District 1	Allen	TR/80	0.0-0.0	04/09/2007	20000	6	2.0	0	ABC
○	wassel	173	District 1	Allen	IR/250	0.0-0.0	04/09/2007	10000	7	50000.0	0	ABC
○	yan	172	District 4	Summit	US/1	105.0-199.0	04/08/2007	3000	30	300000.0	0	ABC
○	Paul Painter	63	District 5	Muskingum	SR/666	5.47-5.7	04/26/2006	0	0	0.0	186	ABC
○	Paul Painter	62	District 5	Muskingum	IR/666	5.37-5.67	04/26/2006	0	0	0.0	132	ABC
○	Paul Painter	61	District 5	Muskingum	SR/666	4.79-4.82	08/21/2006	0	0	0.0	42	ABC

Figure 5.9 Part B data



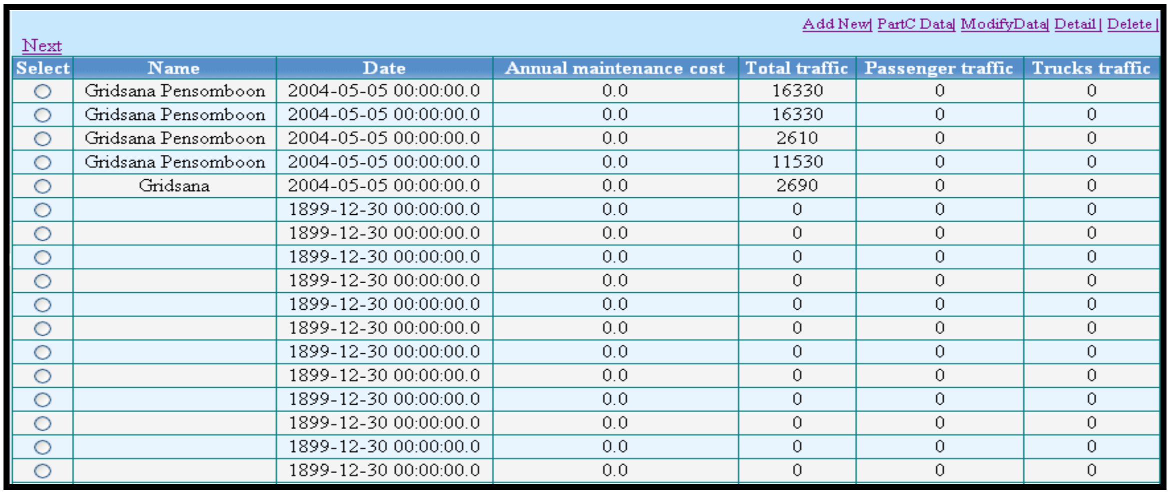
Select	Name	LSID	District	County	RS/No	Vulnerability	Rank Score
○	wassel	174	District 1	Allen	TR/80	Low	0.0
○	wassel	173	District 1	Allen	IR/250	Low	0.0
○	yan	172	District 4	Summit	US/1	Low	0.0
○	Paul Painter	53	District 5	Muskingum	SR/666	Moderate	198.0
○	Paul Painter	55	District 5	Muskingum	SR/666	Moderate	54.0

Figure 5.10 Part C data

5.4.1.2 PART B LIST

Part B list stores the Part B information of the entire database. By clicking on the *Part B List* icon as shown in Figure 5.4, a new window containing a list of Part B for all sites in

the entire website appears as shown in Figure 5.11. A user can manipulate the Part B and Part C information by following the steps as previously mentioned in section 5.4.1.1.

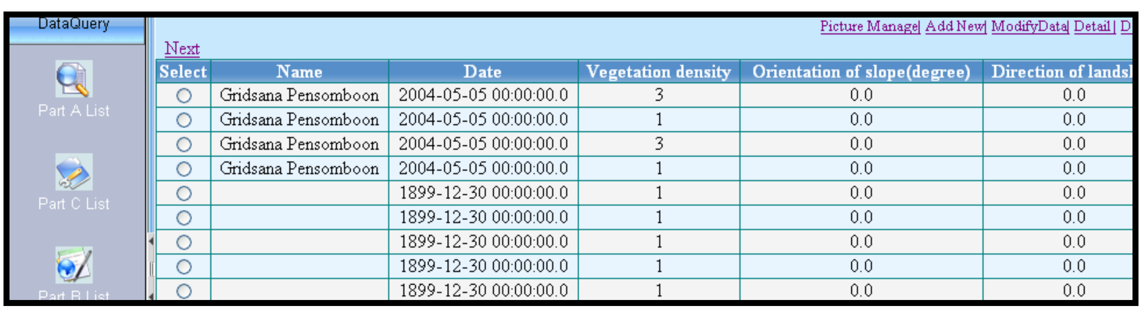


Select	Name	Date	Annual maintenance cost	Total traffic	Passenger traffic	Trucks traffic
○	Gridsana Pensomboon	2004-05-05 00:00:00.0	0.0	16330	0	0
○	Gridsana Pensomboon	2004-05-05 00:00:00.0	0.0	16330	0	0
○	Gridsana Pensomboon	2004-05-05 00:00:00.0	0.0	2610	0	0
○	Gridsana Pensomboon	2004-05-05 00:00:00.0	0.0	11530	0	0
○	Gridsana	2004-05-05 00:00:00.0	0.0	2690	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0
○		1899-12-30 00:00:00.0	0.0	0	0	0

Figure 5.11 Part B list

5.4.1.3 PART C LIST

A user can click on the *Part C* list icon to reveal a list of Part C of all sites for the entire database. The user can add picture and add, modify, review and delete Part C information. The procedure to perform these tasks is the same as previously discussed in Section 5.4.1.1.



Select	Name	Date	Vegetation density	Orientation of slope(degree)	Direction of landsl
○	Gridsana Pensomboon	2004-05-05 00:00:00.0	3	0.0	0.0
○	Gridsana Pensomboon	2004-05-05 00:00:00.0	1	0.0	0.0
○	Gridsana Pensomboon	2004-05-05 00:00:00.0	3	0.0	0.0
○	Gridsana Pensomboon	2004-05-05 00:00:00.0	1	0.0	0.0
○		1899-12-30 00:00:00.0	1	0.0	0.0
○		1899-12-30 00:00:00.0	1	0.0	0.0
○		1899-12-30 00:00:00.0	1	0.0	0.0
○		1899-12-30 00:00:00.0	1	0.0	0.0
○		1899-12-30 00:00:00.0	1	0.0	0.0

Figure 5.12 Part C list

5.4.1.4 INSPECTION

A schedule for the next site visit is shown when clicking on *Inspection* as illustrated in Figure 5.5. Once clicked, a report in a new window appears as shown in Figure 5.8. Information regarding landslide site, such as *LSID, District, County, RS/No, Mile Marker, Last inspection Date, Interval, Inspection status, Rank Score and Data Status* is included in the Inspection Report.

5.4.1.5 DATA QUERY

DataQuery provides a user with useful search options. Once a user clicks the *DataQuery* icon as shown in Figure 5.4, a new window appears as in Figure 5.13. The *search mode* criteria in a dropdown box, as seen in Figure 5.13 can be selected. The information based on the selected search mode would appear. Also, individual District, County, Jurisdiction, Route System and Route Number can be selected as one of search criteria.

Figure 5.13 DataQuery window

5.4.2 FILE MANAGEMENT

File Management is for a user to store landslide pictures or other image files in the database (see Figure 5.14). Once pictures are loaded into the system, the user can

associate them to a particular landslide site. The procedure to associate a picture to a landslide site has been described previously in section 5.4.1.1 (*FileManage*). To load pictures to the system, the user can follow the following procedures.

Loading landslide pictures to system

1. Click on the *File Management* bar (Figure 5.14).
2. Click on the *File Manage* icon under the *File Management* bar (Figure 5.14). A window as shown in Figure 5.15 appears which provides a list of pictures that have been previously loaded into the system.
3. A user can use the search filters to review pictures that are previously added into the system.
4. To add a picture, click on *Add File* as seen in Figure 5.15. A window, as seen in Figure 5.16, appears where the user inputs the required information, such as name, username, district, county and descriptions. Then, the user browses to where the picture is stored in his/her computer, and finally clicks on the *Submit* button. The picture is uploaded to the system.
5. To delete a picture from the system, select the picture to be deleted and then click on *Delete File* (see Figure 5.15). The picture would be deleted from the System.

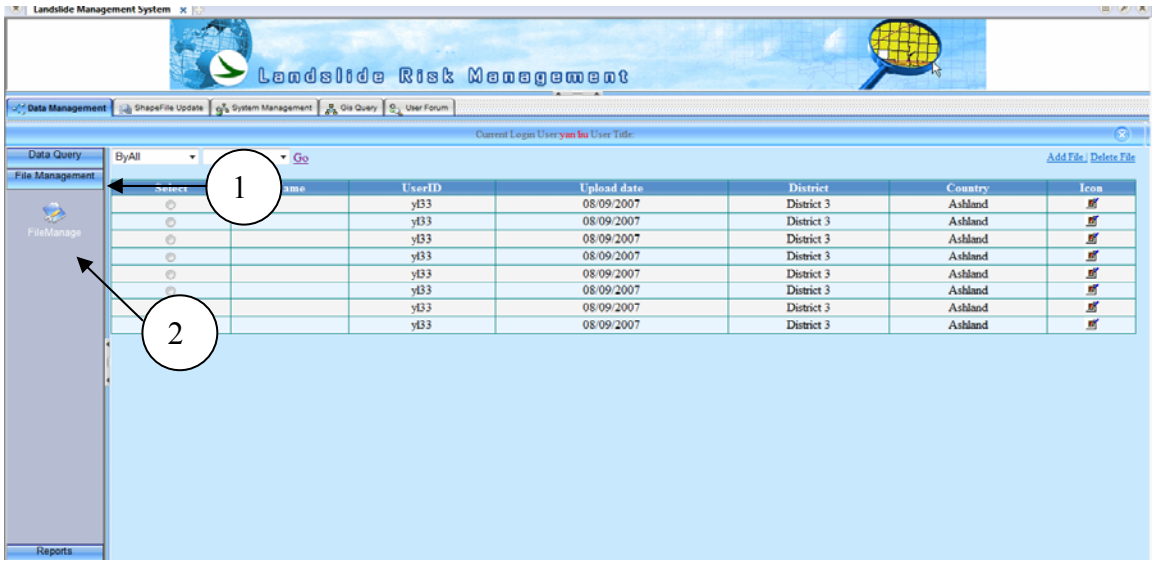


Figure 5.14 Picture manage

Figure 5.15 List of pictures in database

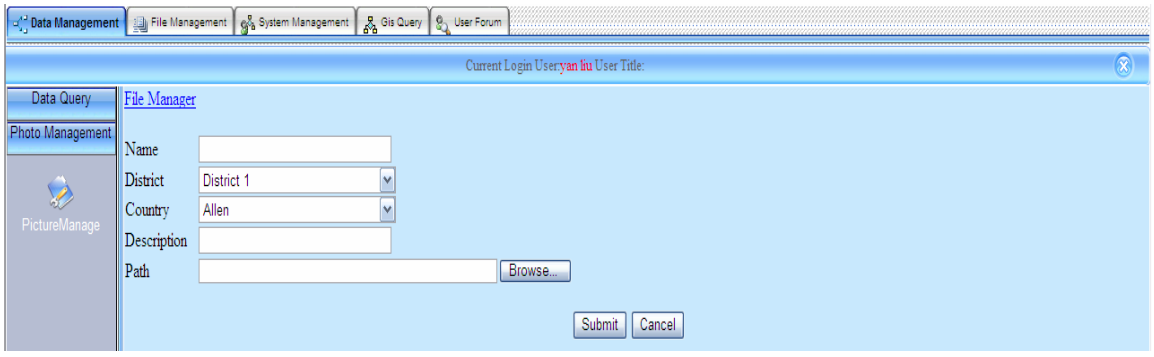


Figure 5.16 Uploading pictures.

SHAPEFILE UPDATE

ShapeFile Update is used to manage shapefiles in the database. The shapefiles are the files obtained from using a GPS handheld device through ArcPad software. When clicking on *ShapeFile Update*, one icon appears(*ShapeFile Manage*). Once a user finishes a field work of collecting landslide information in the GPS handheld device, he/she would upload the shapefiles to *ShapeFile Manage*. The shapefiles would then be linked into the GIS server. The landslide site appears as a Blue Triangle in GIS map.

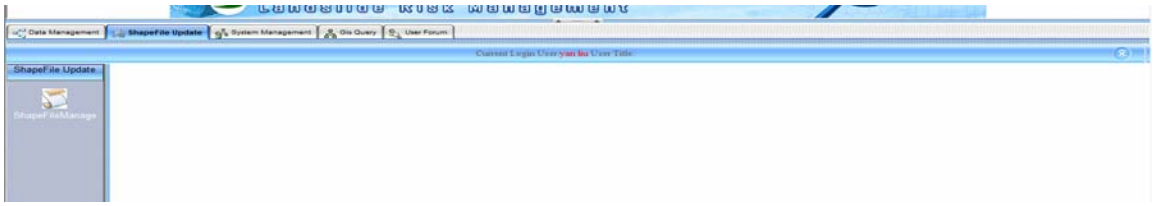


Figure 5.17 ShapeFile Update

Uploading shapefiles into *ShapeFileManage*

1. Click on *ShapeFileManage* shown in Figure 5.17, a window as shown in Figure 5.18 appears.

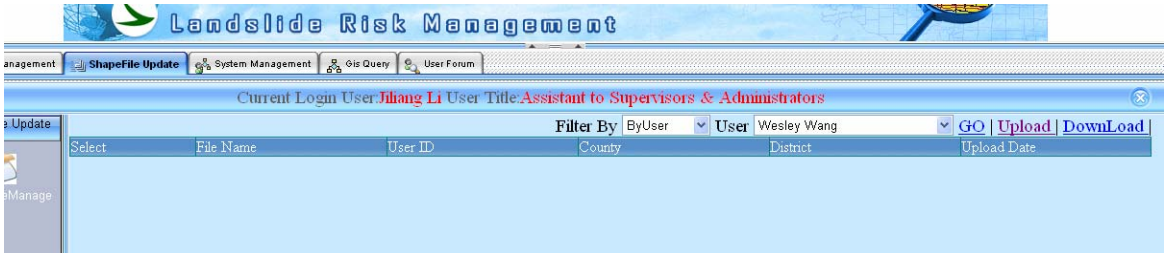


Fig. 5.18 ShapeFileManage

2. Select *Upload* at the upper right corner. It reveals an upload window, as shown in Figure 5.19.
3. Fill in information and browse shapefiles that need to be submitted.

4. Click on *Submit* to store the shape files in database.

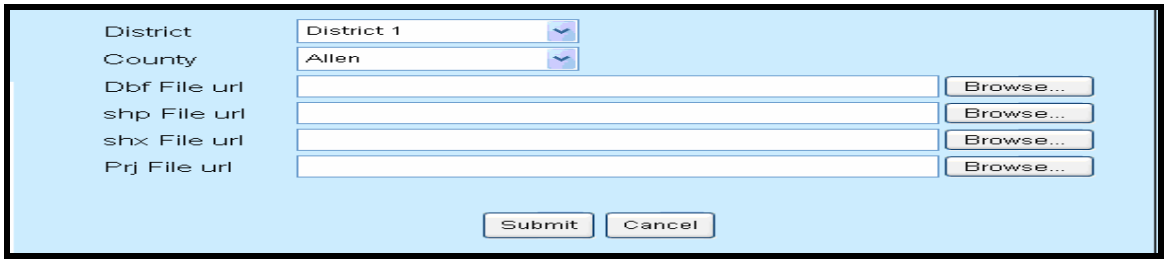


Figure 5.19 Shapefile upload window

Downloading shapefiles from "ShapeFileManage"

1. Click *ShapeFileManage*, see Figure 5.20, a list of shapefiles in the database appears.
2. Select a shapefile that needs to be downloaded.
3. Click on *Download* at the upper right corner. A new window as shown in Figure 5.20 pops up.
4. Select a shapefile type to be downloaded (see Figure 5.21). A download dialog box appears.
5. Click on *Save* to save the file in the user's local computer.

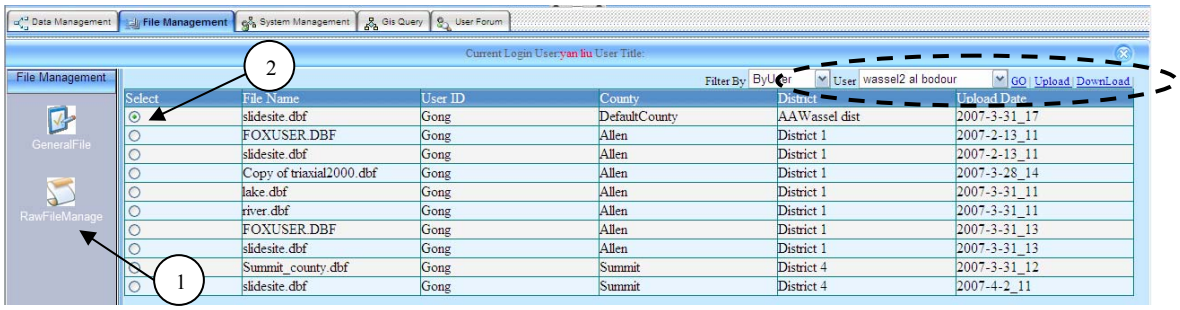


Figure 5.20 Download Shapefiles (1)

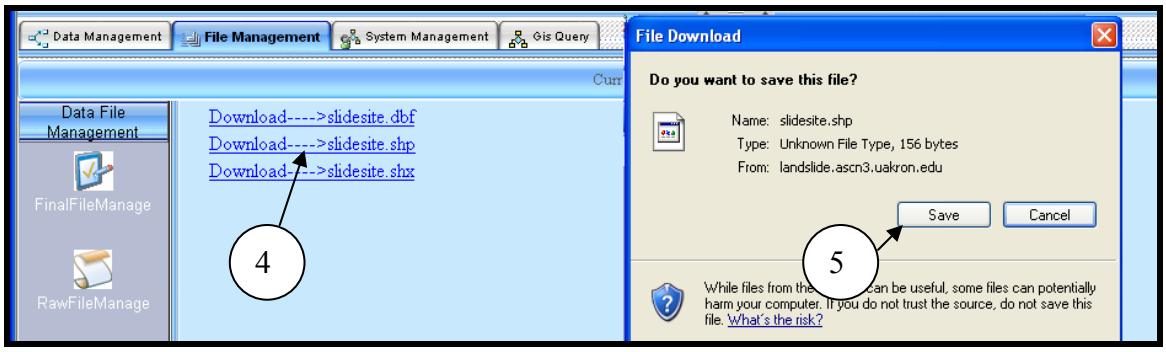


Figure 5.21 Download Shapefile (2)

5.6 SYSTEM MANAGEMENT

System Management provides controls for five features: *User Management, Page Management, Resources, Regions, and Detour Cost.*

5.6.1 USER MANAGEMENT

User Management provides an authorized user to control the registered users. When a user clicks on *User Management* bar, it reveals *UserManage* and *GroupManage icons.* Users of the landslide database are categorized into the following groups.

(i) Normal users

(ii) County power users (CM/TM)

(iii) District power users (DGE)

(iv) State power users

(v) System power users

(vi) Administrators

(vii) Supervisors.

5.6.1.1 USER MANAGE

An authorized user can use *UserManage* to register a new user. Also, he/she can edit and delete a user. The process to add, edit, and delete a user is as follows:

Adding a new user

1. Click on *System Manage*ment as shown in Figure 5.22.
2. Click on *UseManage* under *User Management.*
3. Click the *add* button at the lower right corner. A new screen pops up as shown in Figure 5.23.
4. Fill up the information and then click on the *Submit* button. The information of a new user is stored in the system. Subsequently, the new user can access to the system under his UserID and password.

Figure 5.22 User Management

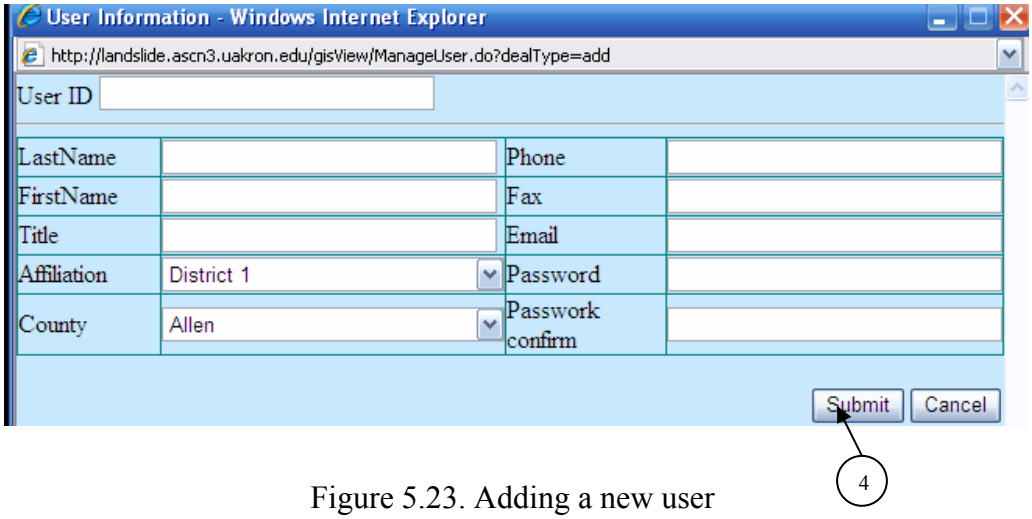


Figure 5.23. Adding a new user

Editing an exiting user

1. Click on *System Management* as seen in Figure 5.22.
2. Click on *UserManage* icon under *User Management* bar.
3. Click the *edit* button at the lower right corner. A new screen pops up as shown in Figure 5.23 with the user's information stored in the system.
4. Modify the required information fields and then click on the *Submit* button. The user's new information is stored in the system.

Deleting an existing user (see Figure 5.24)

1. Select a user name to be deleted.
2. Click *delete* at the bottom right corner of the window. The user is deleted from the system.

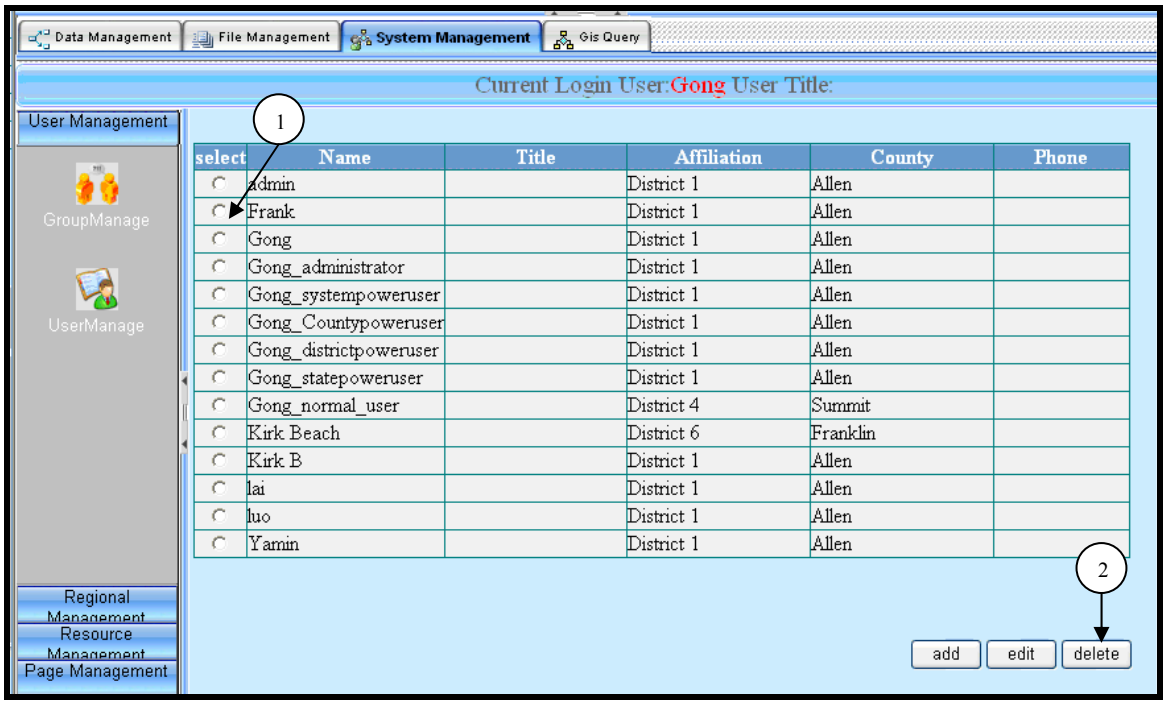


Figure 5.24. Delete a user

5.6.1.2 GROUP MANAGE

An authorized user can assign the user to a user group using *GroupManage.* Once a new user is registered, he/she is assigned to a particular group corresponding to his/her responsibility. The system is designed to have seven groups as they are previously mentioned. In case that the system needs to create a new user group, the process to add the new user group is as follows.

Adding a new group of users and assign a user to a user group

1. Click on *System Management.* (see Figure 5.25)
2. Click on *GroupManage*.
3. Click on the *add* button at the lower right corner of the window. A new window shows up as seen in Figure 5.26.

4. Fill up the information and click on the *Submit* button to save the information.
5. An authorized user can assign a new user to the desired user group. Click on the *Add Users* button at the lower left corner of Figure 5.25, a new window as in Figure 5.26 appears.
6. The users that have not yet been assigned to a user group are shown in the left box. Select a user name and then tap the ">>". The selected user is then assigned to the selected user group.
7. Press the *Submit* button to save the selection.

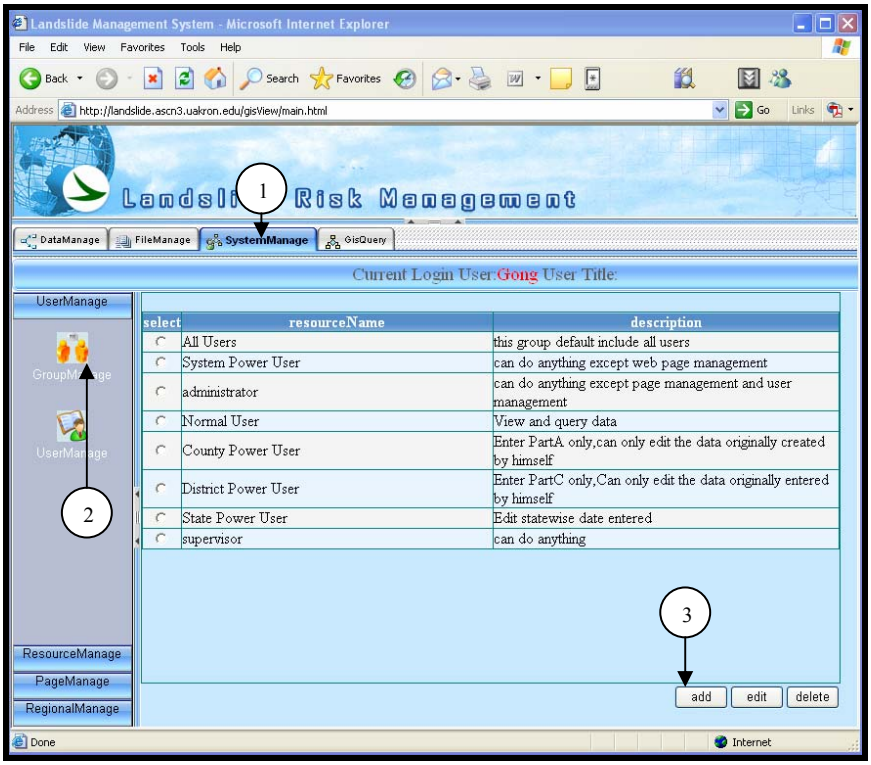


Figure 5.25 Adding user group

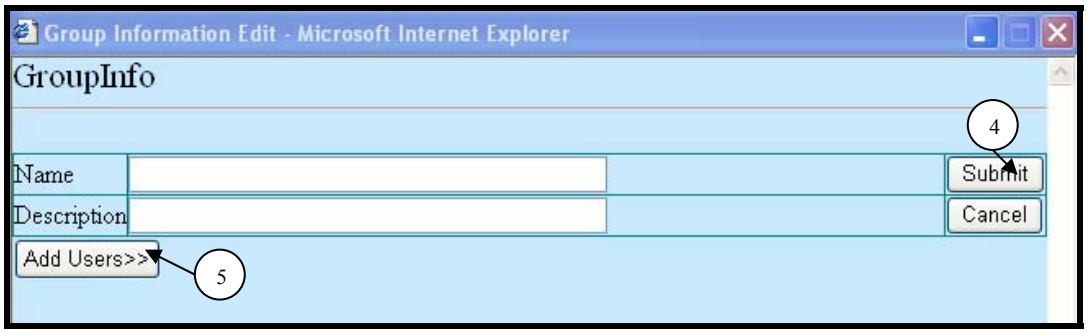


Figure 5.26 Adding a new group of user

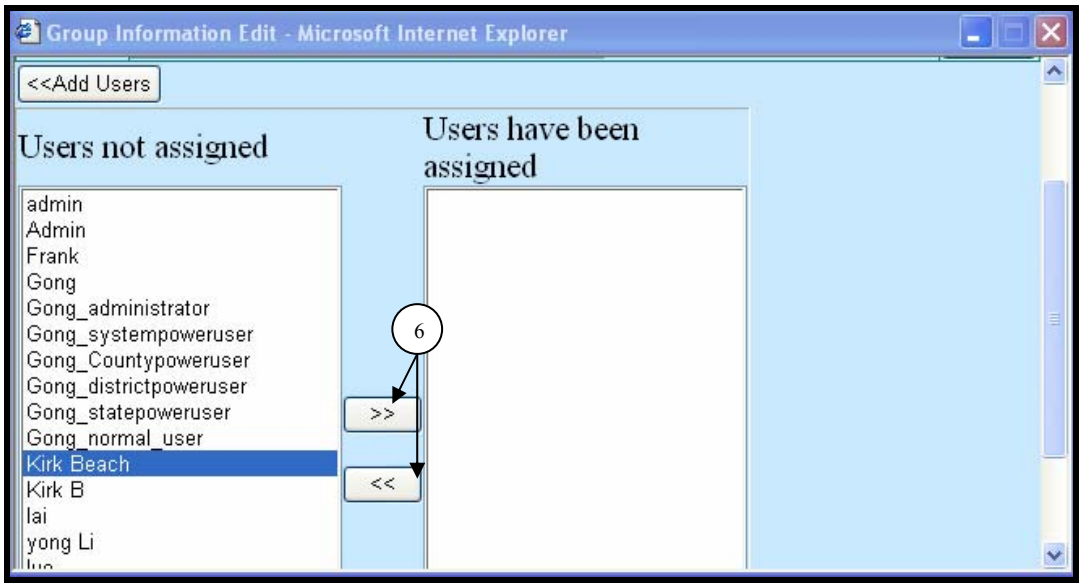


Figure 5.27 Assigning new user to a user group

Editing an existing group

1. Click on *System Management* as shown in Figure 5.28.
2. Click on *GroupManage*.
3. Select a user group that needs to be edited.
4. Click on the "edit" button at the lower right corner. A window pops up as seen in

Figure 5.29.

5. Modify the existing information and then click on the *Submit* button to save the information in the system.
6. The authorized user can also add a user to the group using the same procedure as discussed in the "adding a new group of user" section.

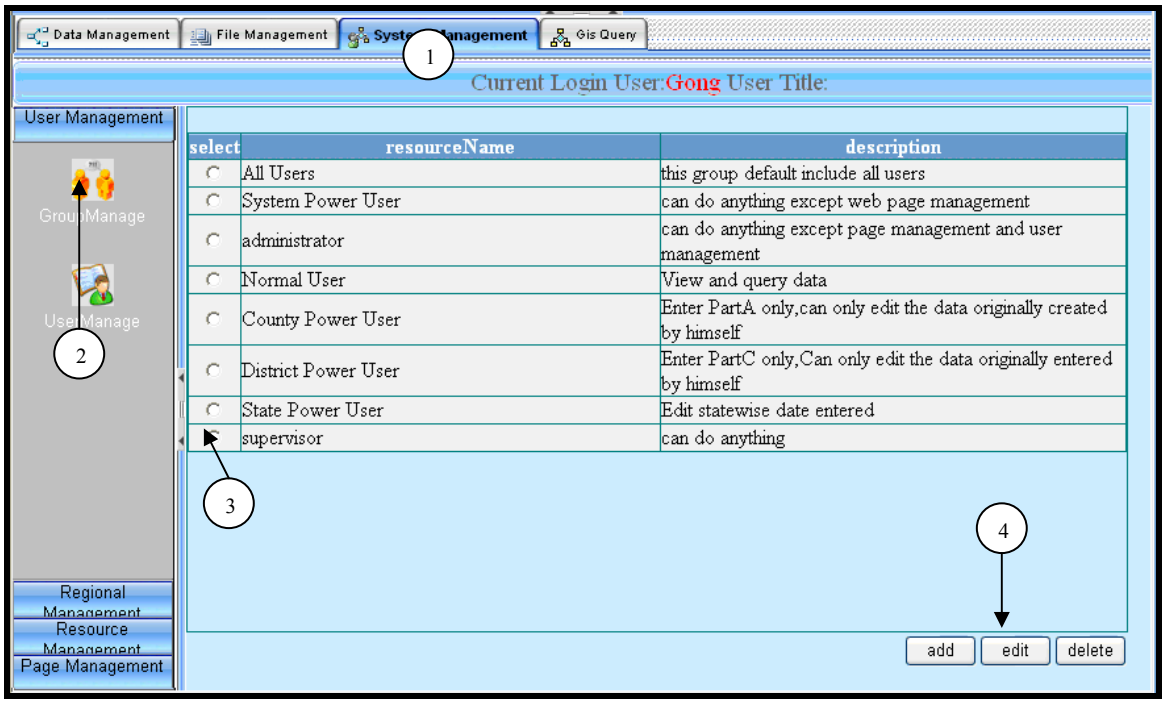


Figure 5. 28 Edit a user group

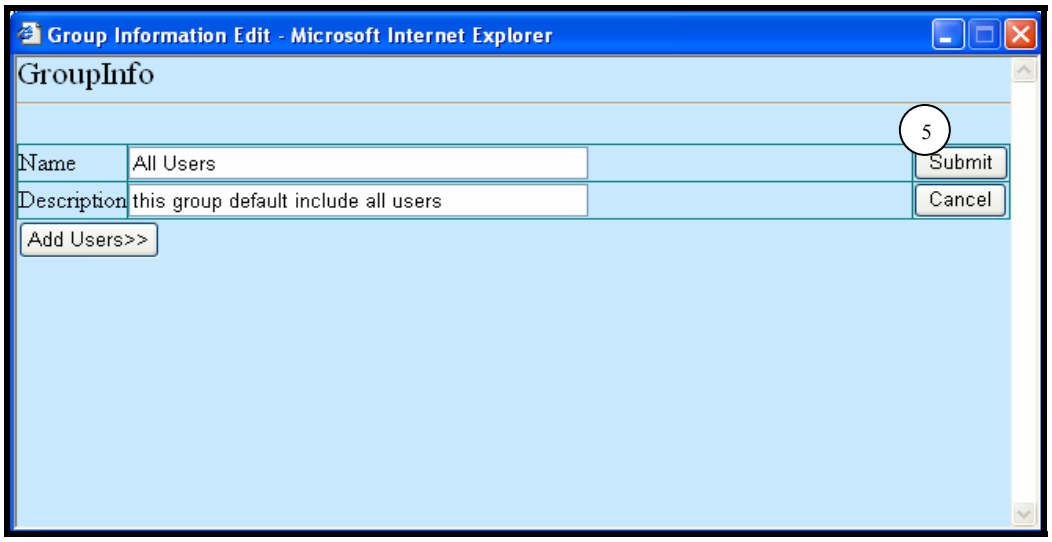


Figure 5.29 Group information editing

5.6.2 RESOURCES

Under the *Resources,* the feature of *PermissionManage* is provided.

5.6.2.1 PERMISSION MANAGE

When an authorized user clicks on the *PermissionManage* icon under the *Resource Management* bar, the two tabs including *PageURLManage* and *PageManage* are revealed. *PageURLManage* is used to assign a privilege to a group of users to modify the database webpage, such as add, edit, delete, etc. *PageManage* is used to assign a user group to view the items on the webpage. The item added through *ItemManage* (Section 5.6.3.3) is listed in *PageManage*. The new item added is assigned to a user group who has privilege to view it. If the privilege set up is not done properly, no one can view the item even if it has been added to the Bar or Tab. The user has to log off after privileges are added or deleted by clicking the *logoff* button on the top right corner as seen in Figure 5.30.

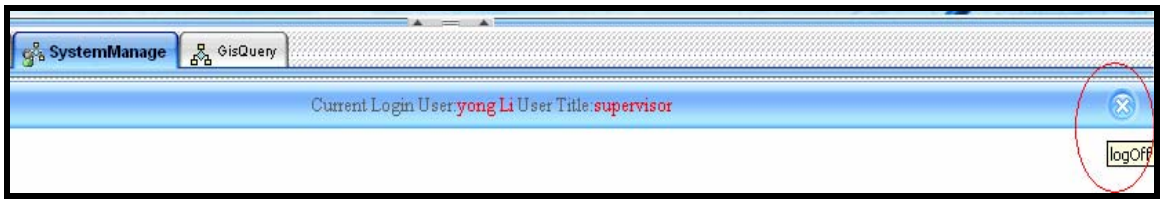


Figure 5.30 Logoff

Authorizing groups of users to PageURLManage

1. Click on *SystemManage* as seen in Figure 5.31.
2. Click on *Resources*.
3. Click on *PermissionManage*.
4. Click on *PageURLManage*.
5. Select an item that you would like to give privilege to the new group of users. By clicking on the item, it would display the user groups that have been previously assigned the privilege to manage this item.
6. Click on the *add* button at the lower right corner in Figure 5.31. It reveals a permission window as shown in Figure 5.32.
7. Click on the *select* button, the list of different types of user groups shows up (Figure 5.33).
8. Select a user group, then click on the ">>" button.
9. By checking an appropriate item in the *action* row in the table in Figure 5.32, a user group is assigned to perform adding, editing, and deleting tasks.
10. At this stage, a user can save the selection.
11. The privilege of a user can be edited and deleted by checking or unchecking the appropriate box next to in the *action* row in Figure 5.32.

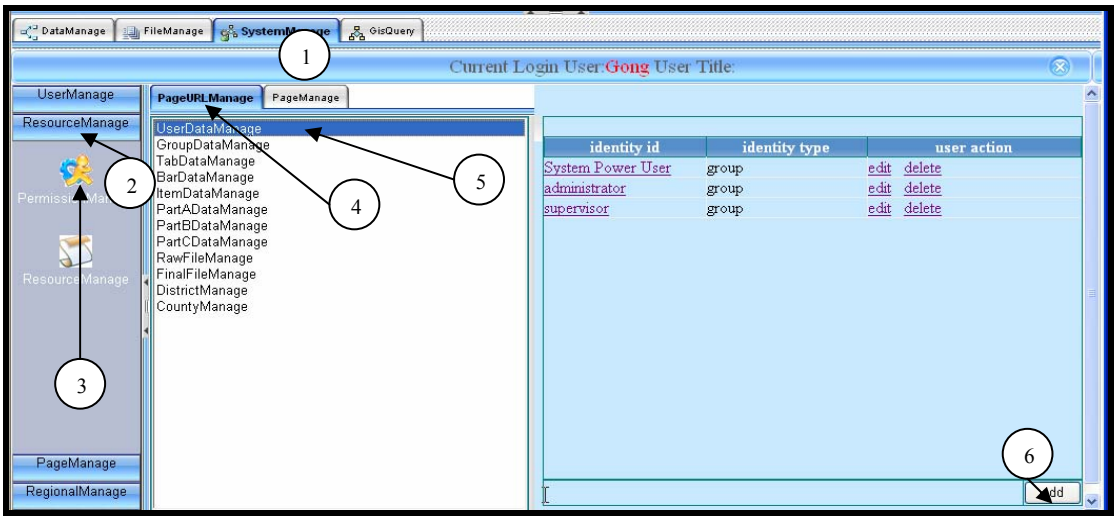


Figure 5.31 ResourceManage

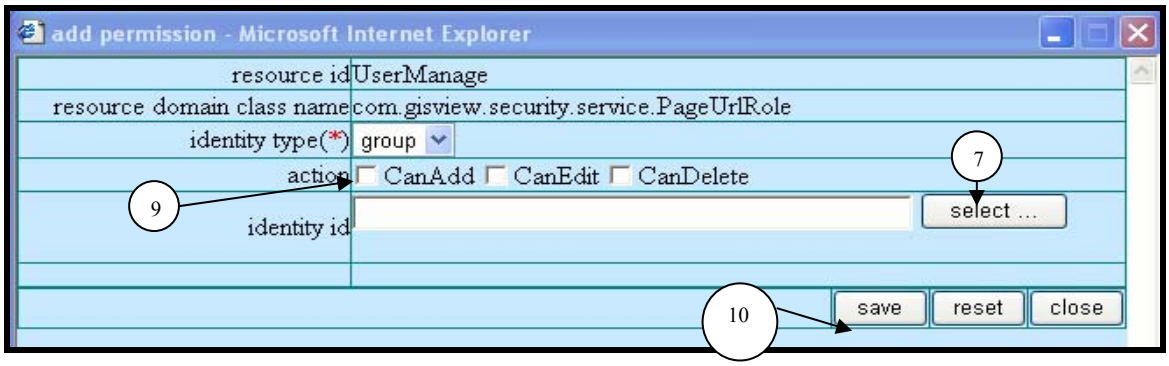


Figure 5.32 Adding permission

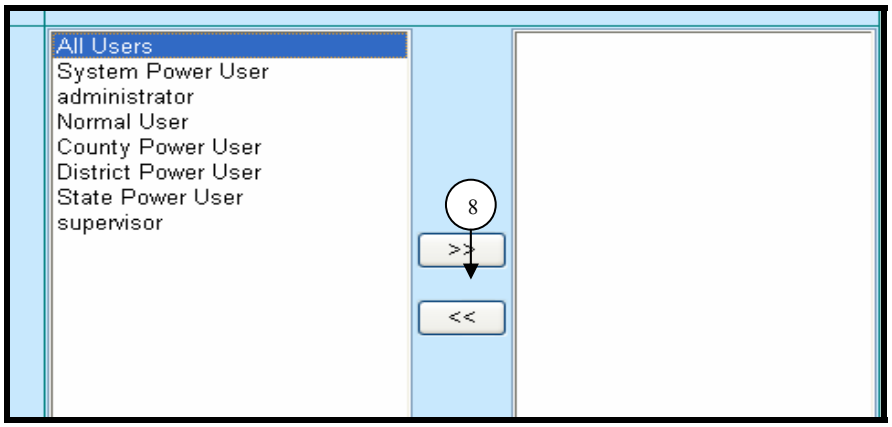


Figure 5.33 List of types of users in adding permission

Authorizing a group of users to *PageManage*

1. Click on *SystemManage* as seen in Figure 5.34.
2. Click on *Resources.*
3. Click on *PermissionManage*.
4. Select *PageManage*.
5. Choose an item to be added in the user privilege.
6. Click on the *add* button. An add permission window is revealed as shown in Figure 5.35.
7. Click on the *Select* button. It reveals a list of user groups to be selected.
8. Authorized users can give other user groups the permission by highlighting the group, then click on the ">>" button.(Figure 5.35)
9. The privilege of a user group can also be assigned by checking mark on the *action* row. This allows an authorized group to add, edit, and delete the information.
10. Save the selection.
11. The privilege of a group can be edited or deleted by clicking on *edit* or *delete* (Figure 5.34).

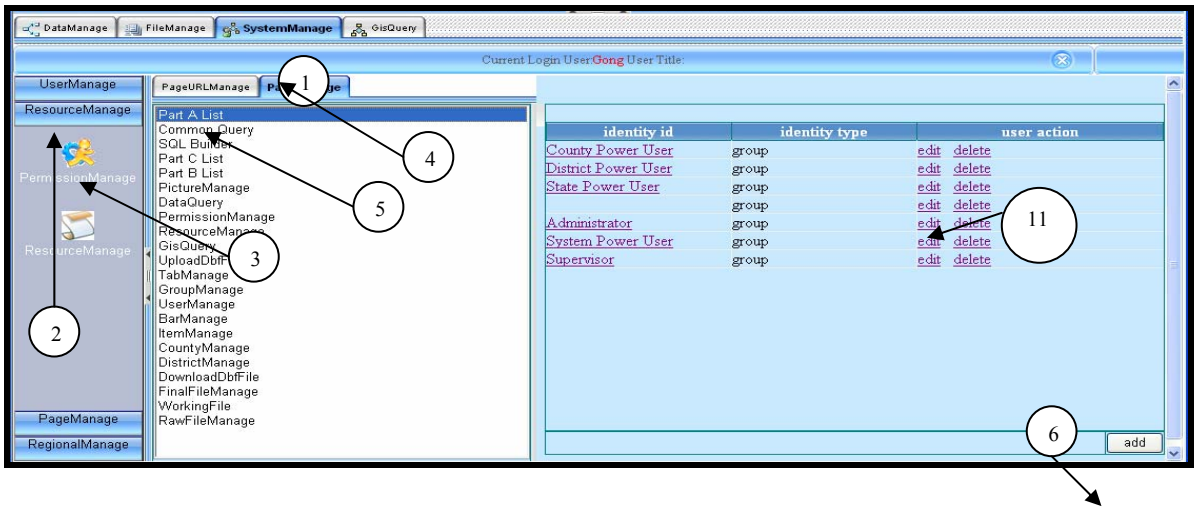


Figure 5.34 List of types of users in adding permission

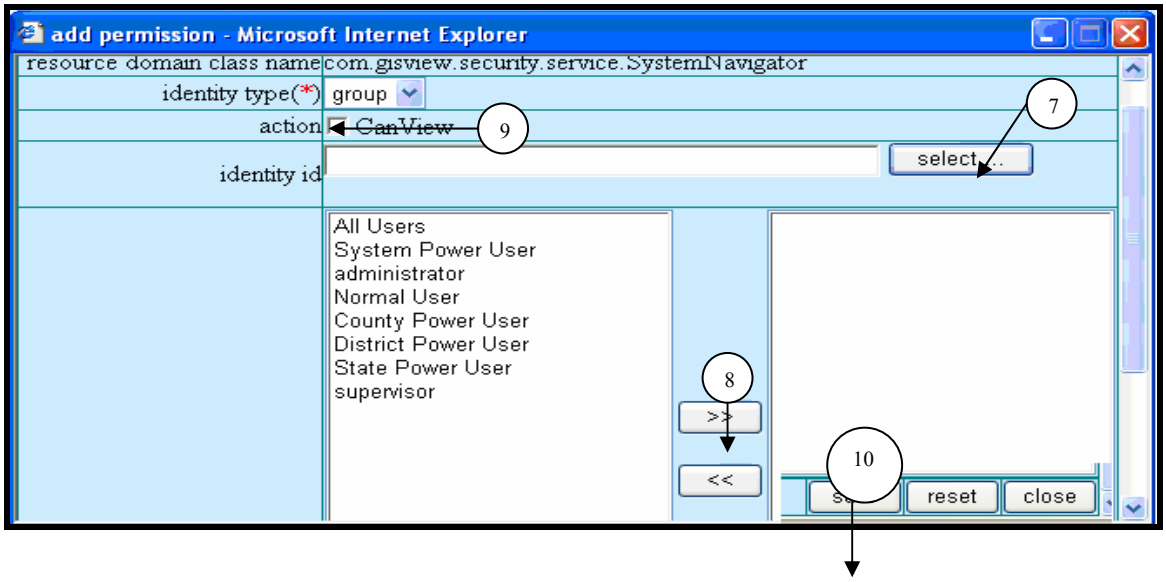


Figure 5.35 Assign some groups who have the rights to view this page

5.6.3 PAGE MANAGEMENT

Page Management controls the configuration of the database on the webpage, including: *TabManage*, *BarManage*, and *ItemManage*. With *Page Management*, an authorized user

can configure the web page layout. Within a tab, it can have several bars. Within a bar, it can have several items. Items are directly linked to URL so that when an item is clicked, the Internet Explorer will navigate to the URL that is associated with these items. Items, bars and tabs must be added at the first time that the web page is configured. The authorized user can add additional features (items, bars, and tabs, see Figure 5.36) to the system for future use.

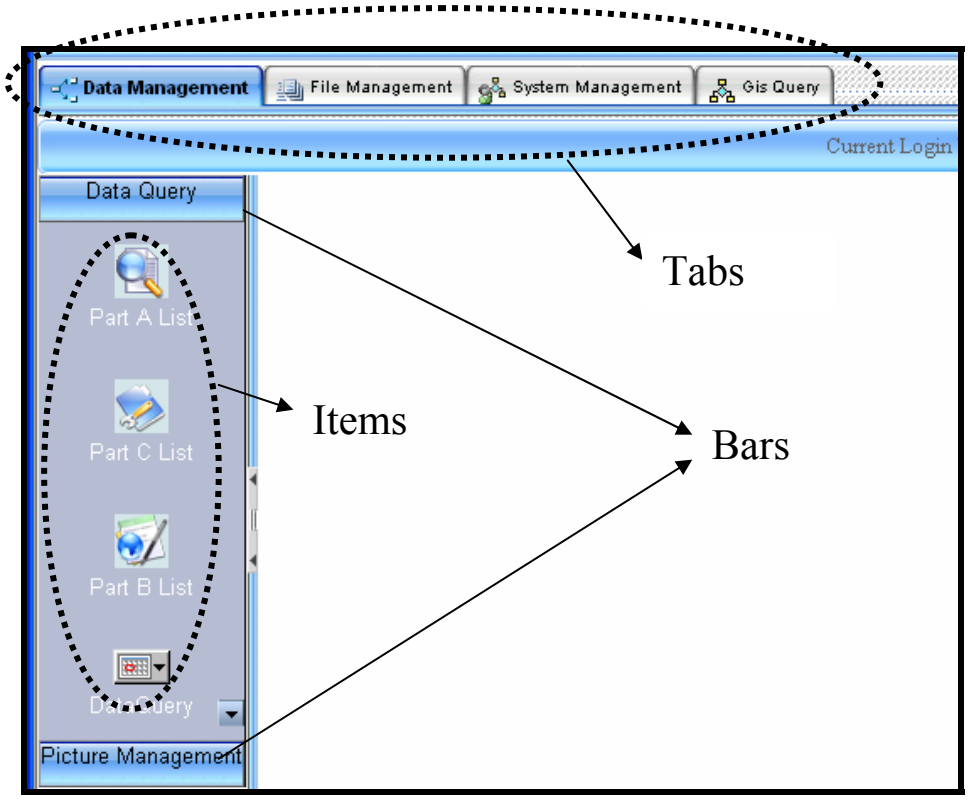


Figure 5.36 Tabs, bars, and items

5.6.3.1 TAB MANAGE

TabManage controls number of tabs on the webpage. Within a tab, there are several bars. An authorized user is permitted to add, edit and delete tabs in the system. For example,

there are 5 tabs that have been created by *TabManage* so far, which are *Data Management, ShapeFile Update, System Management, User Forum,* and *GIS Query*.

Adding a tab

1. Click on *System Management* in Figure 5.37.
2. Click on *TabManage*.
3. Click on the *add* button at the lower right corner of the window. The *Tab Edit* window would appear as shown in Figure 5.38.
4. Fill up the information and then click on the *Submit* button to save the information.

Adding a bar in a tab

5. Click on *Add Bars* in Figure 5.38.
6. Highlight a bar to be added to the tab and then click on ">>" to add the bar to the tab.
7. Click on the *Submit* button.

Editing a tab

8. Select a tab to be edited in Figure 5.37.
9. Click on the *edit* button. A window as same as Figure 5.38 reveals. This window contains the information of the tab to be edited. Click *Submit* button when finishing editing.

Deleting a tab

10. To delete a tab from the webpage, a user selects a tab to be deleted and then click on the *delete* button. The tab is deleted from the system.

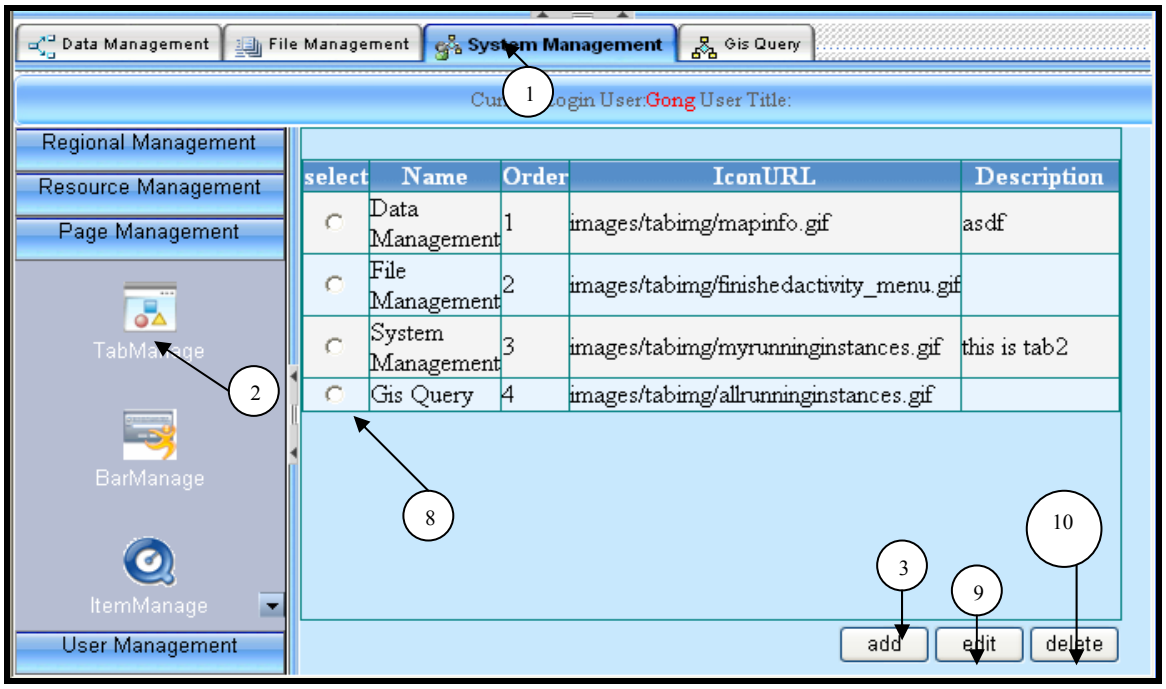


Figure 5.37. TabManage

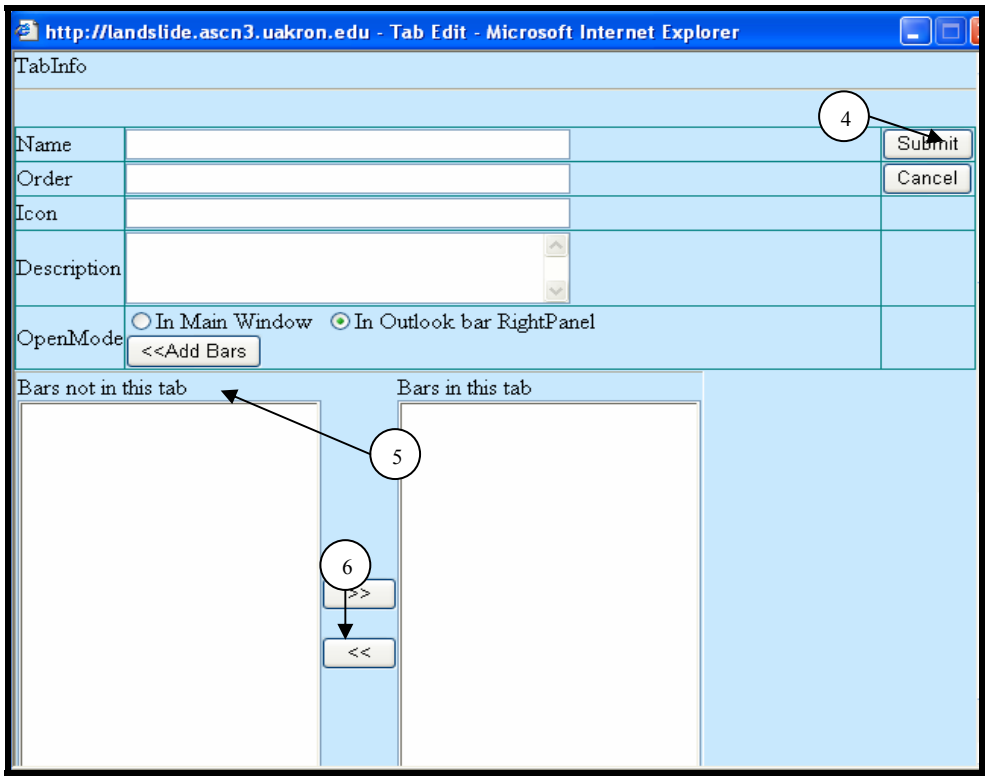


Figure 5.38 Adding tab bars

5.6.3.2 BAR MANAGE

BarManage allows a user to control the number of bars on a webpage. The process to manage bars in the system is as follows:

Adding a bar

1. Click on *System Management* as shown in Figure 5.39.
2. Click on *PageManage.*
3. Click on *BarManage.*
4. Click on the *add* button at the lower right corner. It reveals a new window as shown in Figure 5.40.
5. Fill up all information and then click on *Submit* to store the bar.

Adding an item to a bar

6. The user can add items to a bar by clicking on the *Add Items* button.
7. Highlighting an item and then clicking on ">>" allows the user to add an item into a bar. In contrast, highlighting an item and then clicking on "<<" would remove the item from that bar.

Editing a bar

8. Select a bar to be edited.
9. Click on the *edit* button at the lower right corner of Figure 5.39. A window that is as same as Figure 5.40 appears. This window contains the information of the bar to be edited. Click on *Submit* button when the user finishes editing.

Deleting a bar

10. To delete a bar, a user selects a bar to be deleted and then clicks on the “delete” button. The bar would be deleted from the system.

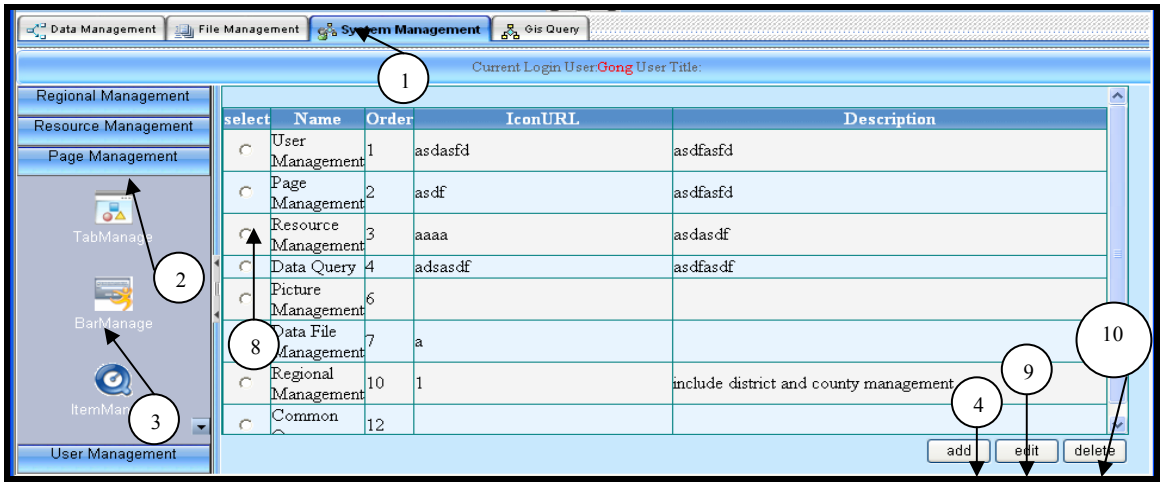


Figure 5.39 BarManage

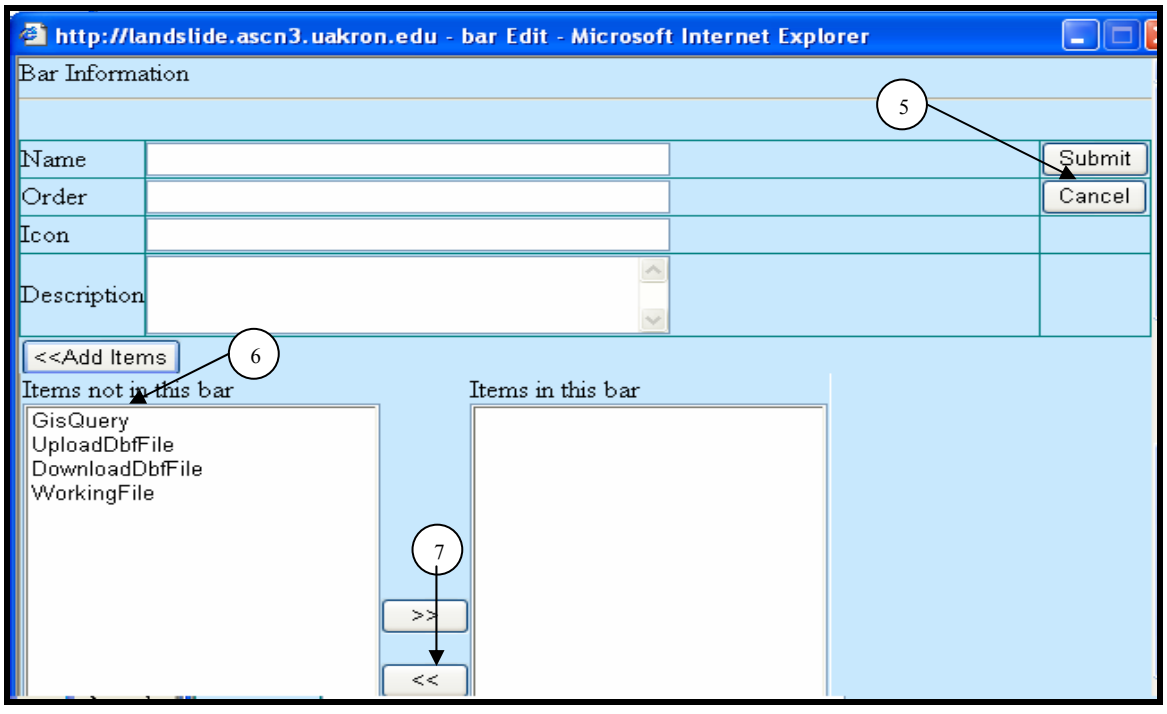


Figure 5.40 Bar edit

5.6.3.3 ITEM MANAGE

Items are the smallest components in the *Page Management*. The *ItemManage* is used to manage items in the system by allowing an authorized user to add, edit and delete items.

Adding an item

1. Click on *SystemManage.*
2. Click on *PageManage.*
3. Click on *ItemManage.* It would show items that have been added into the system as shown in Figure 5.41.
4. Click on the *add* button at the lower right corner of the window. It would reveal a *CreateItem* window as shown in Figure 5.42.
5. Fill up the information and then click on the *Submit* button. The information is stored in database.

Editing an item

6. Select an item to be edited.
7. Click on the *edit* button. A window that is the same as Figure 5.41 with the item information appears. Modify the information and then click on *Submit* to save editing.

Deleting an item

8. To delete an item, select an item that needs to be deleted and then click on the "delete" button. The selected item would be deleted from the system.

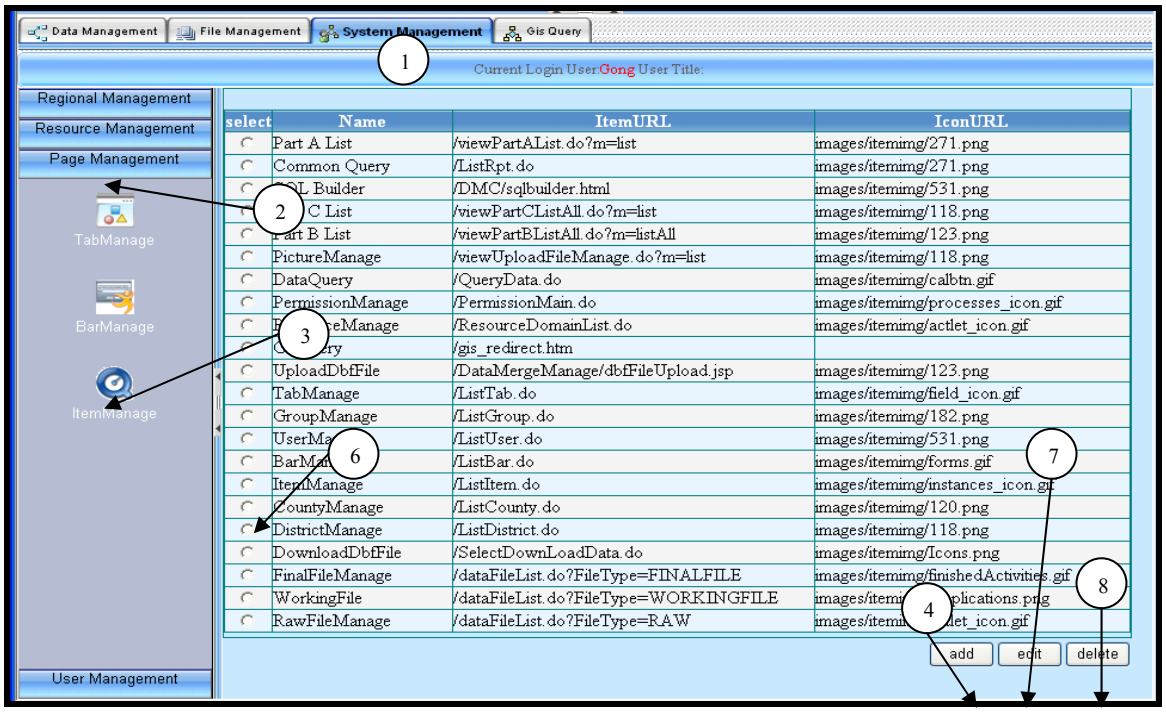


Figure 5.41 ItemManage

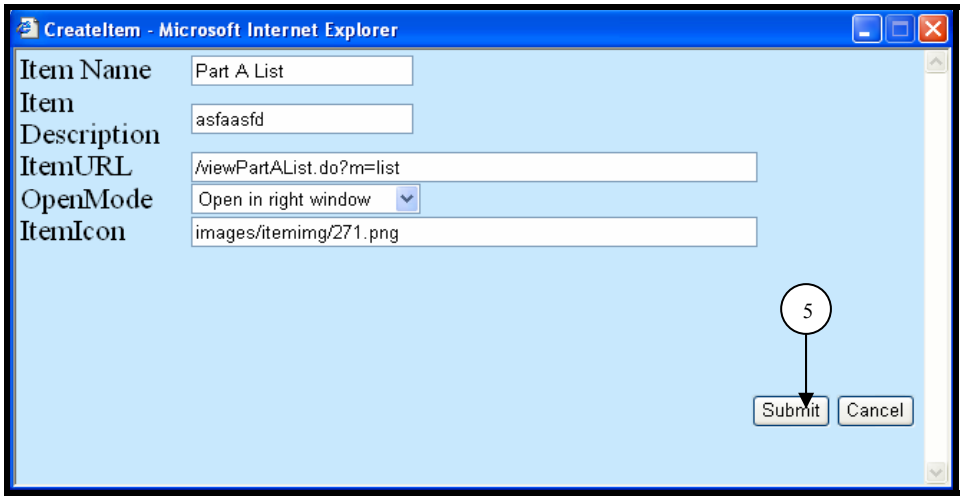


Figure 5. 42 Create item window

5.6.4 REGIONS

Regional Management contains two management features, including *CountyManage* and *DistrictManage*. A user can manage county and district information in the system.

5.6.4.1 DISTRICT MANAGE

Adding a district

1. Click on *SystemManage* in Figure 5.43.
2. Click on *Regional Mangement.*
3. Click on *DistrictManage.*
4. Click on the add button at the lower right corner of the window. A district information window appears as shown in Figure 5.44.
5. Fill up the district information and then click on the *Submit* button to save the information.

Editing a district

6. Editing the district information can be made by first selecting the district to be modified.
7. Click on the *edit* button in Figure 5.43. A window as seen in Figure 5.44 appears. Modify the information as needed. Click on the *Submit* button to save the modified information.

Deleting a district

8. Select the district to be deleted. Click on the *delete* button at the lower right corner of Figure 5.43. The district is deleted from the system.

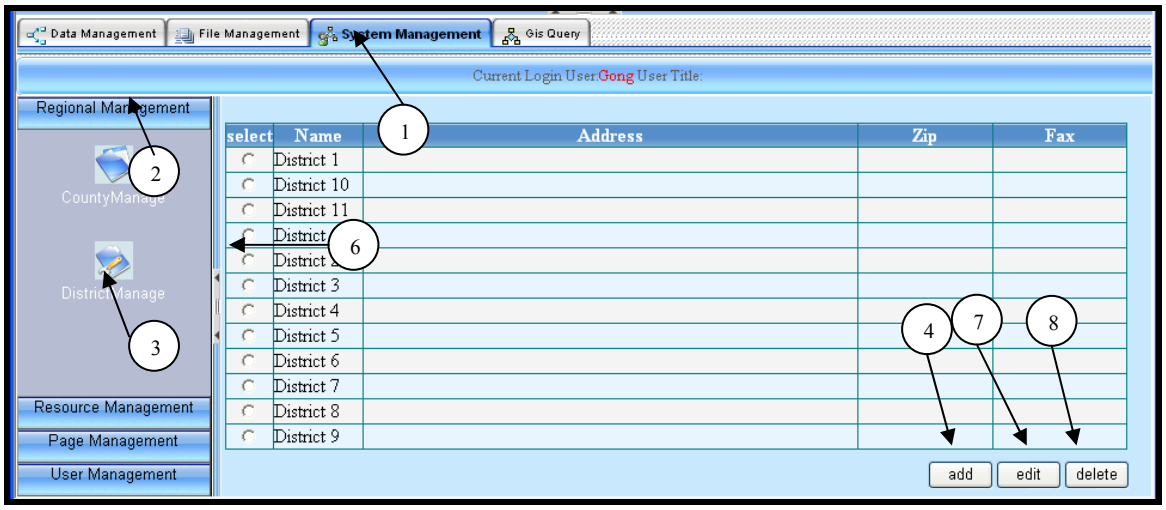


Figure 5.43 DistrictManage

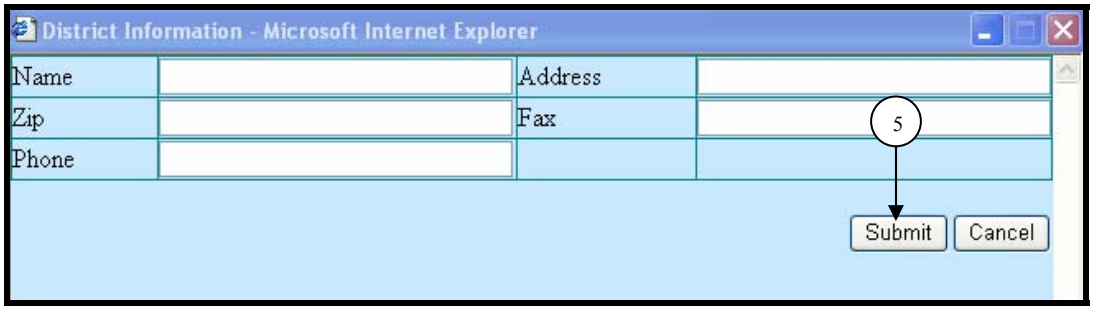


Figure 5.44 Adding and editing district

5.6.4.2 COUNTY MANAGE

A user can input county information in the system. However, before adding the county information in the system, district information is needed so that a county can be related to a district. The user can also edit and delete the county information stored in the system.

Adding a county

1. Click on *SystemManage* as seen in Figure 5.45.
2. Click on *Regional Mangement.*

3. Click on *CountyManage.* It reveals a list of the counties that has been added into the system.
4. Click on the *add* button on the lower right corner of the window. A county information window appears as seen in Figure 5.46.
5. Relate the county to the correspondent district by selecting the district name from the dropdown list as shown in Figure 5.46.
6. Click on the *Submit* button to save the county information.

Editing a county

7. First select the county to be edited.
8. Click on the *edit* button in Figure 5.45. Edit the information and then click on the *Submi*t button. The information is saved.

Deleting a county

9. A user can delete a county. Select the county to be deleted and then click on the *delete* button. The county is deleted from the system.

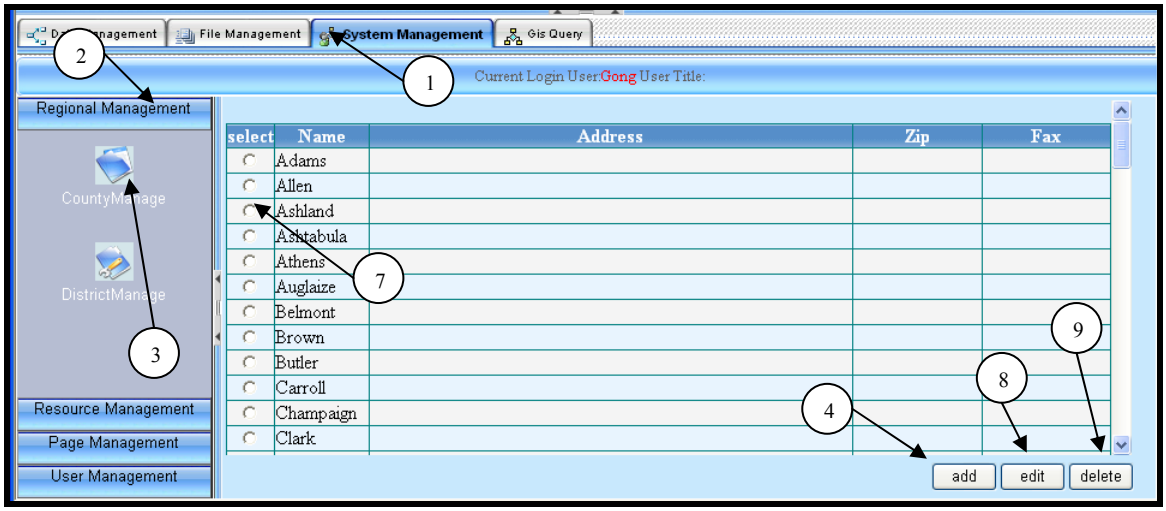


Figure 5.45 County Manage

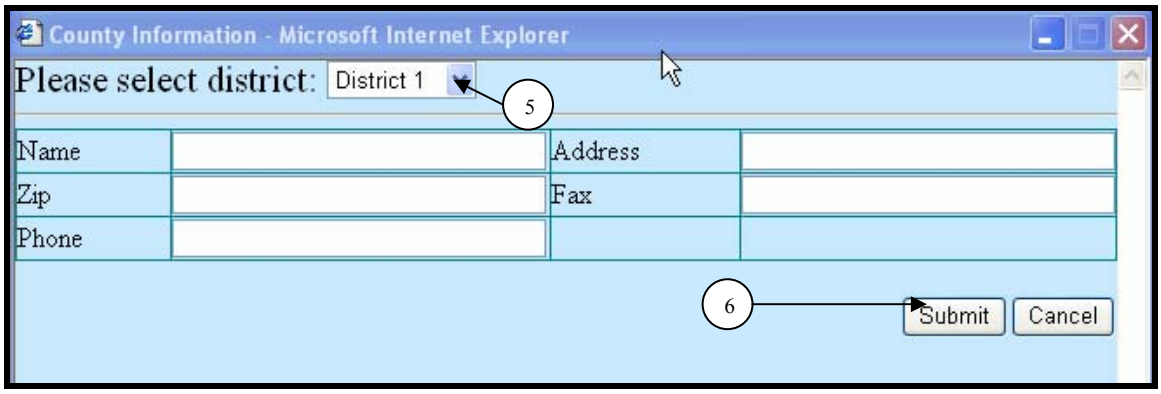


Figure 5.46 Adding and editing county information

5.6.5 DETOUR COST

Detour Cost Factor allows for setting car/truck detour cost factors which are used for cost benefit ration computation.

5.7 GIS QUERY

A GIS map with landslide locations can be viewed by clicking on the *Gis Query* tab, as shown in Figure 5.47. The query icons of the *GIS Query* are listed on the left column.

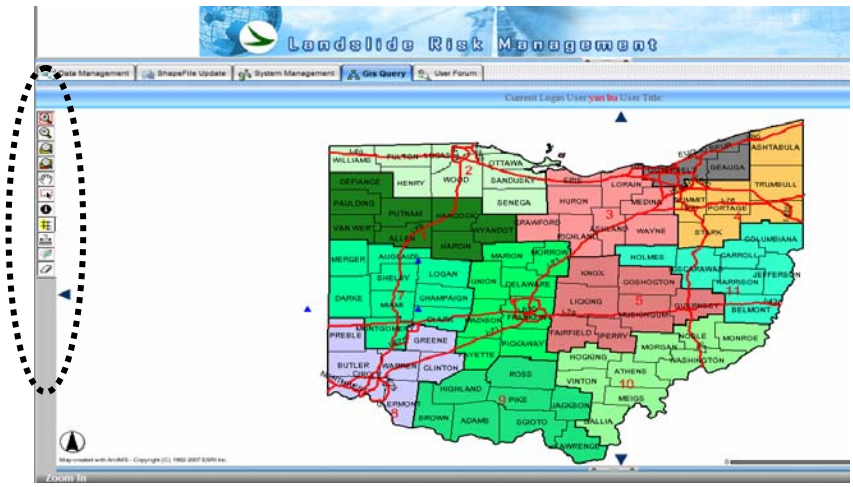


Figure 5.47 GisQuery

5.7.1 GIS QUERY FEATURES

Search functions of the *GIS Query* are explained as follows.

1. The magnify glass "  " icons are for zooming in and out, respectively. To zoom in and out, click on the icon, and drag the pointer over the GIS map.

2. The icons of "  " is used for zooming to the fully extend.

3. The "  " icon is for zooming to the active map layers.

4. Click on the "  ". A user can pan the GIS map. Move the pointer over the map area to be panned, hold the left mouse button and then drag the pointer to the location as needed.

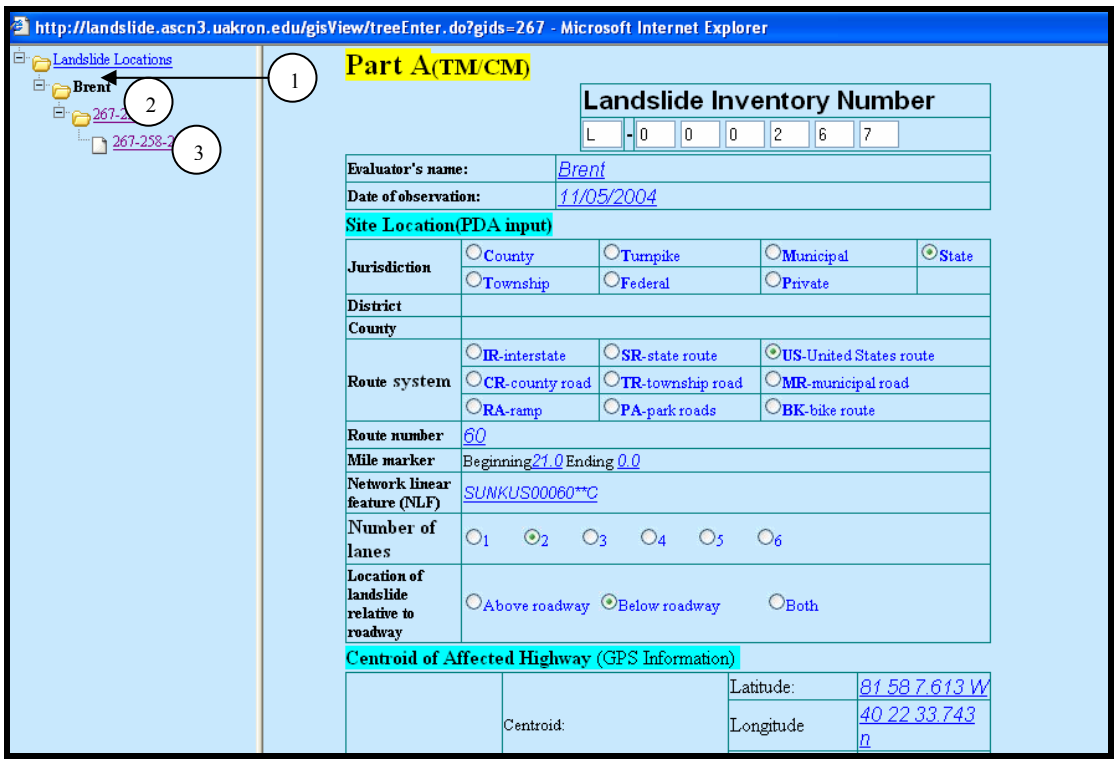


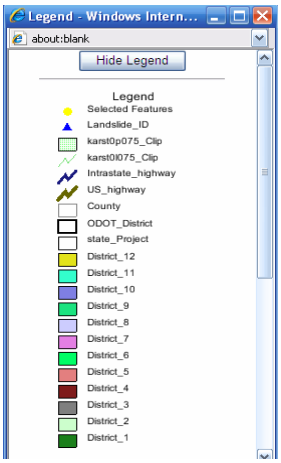
Figure 5.48 Hyperlink features

5. The identification button "  " is used to identify the landslide information on

the landslide map. Simply click on the *identification* icon, move cursor onto a site and then click. The site information is popped up as shown in Figure 5. 48.

6. The buffering icon "  " is used to check nearby interest point (landslide site) by configuring distance of interest point and layer to be checked. Its buffer zone (circle around selected points) will be displayed and associated layer features are available, if any.

7. A measure icon "  " is used as a measuring tool to determine the distance between two or more points. It works by simply selecting the measure icon. Then click on the first and second point to be measured. The program automatically calculates the distance between the two points.

8. When you click  , it will show you the legend. 

9. The selection that has been made on the map can be cleared by using the *clear selection* "  " button.

5.8 USER FORUM

When an authorized user clicks on the *User Forum* icon under the *User Forum* bar, the two tabs including *BugReport and Suggestions* are revealed. Different users can use

this forum to report and discuss some bugs existing in the database. Users can also give recommendations and comments in *Suggestions* part.

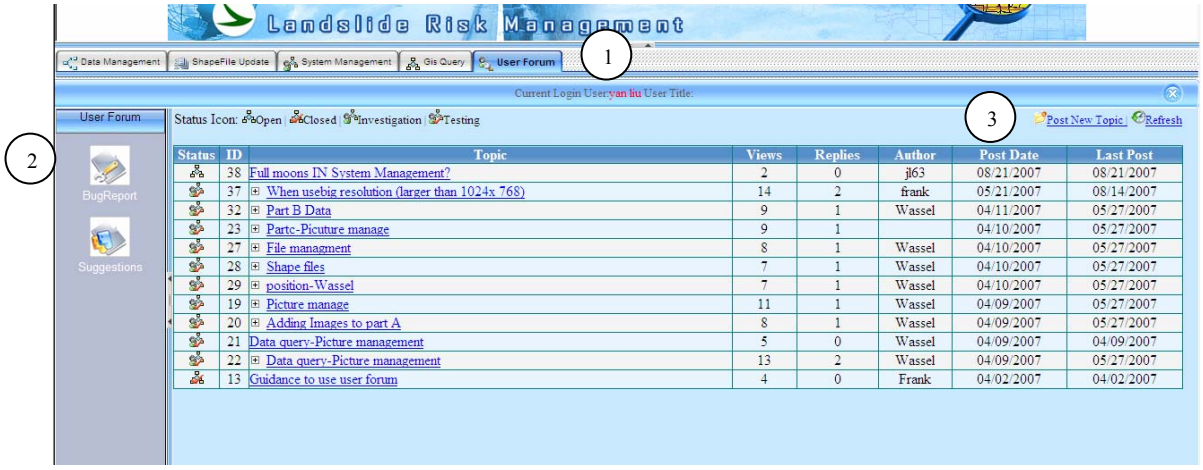


Figure 5.49 User Forum

5.8.1 BUGREPORT

Post New Topic

1. Click on *UserForum* as seen in Figure 5.49.
2. Click on *BugReport.* It reveals a list of topics that have been added into the system.
3. Click on *Post New Topic.* on the right corner of the window. Another window appears as seen in Figure 5.50.

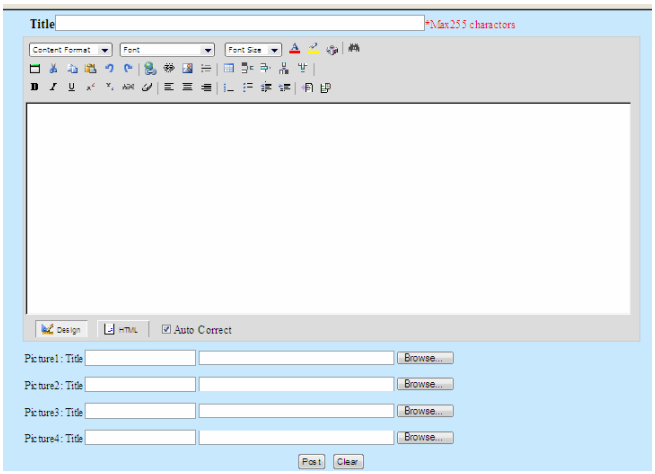


Figure 5.50 Post New Topic

4. Write down the TITLE and the CONTENT of the topic
5. Click on the *Post* button to add a new topic.

Reply a topic

1. First select the topic to be replied. Another window pops up.
2. Write down the TITLE and the CONTENT of the topic.
3. Click on the *Post* button to reply to the topic.

5.8.2 SUGGESTIONS

Post New Topic

1. Click on *UserForum* as seen in Figure 5. 49.
2. Click on *Suggestions.* It reveals a list of topics that have been added into the system.
3. Click on *Post New Topic* on the right corner of the window. Another window appears as seen in Figure 5.50.

4. Write down the TITLE and the CONTENT of the topic
5. Click on the *Post* button to add a new topic.

Reply to a topic

1. First select the topic to be replied. Another window pops up.
2. Write down the TITLE and the CONTENT of the topic.
3. Click on the *Post* button to reply to the topic.

CHAPTER VI

USING ARCPAD AND WINDOW CE

FOR LANDSLIDE DATA COLLECTION

6.1 OVERVIEW

The landslide field reconnaissance form can be filled in electronically through the use of a GPS Handheld device or a laptop computer. This chapter provides the users with the step-by-step guides on some basic ArcPad skills that the users need to perform during the landslide data collection in the field. When finishing the data collection processes, the users can update the shapefiles in the GIS database map.

6.2 SETTING THE DATA PATH

1. Select start on the window CE, go to programs and then start ArcPad. The ArcPad will open with a blank map window as seen in Figure 6.1.
2. Select the tool button "  "on the top of the main toolbar in Figure 6.1. This will open the ArcPad option dialog box.

Figure 6.1 A blank map window

3. Use the left and right arrow to find the Path tab.
4. Locate the file that contains the default map and data file for the landslide site to be visited. Select the browse to navigate through these folders. Normally, these files can be stored in the My Document folder in the window CE computers. (see Figure 6.2)
5. Then tap Ok.

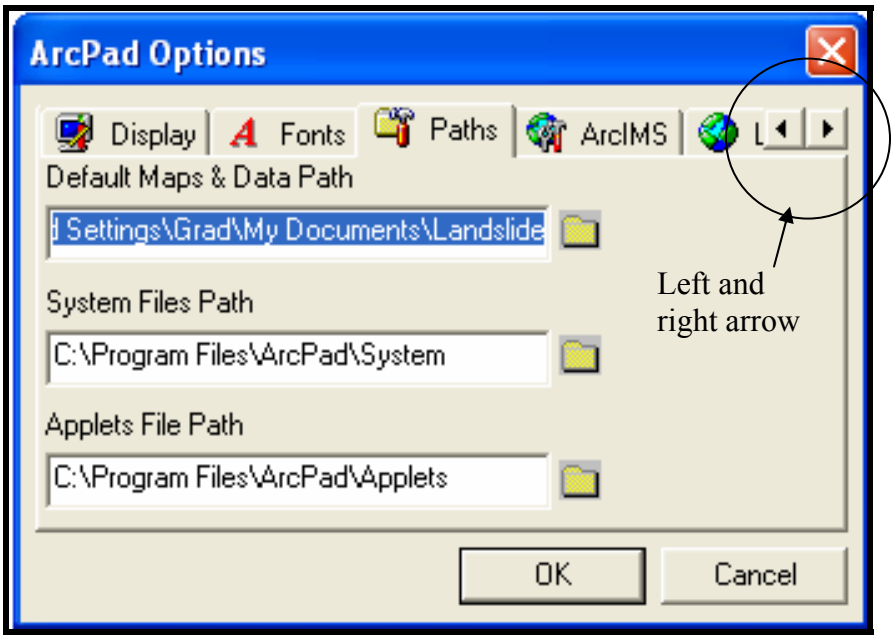


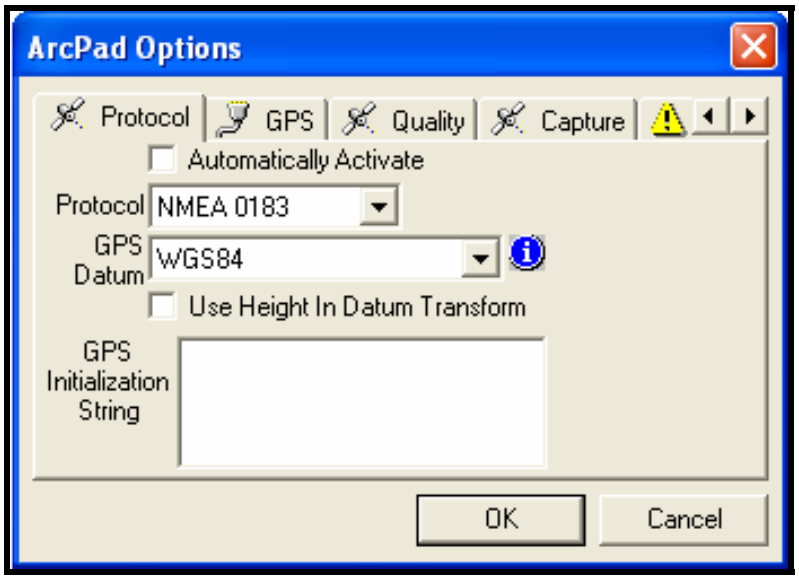
Figure 6.2 Setting the default map and data path

6.3 SETTING THE COMMUNICATION BETWEEN ARCPAD AND GPS

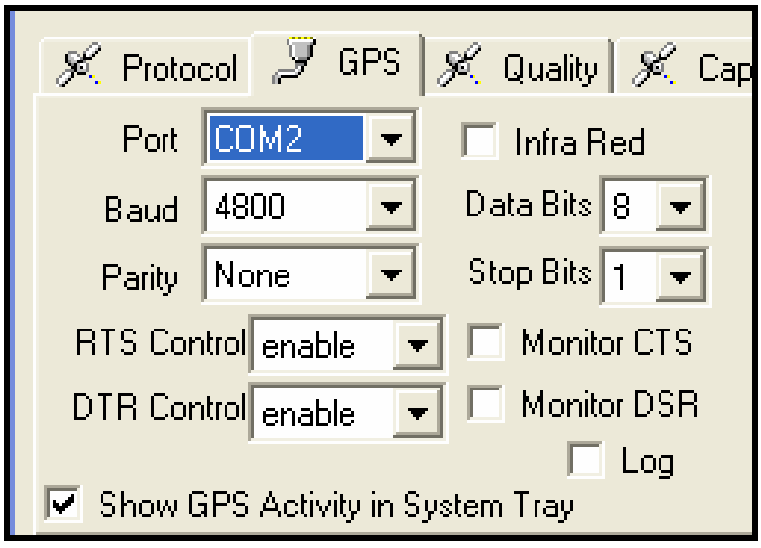
Before the user activates the GPS, he/she has to set the GPS communication parameters to match those that have been set on his/her GPS receiver.

1. Open the *ArcPad Options* dialog box by clicking on  .
2. Locate the protocol page by using the left and right arrow as seen in Figure 6.3.
3. Click the *Protocol* dropdown arrow to find the protocol used by your GPS receiver to the output data (NMEA 0183).
4. Click the *GPS Datum* dropdown arrow to select the datum used by the GPS receiver to the output coordinates (WGS84).
5. Click the *GPS* tab on the ArcPad option dialog box to display the GPS page.

6. Select the serial port on your GPS handheld device. Set The *Port* to *COM2* for ArcPad application.
7. Set the remaining communication parameters to match the settings on your GPS receiver as shown in Figure 6.3(b).



(a)



(b)

Figure 6.3 Setting communication between the ArcPad and the GPS

6.4 ACTIVATING THE GPS

There are two ways to activate the GPS.

1. A user can activate the GPS by tapping the GPS position window button "  ". The message box will pop up the message "The GPS is not activated. Would you like to activate it now?" (see Figure 6.4). Selecting "Yes" will activate the GPS and open the GPS position window.

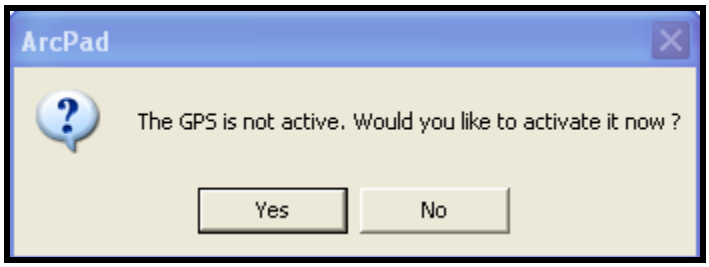


Figure 6.4 Activating the GPS (1)

2. A user can also activate the GPS by tapping the arrow next to the GPS position window. Selecting the *GPS Active* allows the GPS to activate.

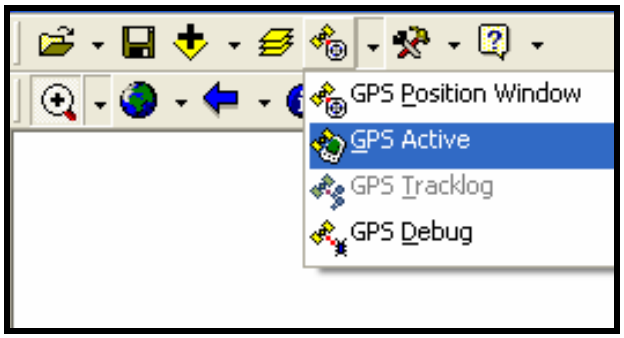


Figure 6.5 Activating the GPS (2)

6.5 ADDING LAYERS

1. Tap the Add Layer button “ ” on the Main tool bar.
2. Tap the Folder button to navigate to the directory that stores the data.
3. Select the folder that contains the layer to be added on the map.
4. Tap O.K.
5. Check mark on the file you want to add.
6. Tap O.K. The selected data layer will be added to the ArcPad map.

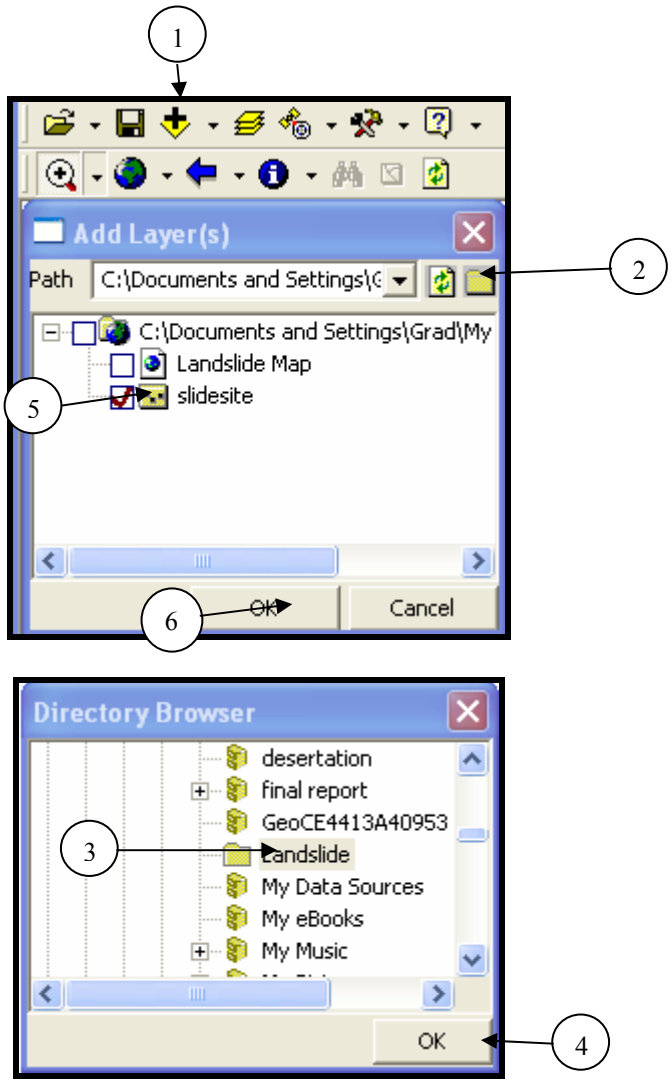


Figure 6.6 Adding map layers on ArcPad

6.6 TURNING A LAYER'S VISIBILITY ON OR OFF

Once a layer has been added to the ArcPad map, the layer can be turned on or off. (See Figure 6.7)

1. Tap on the layers button. The layer dialog box opens and displays a list of the layers that have been added to the map.
2. Check the visible check box to turn the layer on. To uncheck the check box turns the layer off.
3. Check mark on the identify tool allows a user to view the attribute information.
4. Check mark on the editing check box allows the user to edit information (Landslide Field Reconnaissance Form) in the shape file.
5. Tap O.K.

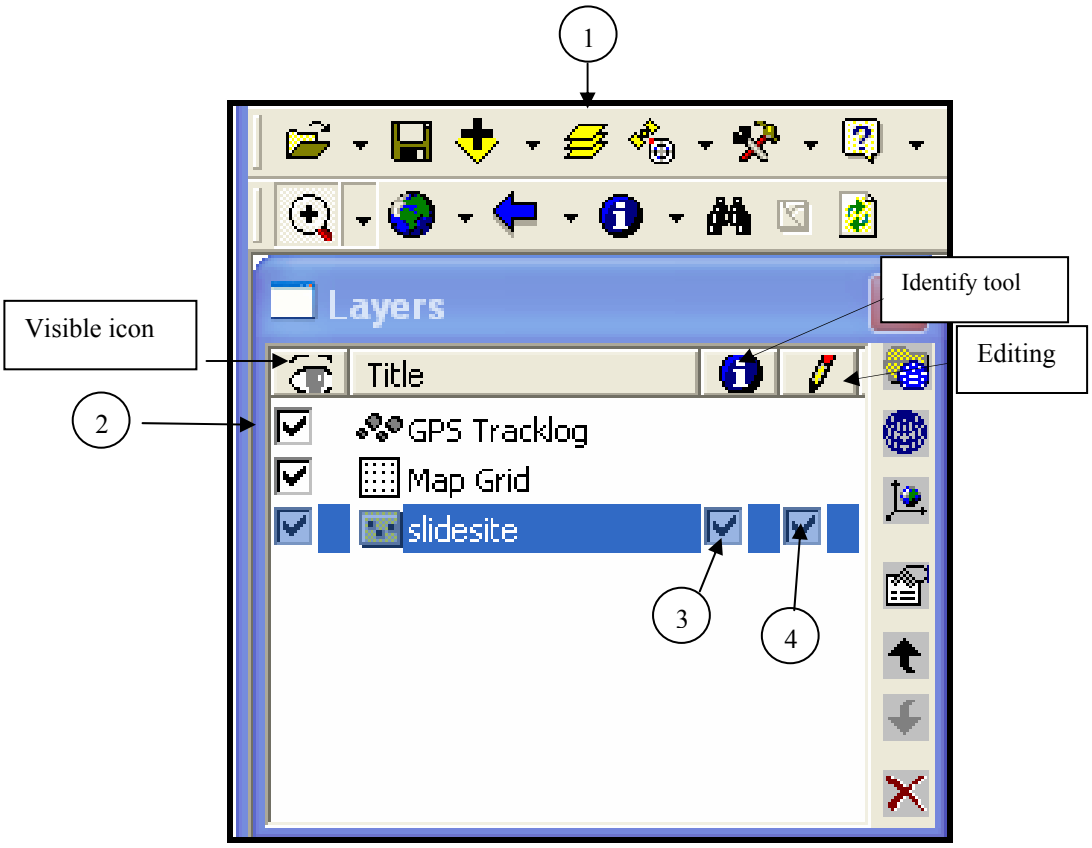


Figure 6.7 Manipulating data layers

6.7 USING THE LANDSLIDE FIELD RECONNAISSANCE FORM IN ARCPAD

Once the working layers have been added in the ArcPad map, then the data collection process can begin. A user can work on the form with or without the GPS being activated.

1. Without the GPS being activated, the user can locate the point button "  " on the third row of the menu bar shown in Figure 6.8.
2. Tap the point button. The landslide field reconnaissance form pops up and a point appears representing a landslide location on the map. Note: this is used when the GPS signal is not available.
3. When the GPS signal is available, the coordinates can be edited on the last page of the form shown in Figure 6.9.
4. Tap O.K., the point moves to the right location on the ArcPad Map.

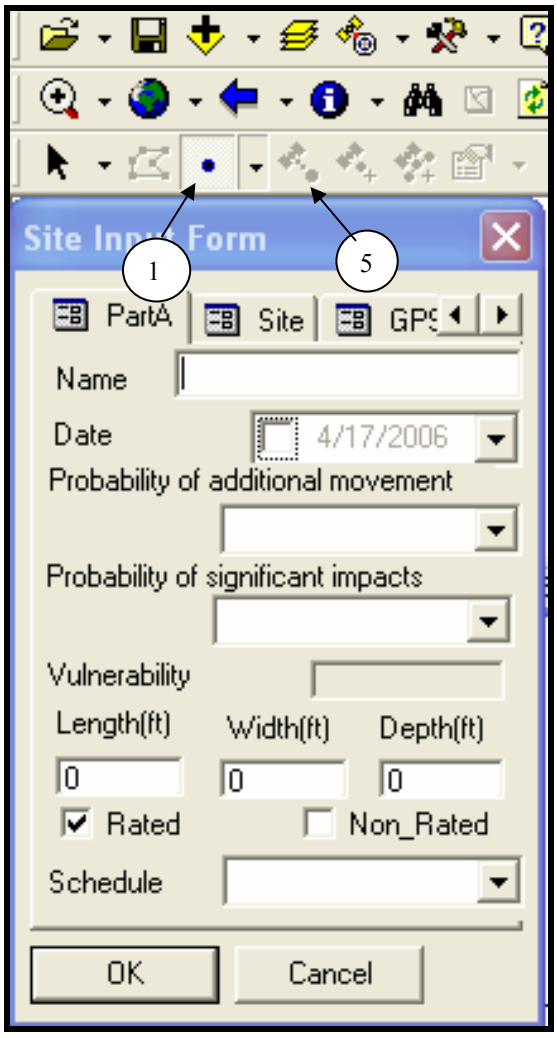


Figure 6.8 Activate the landslide field reconnaissance form with and without GPS

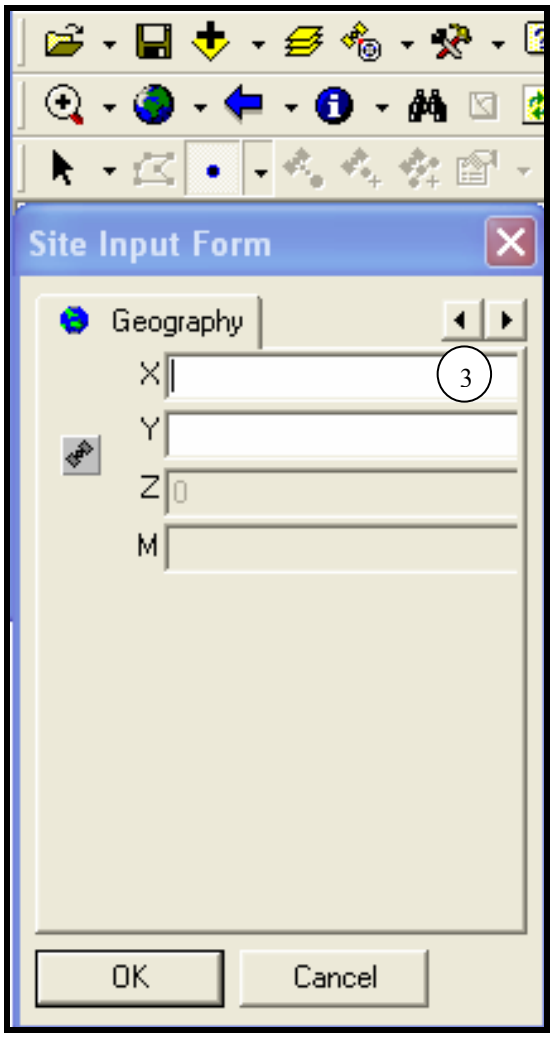


Figure 6.9 Updating the GPS coordinates

5. When the GPS signal is available, a user can tap the capture point button "  " in Figure 6.8.
6. By selecting this button, the form pops up. When finishing filling out the information, the user clicks O.K. The information is stored as the location of landslide on the GIS map.

6.8 UPDATING THE DATABASE USING THE INFORMATION COLLECTED BY ARCPAD

Once a user finishes landslide data collection by using ArcPad, he/she needs to upload the files to the landslide database. The process is as follows.

1. Synchronize the handheld unit with the local computer.
2. Locate the file directory in the handheld unit that contains the landslide data by the local computer.
3. The files needed for uploading are dbf, shp, shx, and prj files.
4. Create a new folder in the local machine and copy and paste these files into this folder.
5. Login the landslide database website.
6. Select the *File Management*. (See Section 5.5 in Chapter 5)
7. Click on *RawFileManage*.
8. Select the *upload* option on the upper right menu tab.
9. Fill up the information as needed, browse the information files, and then click on submit. The data will be uploaded into the database.

APPENDIX A

LANDSLIDE FIELD RECONNAISSANCE FORM

OHIO LANDSLIDE HAZARD RATING SYSTEM

Landslide Inventory Number
□-□□□□□□

Landslide Observation Report *filled by Highway/construction worker*

Name of reporter		
Affiliation (District)		
Date		
Site Location	**County**	
	Route	
	Mile marker (county basis)	

Description (Visual Inspection)

Landslide material(s)	__Soil __Rock __Both
Number of lanes (one direction)	__1 __2 __3 __4 __5 __6
Posted speed limit (miles/hr)	__15 __20 __25 __30 __35 __40 __45 __50 __55 __60 __65 __70
Location of landslide relative to roadway	__Above roadway __Below roadway __both
Position of impact on roadway	Position of cracks/dips: __Pavement __Shoulder __Ditch __None
	Position of earth debris: __ Pavement __Shoulder __Ditch __None
Impact to adjacent structures or properties	__Roads __Railroads __Residential __Buildings __Commercial __Bridge __Utilities __Others_____
Vegetation	Barren__% Grass __% Shrub__% Tree __% Other_____
Presence of surface water	__Yes __No
Presence of groundwater	__Yes __No __Unknown
Previous site works (Based on observation at the site)	__Temporary __Failed temporary __Permanent __Failed permanent __Patching of asphalt __Guardrail work __Other_____
Recent precipitation	__Heavy __Moderate __Light
Duration	__24-hr __3-d __7-d __15-d
Date identifying first evidence of instability	
Name of verifier (CM/TM)	
Date of verification	
Signature	

OHIO LANDSLIDE HAZARD RATING SYSTEM

Landslide Inventory Number
□-□□□□□□

Part A filled by Transportation/County Manager

Evaluator's name	
Date of observation	

Site Location

Jurisdiction	__**C**ounty __**T**urnpike __**M**unicipal __**S**tate __**T**ownship __**F**ederal __**P**rivate
County	
District	
Route system	__**IR**-interstate __**US**-United States route __**SR**-state route __**CR**-county road __**TR**-township road __**MR**-municipal road __**RA**-ramp __**PA**-park roads __**BK**-bike route
Route number	
Mile marker (county basis)	Beginning: Ending:
Network linear feature (NLF) (auto generation)	
Number of Lanes (one direction)	__1 __2 __3 __4 __5 __6
Location of landslide relative to roadway	__Above roadway __Below roadway __Both

Centroid of Affected Highway (GPS Information)

GPS coordinates	Centroid: Latitude: _____ Longitude: _____ Elevation: _____ft
	Beginning point: Latitude: _____ Longitude: _____ Elevation: _____ft
	Ending point: : Latitude: _____ Longitude: _____ Elevation: _____ft
State coordinates (Mid-point) (Auto generation)	Zone: _____ Northing: _____ Easting: _____
USGS Quad (Auto generation)	Name: _____ Number: _____

OHIO LANDSLIDE HAZARD RATING SYSTEM

Landslide Inventory Number
□-□□□□□□

Landslide vulnerability table

Probability of additional movement	**Probability of significant impacts to the roadway, structures, adjacent property or features**			
	Very High	***High***	***Moderate***	***Low***
Very High	Very High	Very High	High	Moderate
High	Very High	High	High	Moderate
Moderate	High	High	Moderate	Low
Low	Moderate	Moderate	Low	Low

Remark: A landslide site having "low" vulnerability is non-rated.

General information

General dimensions (Rough estimate)	Length (ft): _____ Width (ft):_____ Estimated maximum depth of sliding surface (ft)_____
Preliminary rating (Use landslide vulnerability table)	__Rated __Non-rated
Inspection frequency	__Hourly __Daily __Weekly __Biweekly __ Monthly __Quarterly __Yearly __Others_____

Landslide Inventory Number

□-□□□□□□

Part A (continued)

Pictures and simple or rough sketches:

- No actual measurement, only rough visual observations.
- Require to take at lease 3 pictures of landslide at BMP, EMP, centroid of affected highway. Additional pictures may include each with downslope, upslope, and cross slope pictures.

OHIO LANDSLIDE HAZARD RATING SYSTEM

Landslide Inventory Number
□-□□□□□□

Part B filled by Transportation/County Manager

Evaluator's name	
Date of observation	

Site Location

Jurisdiction	__**C**ounty __**T**urnpike __**M**unicipal __**S**tate __**T**ownship __**F**ederal __**P**rivate
County	
District	
Route system	__**IR**-interstate __**US**-United States route __**SR**-state route __**CR**-county road __**TR**-township road __**MR**-municipal road __**RA**-ramp __**PA**-park roads __**BK**-bike route
Route number	
Mile marker (county basis)	Beginning: Ending:
Network linear feature (NLF) (auto generation)	
Number of lanes (one direction)	__1 __2 __3 __4 __5 __6
Location of landslide relative to roadway	__Above roadway __Below roadway __Both

Site History

Date of original construction (m/d/y)	_____/_____/_____
Date of alignment modifications (m/d/y)	_____/_____/_____
Date of remedial activities (m/d/y)	_____/_____/_____
Past remedial activities	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others_____
Existing remediation	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others_____
Annual maintenance frequency (times/year)	
Annual maintenance cost (Average Over the Past 5 to 10 Years) (dollars/year)	
Maintenance response (Based on judgment)	__No response __Require observation with periodic maintenance __Require routine maintenance response to preserve roadway __Require immediate response for safe travel or to protect adjacent structure

OHIO LANDSLIDE HAZARD RATING SYSTEM

Landslide Inventory Number
□-□□□□□□

Traffic Data

Average daily traffic (ADT)	Total traffic: _____vehicles/day Passenger traffic: _____vehicles/day Trucks traffic: _____vehicles/day
Accident history in past 10 years (Number of occurrence)	Number of accident in past 10 years_____ Number of accident without loss_____ Number of accident with vehicle and property damage_____ Number of accident with injury_____ Number of accident with fatality_____
Estimated detour route length (miles)	_____miles
Posted speed limit (miles/hr)	__15 __20 __25 __30 __35 __40 __45 __50 __55 __60 __65 __70
Estimated traveling time of detour (hr)	Truck_____hr Passenger_____hr

OHIO LANDSLIDE HAZARD RATING SYSTEM

Landslide Inventory Number
□-□□□□□□

Part C (District Geotechnical Engineer)

Evaluator's name	
Date of observation	

Site Location verified by DGTE (provide O.K. click button)

Jurisdiction	__**C**ounty __**T**urnpike __**M**unicipal __**S**tate __**T**ownship __**F**ederal __**P**rivate
County	
District	
Route system	__**IR**-interstate __**US**-United States route __**SR**-state route __**CR**-county road __**TR**-township road __**MR**-municipal street __**RA**-ramp __**PA**-park roads __**BK**-bike route
Route number	
Mile marker (county basis)	Beginning: Ending:
Network linear feature (NLF) (auto generation)	
Number of lanes (one direction)	__1 __2 __3 __4 __5 __6
Location of landslide relative to roadway	__Above roadway __Below roadway __Both

Centroid of Affected Highway (GPS Information) verified by DGTE (provide O.K. click button)

GPS coordinates	Centroid:	Latitude: _____ Longitude: _____ Elevation: _____
	Beginning point:	Latitude: _____ Longitude: _____ Elevation: _____
	Ending point: :	Latitude: _____ Longitude: _____ Elevation: _____
State coordinates (Mid-point) (Auto generation)	Zone: _____ Northing: _____ Easting: _____	
USGS Quad (Auto generation)	Name: _____ Number: _____	

OHIO LANDSLIDE HAZARD RATING SYSTEM

Landslide Inventory Number
□-□□□□□□

Part C (continued)

Required information for data collection (use landslide vulnerability table)

Low (0< X ≤ 2 points)	Moderate and High (2< X ≤ 9 points)	Very high (X > 9 points)
• Verify and fill out C.1 • Very rough sketches by CM/TM • Take additional photos C.14	• Verify and fill out C.1 • Fill out C.2 to C.11 • Verify rough sketches by CM/TM • Take additional pictures C.14	• Verify and fill out C.1 • Fill out C.2 to C.13 • Take additional photos C.14

Landslide vulnerability table

Probability of additional movement (A)	**Probability of significant impacts to the roadway, structures, adjacent property or features (B)**			
	Very High(4)	***High(3)***	***Moderate(2)***	***Low(1)***
Very High(4)	Very High (16)	Very High (12)	High (8)	Moderate (4)
High(3)	Very High (12)	High (9)	High (6)	Moderate (3)
Moderate(2)	High (8)	High (6)	Moderate (4)	Low (2)
Low(1)	Moderate (4)	Moderate (3)	Low (2)	Low (1)

Vulnerability score (X) = A× B

Inspection schedule

Inspection frequency			
	__Hourly	__Daily	__Weekly
	__Biweekly	__ Monthly	__Quarterly
	__Yearly	__Others_____	

OHIO LANDSLIDE HAZARD RATING SYSTEM

Landslide Inventory Number
□-□□□□□□

Part C (continued)

Slope Characteristics

Slope type		__Natural __Cut __Fill __Cut and fill
Average slope angle (α_{ave}°)		$\alpha_{ave} = \frac{\alpha_1 \cdot l_1 + \alpha_2 \cdot l_2 + ...\alpha_n \cdot l_n}{L} =$ _____ °
Slope surface appearance		__Straight __Concave __Convex __Hummocky __Terraced __Complex
Vegetation cover		__Grass__% __Shrub__% __Cultivated land__% __Reforestation__% __Woodland__% __Other _____
Vegetation density		__Sparse __Moderate __Dense
Hydrogeology	**Surface water**	**Types of water sources** __Reservoir __Lake __River __ Creek __Pond __Surface drainage __Others_____ __None **Location of water sources that may affect landslide** __Above __Below __Both
	Groundwater (use visual inspection)	**Groundwater flow** __Into landslide __ Off landslide __Both __Unknown __None **Groundwater condition** __Spring __Seep __Both __Unknown __None **Location of ground water:** __Above __Below __Middle __None **Presence of monitoring or water well** __Artesian __Flowing artesian __Pooled __None observed
Erosion area		__Head __Toe __Flank __Body __None
Possible cause of failure		__Erosion of the toe __Precipitation __Failure of drainage __Drainage outlet __Surface water __Weathering of materials __Deforestation __Change of water level
Orientation of slope (Azimuth; The clockwise angle from the north)		_____degree
Direction of landslide (Azimuth; The clockwise angle from the north)		_____degree

OHIO LANDSLIDE HAZARD RATING SYSTEM

Landslide Inventory Number
□-□□□□□□

Part C (continued)

Slope Materials (by Visual Inspection and Judgment)

Soil origin	__Colluvium __Alluvium __Till __Residual soil __Weather rock __Unweathered rock __Fill __Combination __Others_____
Soil type	__Boulders/cobbles __Stone fragments __Gravel __Sand __Fine sand __Silty gravel __Silty sand __Clayey gravel __Clayey sand __Silty soil __Clayey soil __Organic __Combination __Others_____
Rock type	__Shale __Mudstone /claystone __Siltstone __Sandstone __Limestone __Coal __Interbedded __Dolomite __Combination __Others_____

Landslide Characteristics

Type of Movement (Rockfall is not included.)	**Slide**	__Rotational rock slide __Translational rock slide __Rotational earth slide __Translational earth block slide __Debris slide __Complex
	Flow	__Slow earth flow __Loess flow __Dry sand flow __Debris avalanche __Debris flow __Block stream __Complex
	Spread	__Rock spread __Earth spread __Complex spread
Rate of movement		_____inches/year __unknown
State of landslide activity		__Active __Inactive __Mitigated

Observed Remediation

Past remedial activities	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others_____
Existing remediation	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others_____

OHIO LANDSLIDE HAZARD RATING SYSTEM

Landslide Inventory Number
□-□□□□□□

Part C (continued)

Preliminary Determination of Causes of Landslide

Human activities	__Excavation/under cutting __Groundwater pumping __Deforestation __Loading __ Defective maintenance __Failure of drainage __Water leakage from pipes __Artificial vibrations __Loose waste dumping __ Construction related __Others_____
Natural activities	__Rainfall __ Snowmelt __Earthquake __Ground water __ Loss of vegetation __Toe erosion __ Inadequate long term strength __Surface water level change/rapid drawdown __Degradation of construction material __Others_____
Comment (limit no more than 50 words)	

Observed Traffic Information

Actual sight distance (ASD) (ft.)	_____ft
Percent decision sight distance (%DSD) %DSD=(ASD/DSD)*100	_____%DSD

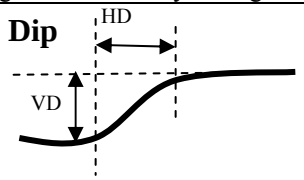
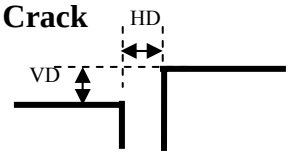
Decision sight distance (DSD)

Posted speed limit (mph)	Decision sight distance (ft)
25	375
30	450
35	525
40	600
45	675
50	750
55	875
60	1000
65	1050
70	1100

Landslide Inventory Number
□-□□□□□□

Part C (continued)

Impact assessment on roadway and beyond right of way

Current and potential impact of landslide on roadway	__On slope with a low potential to affect shoulder __On slope with a low potential to affect roadway __On shoulder or on slope with a moderate potential to affect roadway __On roadway, or on slope with a high potential to affect roadway or structure	
Current and potential impact of landslide on the area beyond right of way	__On slope with a low potential to impact area beyond right of way __On slope with a moderate potential to impact area beyond right of way __On slope with a high potential to impact area beyond right of way __On slope with a high potential to impact building or structure beyond right of way	
Evidence of impact on roadway	**Dip** __Yes __No **Maximum displacement of dip** Vertical displacement (VD) (inch)_____ Horizontal displacement (HD) (inch)_____	
	Crack __Yes __No **Maximum displacement of crack** Vertical displacement (VD) (inch)_____ Horizontal displacement (HD) (inch)_____	
	Earth debris on roadway __Yes __No Estimated volume (Yd^3) _____	

Adjacent Structures and Areas

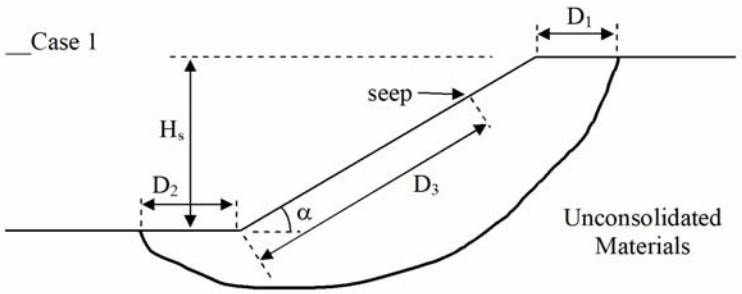
Adjacent structures	__Roads __Railroads __Residential __Buildings __Bridge __Utilities __Others_____
Surrounding area	__Forest __Agriculture __Rural __Urban __Housing development __Others_____

Landslide Inventory Number
□-□□□□□□

Part C (continued)

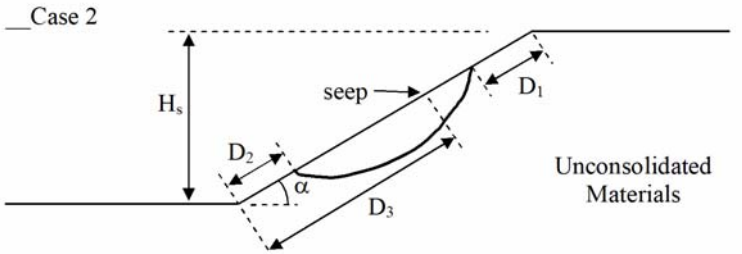
Information for estimation of landslide repair cost

__Case 1



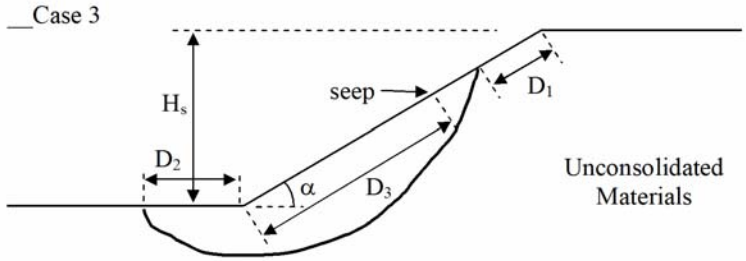
1. Average slope angle, α,_____
2. Height of slope, H_s (ft)_____
3. Length of slope repair, L, parallel to highway (ft)_____
4. Distance from crest of slope to failure surface, D_1(ft)_____
5. Distance from toe of slope to failure surface, D_2 (ft)_____
6. Distance along slope (measured from toe) to groundwater seeps, D_3, and approximate quantities of groundwater (ft)_____

__Case 2



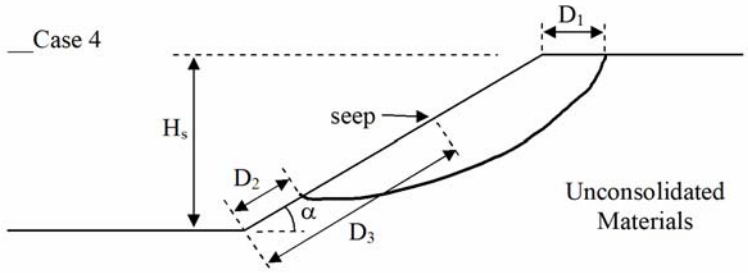
1. α,_____
2. H_s (ft)_____
3. L(ft)_____
4. D_1(ft)_____
5. D_2(ft)_____
6. D_3(ft)_____

__Case 3



1. α,_____
2. H_s (ft)_____
3. L(ft)_____
4. D_1(ft)_____
5. D_2(ft)_____
6. D_3(ft)_____

__Case 4



1. α,_____
2. H_s (ft)_____
3. L(ft)_____
4. D_1(ft)_____
5. D_2(ft)_____
6. D_3(ft)_____

Cost Estimate

Repair cost	
Benefit cost ratio	
Estimated time required for remediation (days)	_____days

Landslide Inventory Number
□-□□□□□□

Part C (continued)

Suggested Remediation Measure

__Benching & regarding
__ Counter berm & regrading
__Flattening Slope
__Soil Drainage
__Bedrock Drainage
__Retaining Walls
__Light Weight Fills
__Dynamic Compaction
__Bio-engineering
__Geofabrics
__Sheet Piling
__H Piling
__Drilled Piling
__Soil Nailing
__Tieback Walls
__Remove & Replace
__Shear Key
__Chemical Treatment
__Relocation
__Bridge
__Change Line or Grade
__Other_____

OHIO LANDSLIDE HAZARD RATING SYSTEM

Part C (continued)

Sources of Supplemental Information

Landslide Inventory Number

□-□□□□□□

__Aerial photos
__Satellite imaginary
__County-ODOT
__State-ODOT
__Soil/Rock/Water samples
__Folder/ File location
__USGS publications and files
__USGS open file map series #78-1057 “Landslide related features”
__Division of geological survey (ODNR)
__Division of mineral resource management (ODNR)
__Division of soil and water (ODNR)
__Others_____

__Field visit
__Local people
__Dist-ODOT
__City and county engineer
__GPS features
__Academia with engineering or geology program
__USGS Quadrangles

Landslide Inventory Number
□-□□□□□□

Part C (continued)

Landslide hazard rating matrix

CATEGORY		RATING CRITERIA and SCORE				Total Item Scores
		Points 3	Points 9	Points 27	Points 81	
Movement location/ impact (select higher score)	Current and potential impact of landslide on roadway	On slope with a low potential to affect shoulder	On slope with a low potential to affect roadway	On shoulder, or on slope with a moderate potential to affect roadway	On roadway, or On slope with a high potential to affect roadway or structure	
	Current and potential impact of landslide on area beyond right of way	On slope with a low potential to impact area beyond right of way	On slope with moderate potential to impact area beyond right of way	On slope with high potential to impact area beyond right of way	On slope with high potential to impact structure beyond right of way	
Hazard to traveling public (Select higher score)	Rate of displacement in roadway if known	<1-inch/year	1 to 3-inches/year No single event ≥1-inch	3 to 6-inches/year No single event ≥3-inches	>6-inches/year Single event ≥3-inches	
	Evidence of displacement in roadway	Visible crack or dip no vertical drop	≤1-inch of displacement	1 to 3-inches of displacement	≥ 3-inches of displacement	
Maintenance (Select higher score)	Maintenance frequency	None to rare	Annually (one time/year)	Seasonal (1 to 3 times/ year)	Continuous throughout year (> 3 times/year)	
	Maintenance response	No response	Requires observation with periodic maintenance	Requires routine maintenance response to preserve roadway	Requires immediate response for safe travel or to protect adjacent structure	
%Decision Sight Distance (%DSD)		≥ 90	89 -50	49-35	< 34	
ADT		<2000	2001-5000	5001-15000	>15001	
Accident history (Related to landslide)		No accident	Vehicle or property damage	Injury	Fatality	
					Total Score	

Landslide Inventory Number
□-□□□□□□

Part C (continued)

Hazard calculation sheet

Hazard category	Explanation	Item Scores
1. Movement Location/ Impact		
2. Hazard to Traveling Public		
3. Maintenance		
4. %DSD		
5. ADT		
6. Accident history (Related to landslide)		
	Total score	

Landslide Inventory Number
□-□□□□□□

Part C (continued)

Detailed mapping with physical measurement

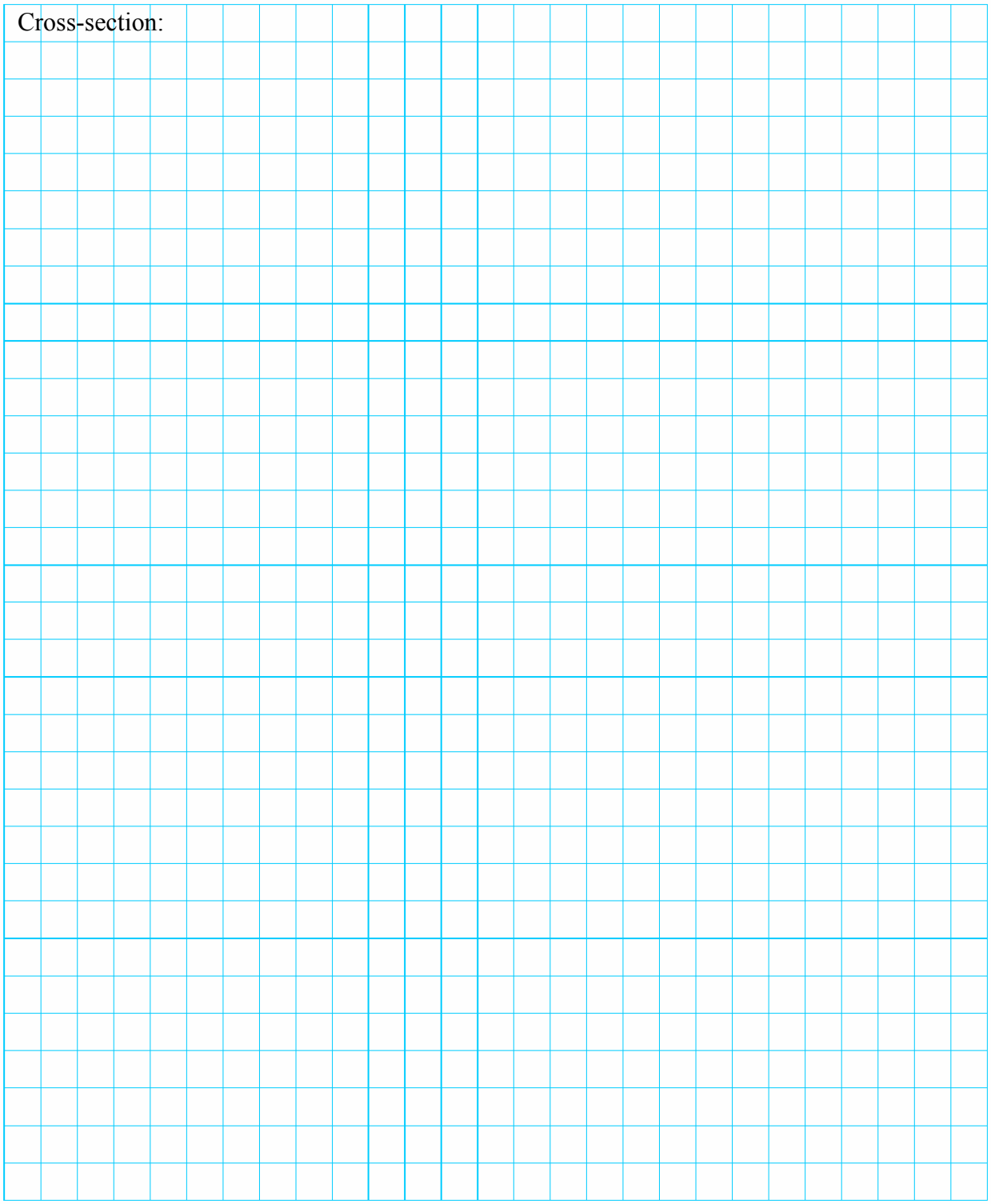
Include all locations of crown, root, edges, spring, surface water, cracks, toe bulge, sloughing, head scarps, guardrail distortion, linear deflections, stream deflections, toe erosion, hydrophytic vegetation, J-trunk trees, slanted poles /trees and etc. The sketch should indicate direction (north arrow), draw to scale, and include reference points for cross section.

Plan:

Landslide Inventory Number
□-□□□□□□

Part C (continued)

Cross-section:



Landslide Inventory Number

□-□□□□□□

Part C (continued)

Additional Pictures

Provide additional pictures of physical evidence as stated in page C. 12 (provide a folder for storing digital pictures)

APPENDIX B

OBSERVATION TIPS

Abramson et at (1996) have summarized the important tips for slope failure observation as follows.

1. **Look for Ground Movements:** Sign of ground movements are evidenced by formation of tension cracks, hummocky surfaces of slopes, breakage of pipe or power lines, tilting of trees, spalling or other signs of distress in highway structures, such as guardrails, cracking of drainage channels on slope, closure of expansion joint in bridges plate or rigid pavements, and loss of alignment of building foundations.

2. **Identify patterns of surface cracks:** Surface cracks are not necessary normal to direction of ground movement. For example, cracks near the crown are normal to the direction of horizontal movement but cracks along the flank are nearly parallel to it. Small echelon cracks commonly develop in the surface soil before other signs of rupture take place. Cracks parallel to slope are indicative of block slide.

3. **Look for troublesome Hydrologic or soil formations:** If the formation has alternate weak and competent soil layers, slides may occur along the weak layers. Other weak areas are soil that is subject to liquefaction. For example, some of embankments, and steep hillsides, erosion removes support from the toe of engineered and natural structure, and landforms.

Naturally occurring springs located at toes or crests of slope may soften the soil, causing it to lose strength and allowing the slopes to fail. Often locations of spring can be found in densely vegetated areas. River banks, natural escarpments, quarries and highway and railway cuts may reveal, through the presence of seeps or springs, information on ground water flow in the area. Fill most likely to be unstable are those in stream valley where the depth of weathered highway material is the greatest, and those constructed on hill side areas where the potential sliding surface is inclined.

4. **Determine existing drainage patterns:** Site drainage is one of the most important factors involving slope instability. Surface water may saturate and weaken the embankments soils, foundation soils, and subgrade. The result often leads to a landslide. Therefore, it is important to look for any drainage flow that may have a potentially adverse effect on slope stability.

   During the field reconnaissance, all stream courses, channels, nullahs, ditches, catch pits, and culverts should be mapped. The details, such as sizes and conditions should be shown on the sketches. This information will be useful when assessing surface drainage characteristics of the existing site.

   Slope instability along an existing roadway may sometimes be attributed to inadequate maintenance of existing drainage features. Therefore, all the existing drainage features should be checked for leakage.

5. **Always Take Note of Natural or Engineered Earth Structures (cut or fill slope and retaining structure) in the vicinity of site:** These structures often give clues as to the most likely and practical way of designing, constructing, and remediating a slope, the potential problem that may occur after construction, and the types of remedial measure to be undertaken should the slope experience instability.

6. **Use common sense to explain features associated with ground movements and to determine the causes of ground movements:** Ground movements occur if the ground experiences "something" that undermines its equilibrium. This "something" could be natural causes, such as weathering, intense rainfall, and existence of soft layers, or human causes, such as under cutting toe of slopes, or overstress the ground.

All observation should be recorded in writing, drawing, and photographs so that they can be reviewed at a later time in the office. In each landslide investigation, the investigator has to take photographs. Photographs will be a good reference in case of the rating score criteria were to be modified in the future. An observation that seems insignificant at the time can be a key to the solution of a difficult design, construction, or remediation problem later on. For example, a small hole on a slope that is thought to be an animal borrow may turn out to be an exit tunnel. Another example is daylighting relict joints of residual soil slopes, which may be an adverse factor that will trigger slope instability.

The following schematic figures are used to illustrate the telltale evidence of the slope movements.

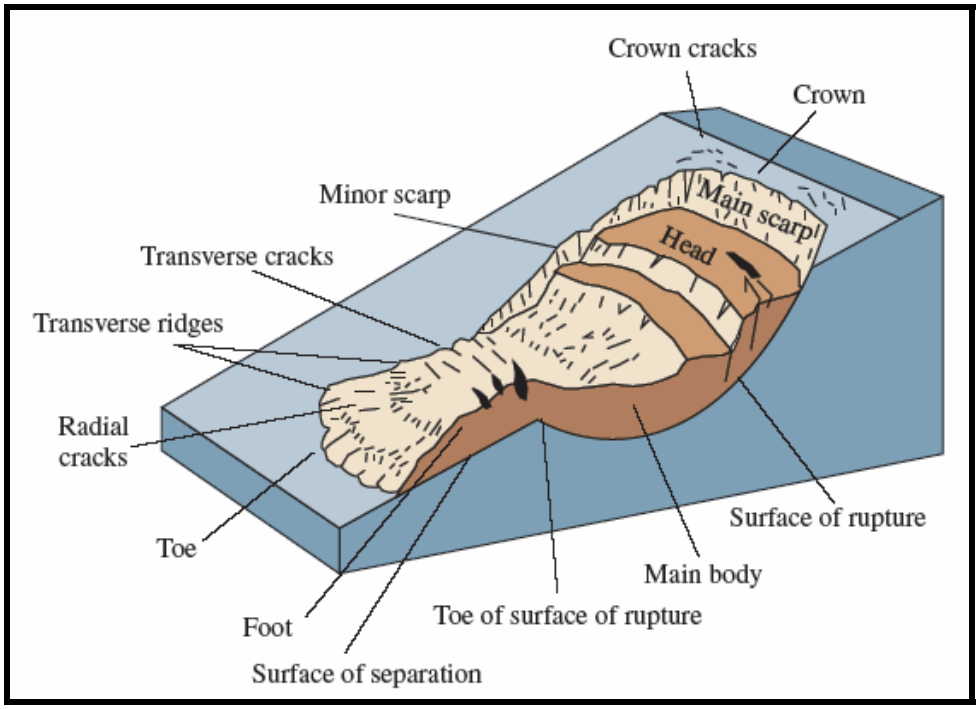


Figure B. 1 An idealized slump-earth flow showing commonly used nomenclature for a landslide (USGS Fact Sheet 2004-3072, July 2004)

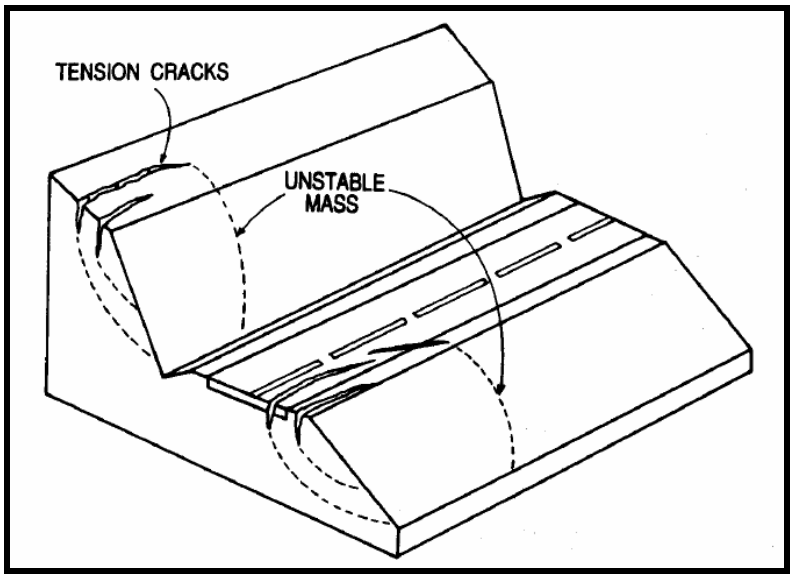


Figure B. 2 Development of tension cracks at top of roadway or cut slope (FHWA, 1988)

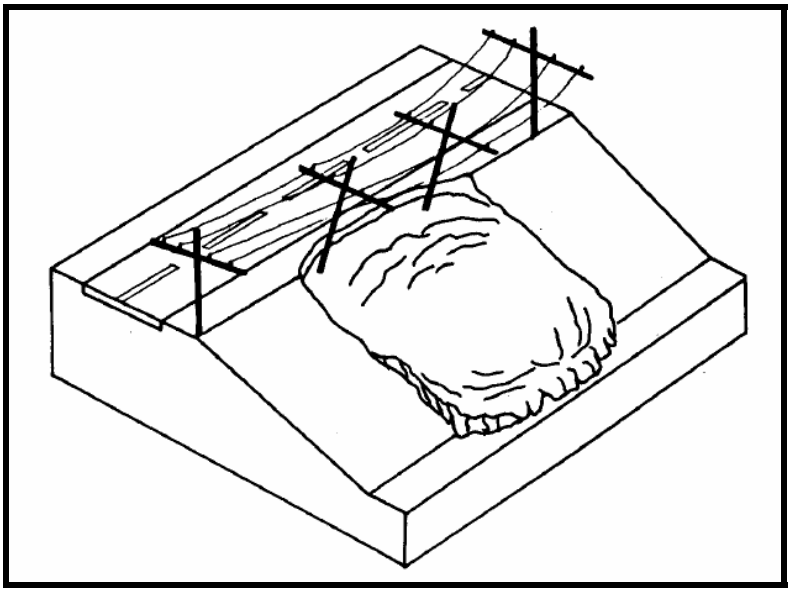


Figure B. 3 Leaning of telephone pole (FHWA, 1988)

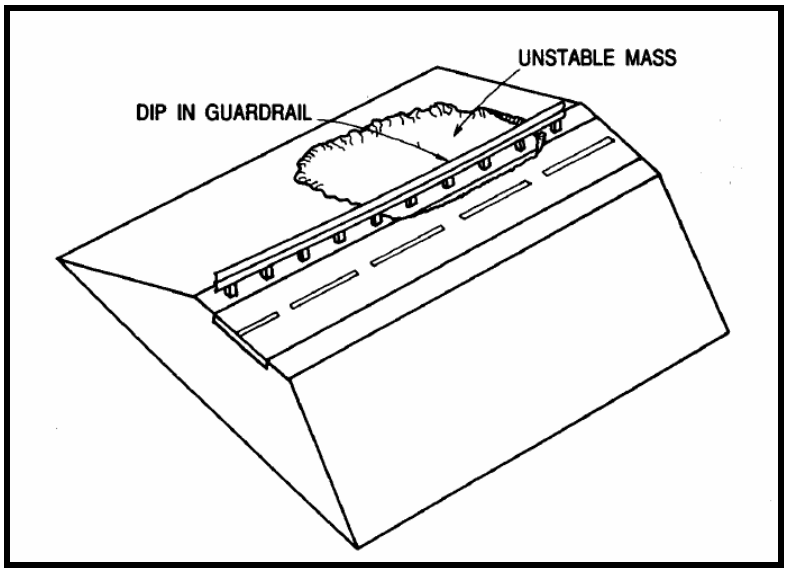


Figure B. 4 Dip in guardrail (FHWA, 1988)

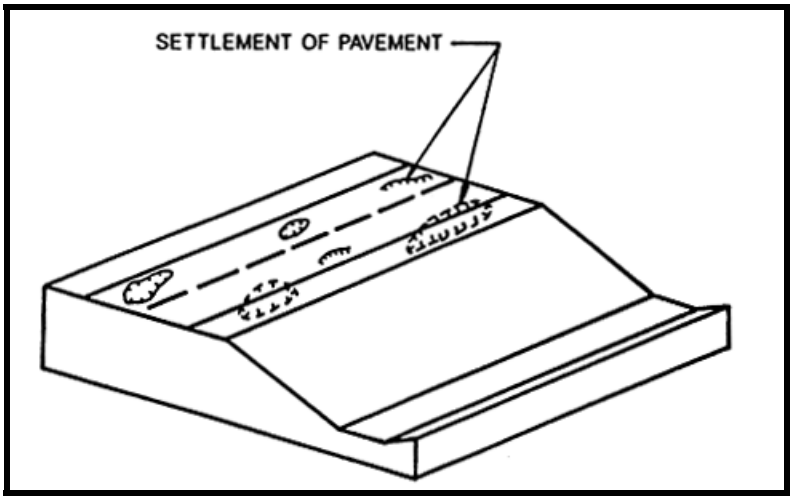


Figure B. 5 Settlement of roadway (FHWA, 1988)

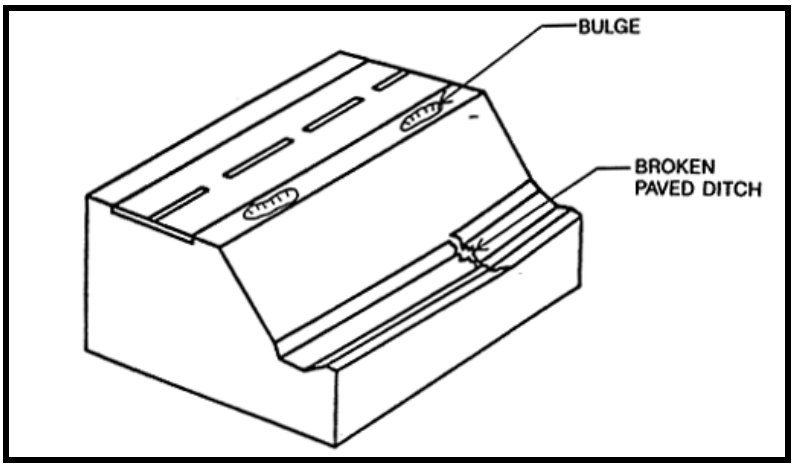


Figure B. 6 Bulge of pavement and broken paved ditch (FHWA, 1988)

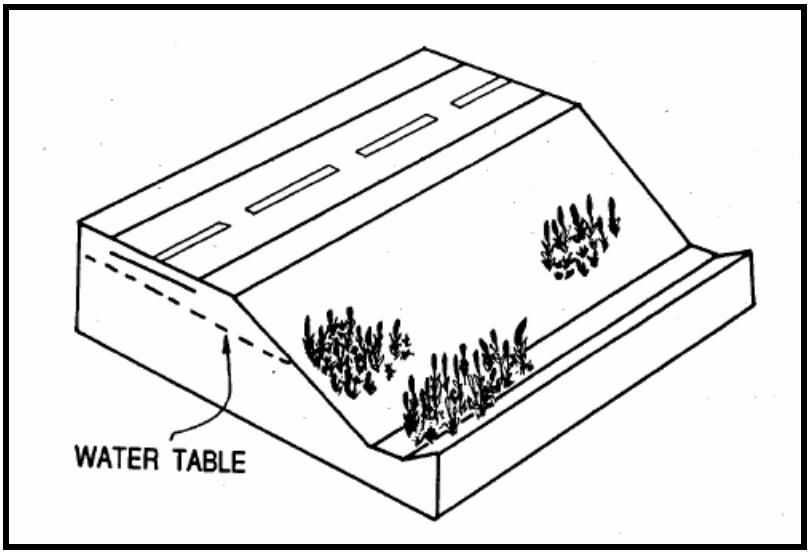


Figure B. 7 Cattails or willow trees warn of subsurface seepage (FHWA, 1988)

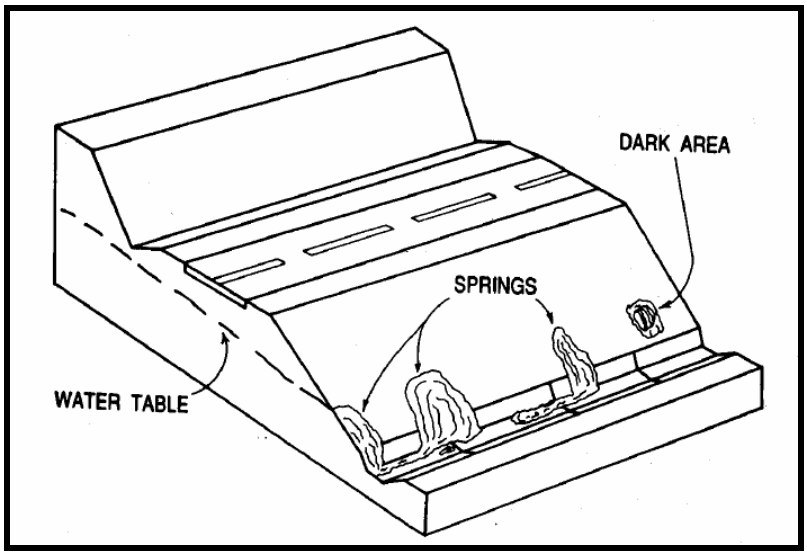


Figure B. 8 Naturally occurring springs on highway slopes (FHWA, 1988)

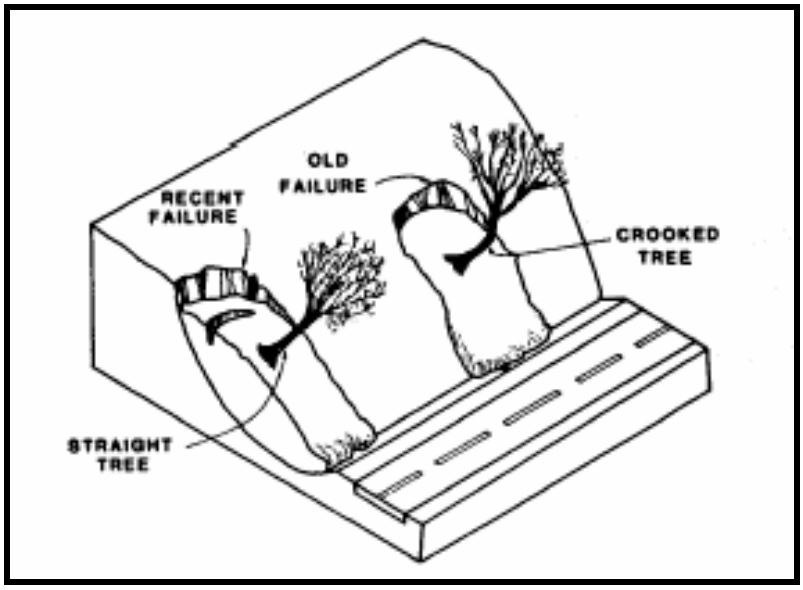


Figure B. 9 Tilted and curved trees (FHWA, 1988)

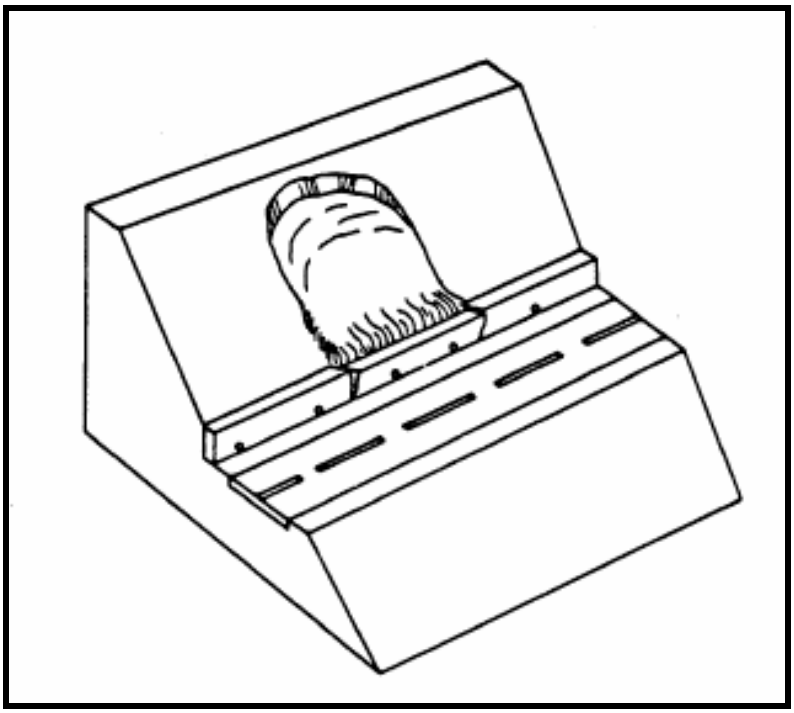


Figure B.10 Impact on retaining structure (tilted on retaining wall) (FHWA, 1988)

APPENDIX C

SOME ADDITIONAL DEFINITIONS AND TERMS

1. Features and dimensions of landslides

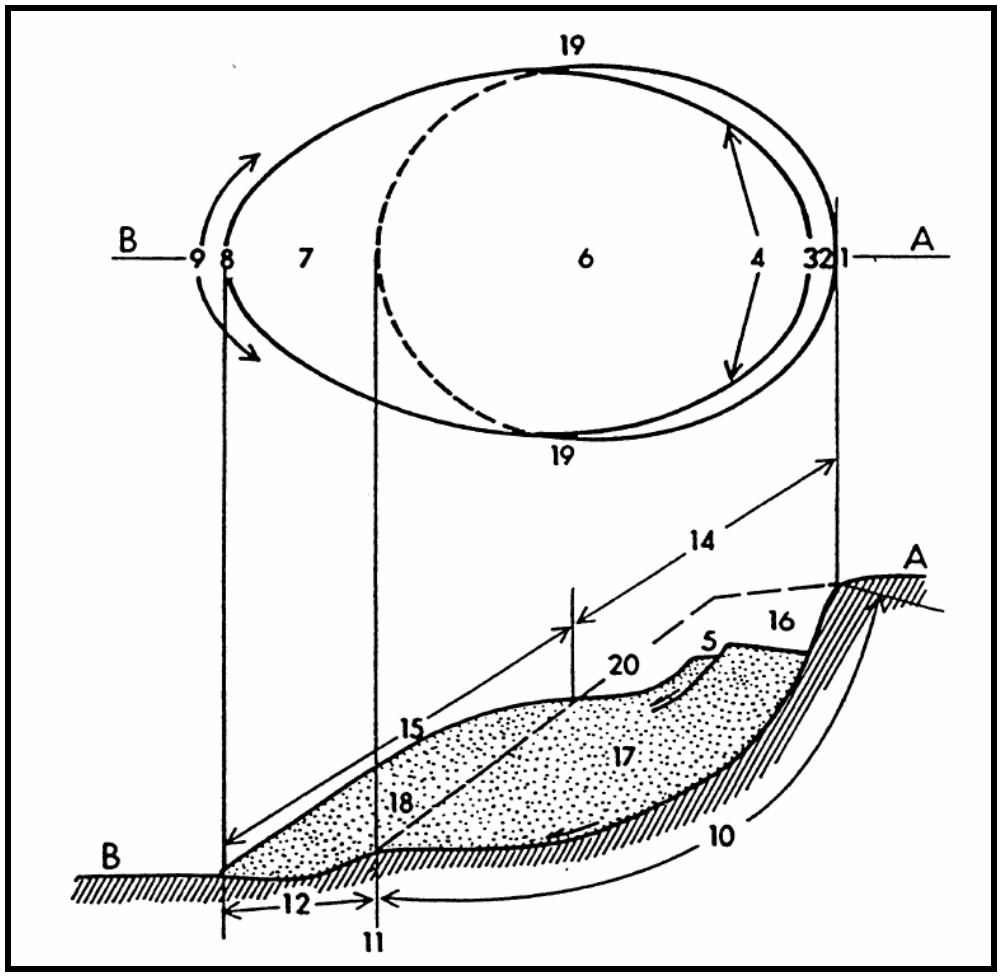


Figure C.1 Landslide features (Cruden and Varnes, 1992)

Table C. 1 Features and dimensions of landslides (Cruden and Varnes, 1992)

No.	Name	Definition
1	Crown	The practically undisclosed material above the main scarp
2	Main scarp	A steep surface on undisturbed ground at the upper edge of the landslide.
3	Top	The highest point of contact between the displaced material and main scarp.
4	Head	The upper parts of the landslide between the displaced material and main scarp.
5	Minor scarp	Steep surface on the displaced material of landslide produced by differential movements.
6	Main body	The part of displaced material of landslide that overlies surface of rupture.
7	Foot	The portion of landslide that has moved beyond the toe.
8	Tip	The point on toe farthest from top.
9	Toe	The lower margin of the displaced material.
10	Surface of rupture	The surface that forms the lower boundary of the displaced material.
11	Toe of surface of rupture	The intersection between the lower part of the surface of rupture and the original ground surface.
12	Surface of separation	The original ground surface now overlain by the foot of the landslide.
13	Displaced material	Material displaced from its original position by landslide movement.
14	Zone of depletion	The area within which the displaced material lies below the original ground surface.
15	Zone of accumulation	The area within which the displaced material lies above the original ground surface.
16	Depletion	The volume bounded by main scarp, the depleted mass, and the original ground surface.
17	Depleted mass	The volume of displaced material that overlies the rupture surface but underlies the original ground surface.
18	Accumulation	The volume of displaced material that lies above the original ground surface.
19	Flank	The undisclosed material adjacent to the sides of the rupture surface.
20	Original ground surface	The surface of the slope that existed before the landslide took place.

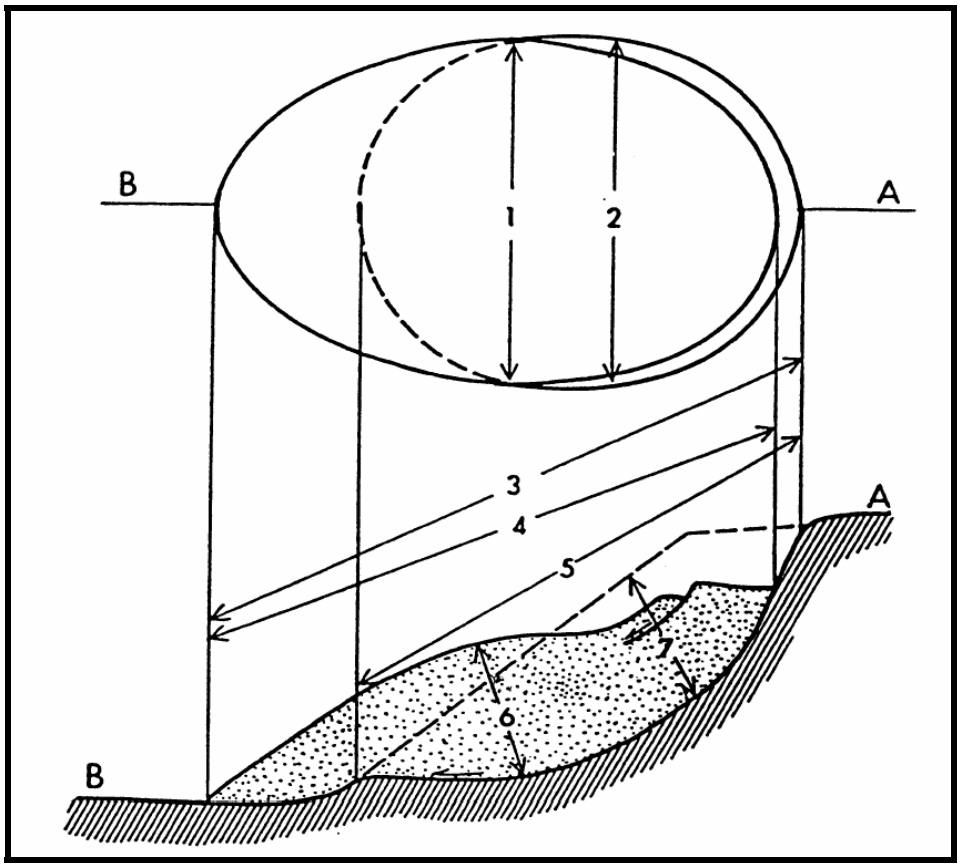


Figure C. 2 Landslide Dimensions (Cruden and Varnes, 1992)

Table C. 2 Definition of landslide dimensions (Cruden and Varnes, 1992)

No.	Name	Definition
1.	Width of displaced mass, W_d	The maximum breadth of the displaced mass perpendicular to the length L_d.
2.	Width of the rupture surface, W_r	The Maximum width between the flanks of the landslide, perpendicular to the length L_r.
3.	Total length, L	The minimum distance from the tip of the landslide to its crown.
4.	Length of displaced mass, L_d	The minimum distance from tip to the top.
5.	Length of the rupture surface, L_r	The minimum distance from toe of the surface of rupture to the crown.
6.	Depth of displaced mass, D_d	The maximum depth of the displaced mass, measured perpendicular to the plane containing W_d and L_d.
7	Depth of the rupture surface, D_r	The maximum depth of the rupture surface below the original ground surface measured perpendicular to the plane containing W_r and L_r.

2. Slope type:

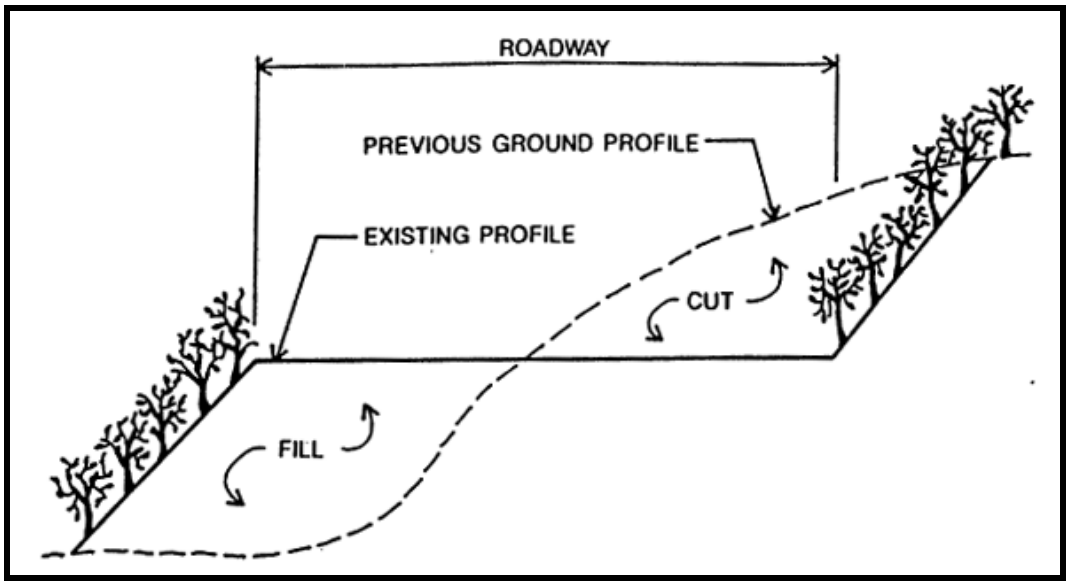


Figure C.3 Cut and Fill observed by vegetation (Abramson et al, 1996)

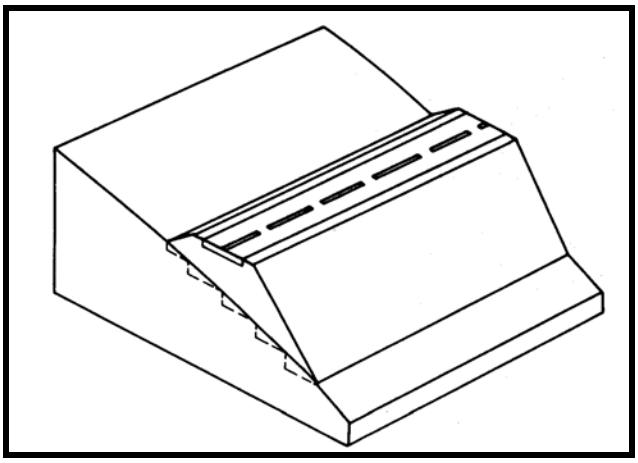


Figure C.4 Fill Slope (FHWA, 1988)

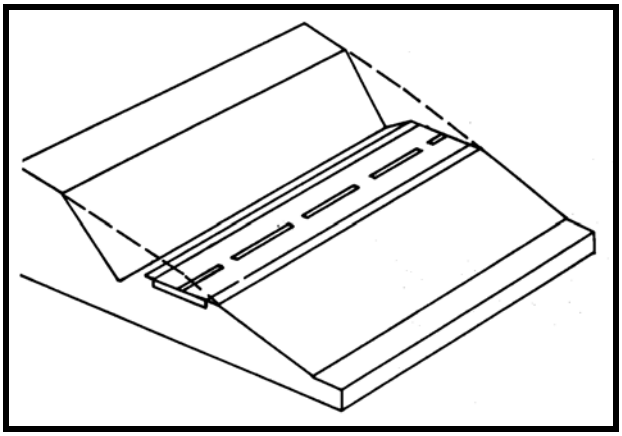


Figure C.5 Cut-slope (FHWA, 1988)

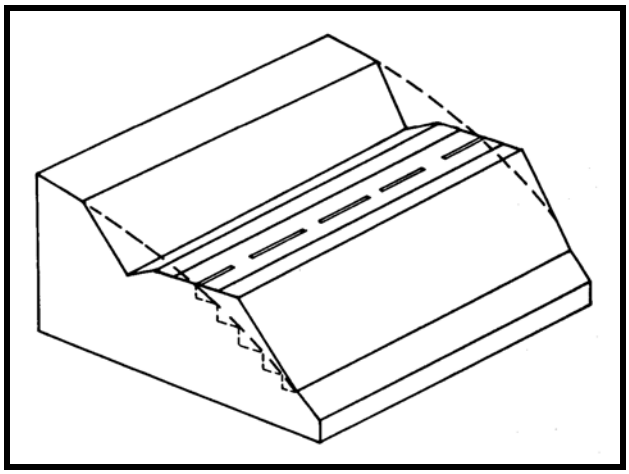


Figure C.6 Cut and fill slope (FHWA, 1988)

3. Average slope angle:

The slope angle is the inclination of the slope relative to the horizontal ground surface. In case of many slope breaks on the slope, the average slope angle can be calculated by summation of multiplication of the small portions of slope lengths and slope angles and then divided by the total length of the slope.

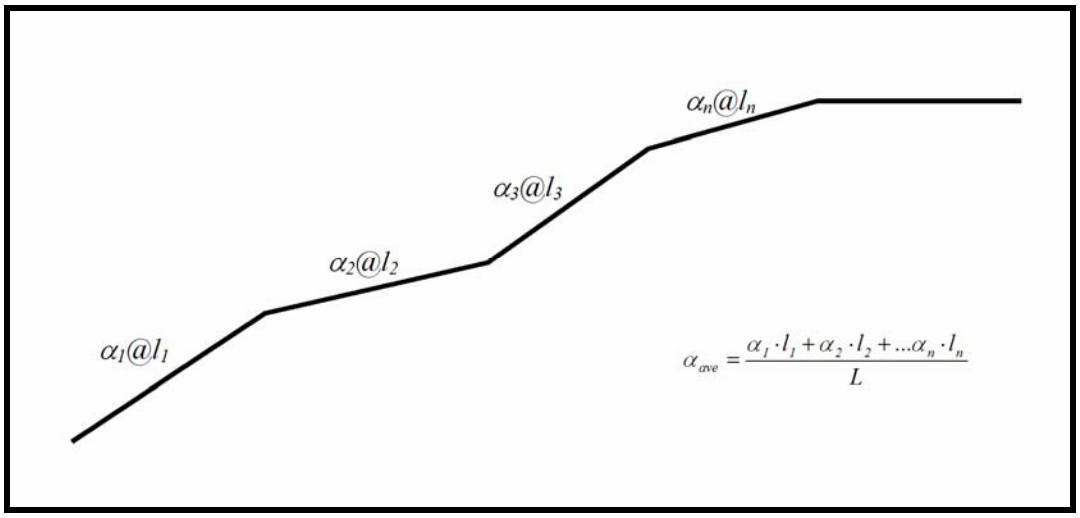


Figure C.7 Average slope angle calculation

4. Slope surface appearance:

Straight: More or less even gradient for the slope

Concave: Steep near the top of the slope and flatten out towards the toe

Convex: Flatter near the top, steepening towards the toe.

Hummocky: Rounded knoll or hillock with multidirectional slopes, where a rise of ground is of no great extent above a level surface

Terraced: Existence of step or terrace features along the contour of steep or long slopes

Complex: Slope with the combination of two or more principal forms or slope with irregular shape.

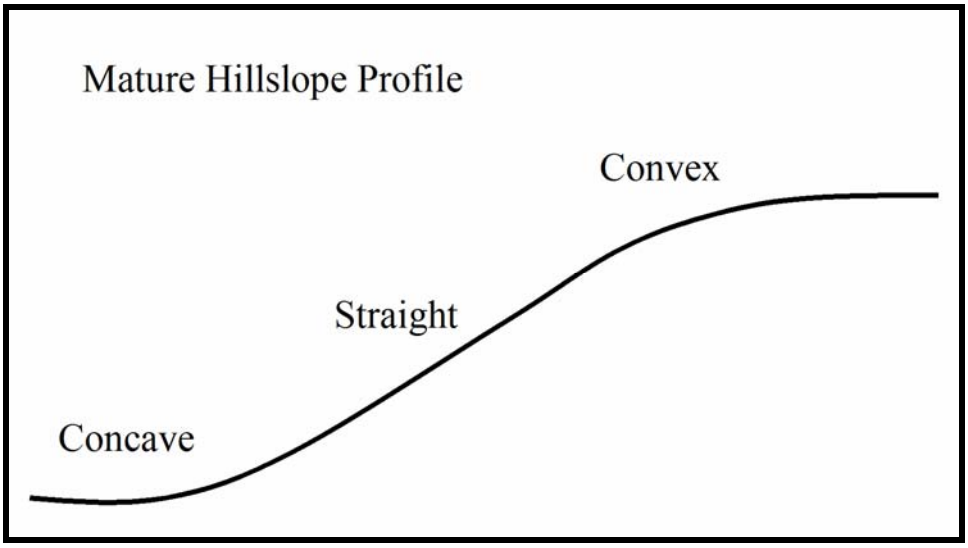


Figure C.8 Ideal mature hill slope profile,
presented by William Morris Davis 1907 (Abramson, 1996)

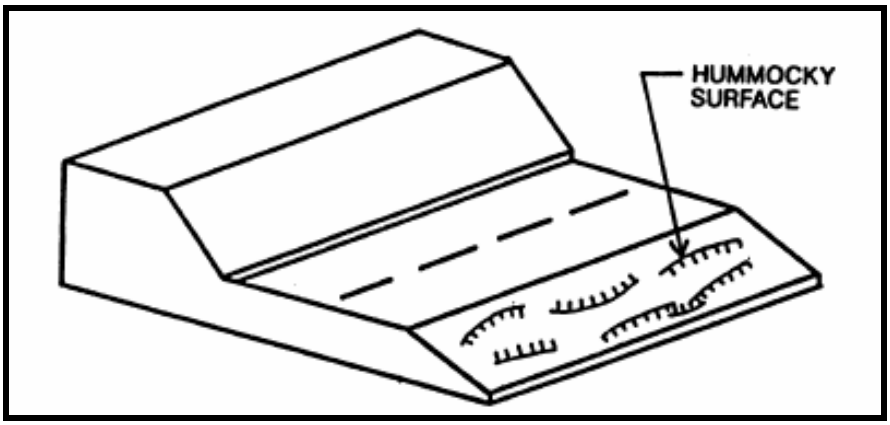


Figure C.9 Hummocky (FHWA, 1988)

5. **Vegetation:** Plants on the slope.

Density **Sparse:** Vegetation is grown in widely spaced intervals.

Moderate: Average quantity or extent of vegetation is found.

Dense: The slope has relatively high density of vegetation.

6. **Soil Origin:**

Colluvium is poorly sorted mixture of angular rock fragments and fine-grained materials deposited by rain, or slow continuous down slope creep. It is usually found at the hill side or gentle slope.

Alluvium is sediment deposit transported by running water and settled down when the speed of water flow is not sufficient to carry them. The deposits are generally of relatively narrow particle size range consisting of cobble and gravel in rushing water or sand from moderately moving rivers or clay from sluggish river.

Till is unsorted, unstratified, unconsolidated, heterogeneous material deposited directly from the ice and generally consists of clay, silt, sand-gravel, and boulder interbedded in varying proportion. Till is usually dense to very dense, high strength, and low compressibility.

Residual soil is formed in place by mechanical and chemical weathering of their parental bedrocks.

Weathered rock is involved in two types of weathering: chemical and mechanical weathering. Chemical weathering is the breakdown of minerals into new compounds by action of chemical agents. Mechanical weathering is the process by which rock is broken down into smaller fragment as a result of energy developed by physical force such as freeze and thaw cycles and temperature change.

Unweathered rock is the rock mass without significant disintegration by either chemical or mechanical weathering.

Fill composes of varieties of materials. The size of materials may range from very fine particles to large cobbles.

7. Soil Type:

Boulders are particles of rock that will not pass a 12-inch square opening.

Cobles are particles of rock that will pass a 12-inch square opening and be retained on a 3-inch sieve.

Gravel: Very large particle sizes, all or nearly all of which are large rock fragments clearly visible to the eye.

Sand: Much smaller particle sizes, but still clearly visible to the eye. The particles will not stick together but will pour loosely when dry. The particle size up to 2 mm is referred to as sand and the particle larger than 2 mm to 200 mm will be called gravel.

Silt: Particle sizes are much smaller than sand. The particles are visible to the eye but with difficulty. The soil feels slightly gritty. A small lump will crush easily between the fingers.

Clay: Particles cannot be seen with the naked eye. The soil feels sticky when wet and can be easily molded between the fingers. When dry, a small lump can be crushed between the fingers but with some difficultly.

Clayey Silt is earth material with high percentage of silt and low percentage of clay.

Silty Clay is earth material having high percentage of clay and low percentage of silt.

Combination: the soil is mixed with many types of soils.

Rock Fragments are particles of rock that have the size bigger than boulders.

Organics are formed basically in situ, such as by accumulation of the fragment of inorganic skeletons or shells of organism.

8. Rock Type:

Shale is sedimentary rock mainly composed of silt-size and clay size particles. Most shales are laminated and display fissility; the rock has a tendency to split along relatively smooth and flat surfaces parallel to the bedding.

Mudstone /Clay stone is pretty much the same as shale except that it does not display fissility.

Siltstone is fine-grained rock of consolidated silt.

Sandstone is a rock made of sand more or less firmly united. Common or siliceous sandstone consists mainly of quartz sand.

Limestone is a common sedimentary rock consisting mostly of calcium carbonate, CaCO3.

Coal is a natural dark brown to black graphite like material used as a fuel, formed from fossilized plants and consisting of amorphous carbon with various organic and some inorganic compounds

Interbedded is a sedimentary rock with many types of multilayer rock.

Dolomite is a magnesia-rich sedimentary rock resembling limestone. It occurs in distinct crystals, often crystalline granular, either white or clouded. It includes much of the common white marble.

9. Landslide Characteristics

Type of Movement (note: rockfall is not included):

Slide:

Rotational slides are the movement of rock or earth which has surface of rupture as curve or concave. In rotational slide in soil, the ratio of depth of surface of rupture and length of surface of rupture is in the range of 0.15 to 0.33. The head of the displaced material may move vertically downward, whereas the upper surface of the displaced material may tilt backward toward the scarp. It may be observed that water may be ponding in the area of backward tilt.

Translational slides are the mass failures sliding along planar or undulating surface of rupture or the original ground surface. The translational slides are generally shallower than rotational slide. They have the ratio between depth and length of surface of rupture typically less than 0.1. Translational slides in rock masses have been called block slides or planar slide.

Debris slides are failures of unconsolidated material that break up into smaller parts. They occur in much steeper slope and failure surface, which have rather high velocity

and rather complicated run out phenomena. The geometry of the failure area is characterized by a low depth to the length ratio of less than 0.05 and high length to breadth ratio about 5 to 10 or more.

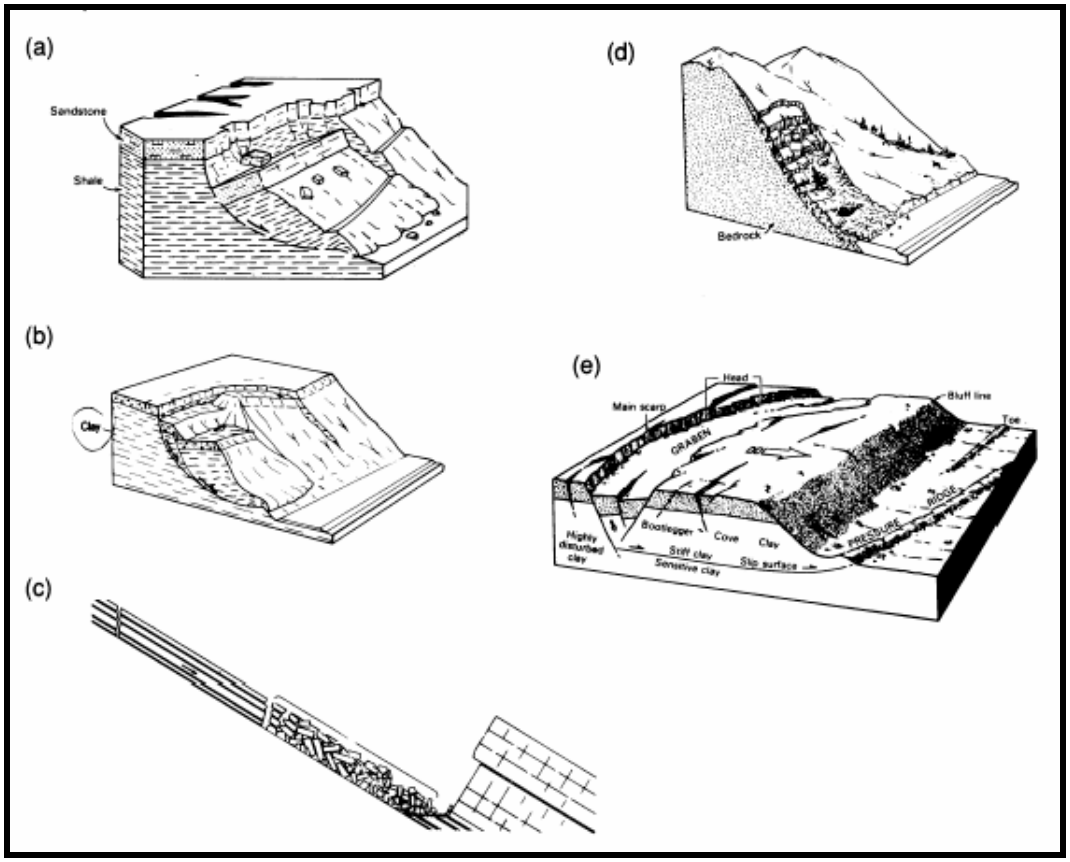


Figure C.10 Example of rotational and translational slides: (a) rotational rock slide, (b) rotational earth slide, (c) translation rock slide, (d) debris slide, (e) translation earth blockslide (Cruden and Varnes, 1996)

Flow:

Flow is a spatially continuous movement in which surfaces of shear are short-lived, closely spaces, and usually not preserved. The distribution of velocities in the displacing mass resembles that in a viscous liquid.

Slow earth flow is somewhat drier and slower earth flow having clay or weathered clay-bearing rocks, moderate slope and adequate moisture.

Loess flow is a type of flow that occurs in the loess material. Loess is the material that is deposited by wind. The materials usually consist of silt and/or fine sand and some clay binder. Loess is easy to erode when flooded or rained on.

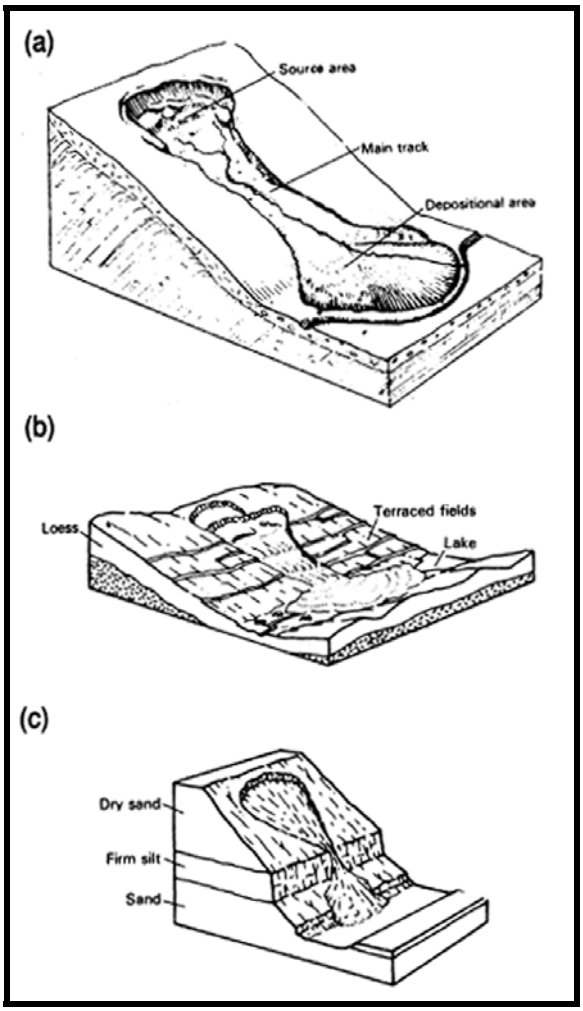


Figure C. 11 Example of flows (a) slow earth flow, (2) loess flow, and (3) dry sand flow (Cruden and Varnes, 1996)

Debris flow can be distinguished from other types of flow by the basis of particle size. The debris flow contains a relatively high percentage of coarse fragments.

Debris avalanche is used to term the debris flow that move extremely rapid.

Block stream is tongues of rocky debris on steep slope moving extremely slow and often fed by talus cone at the head.

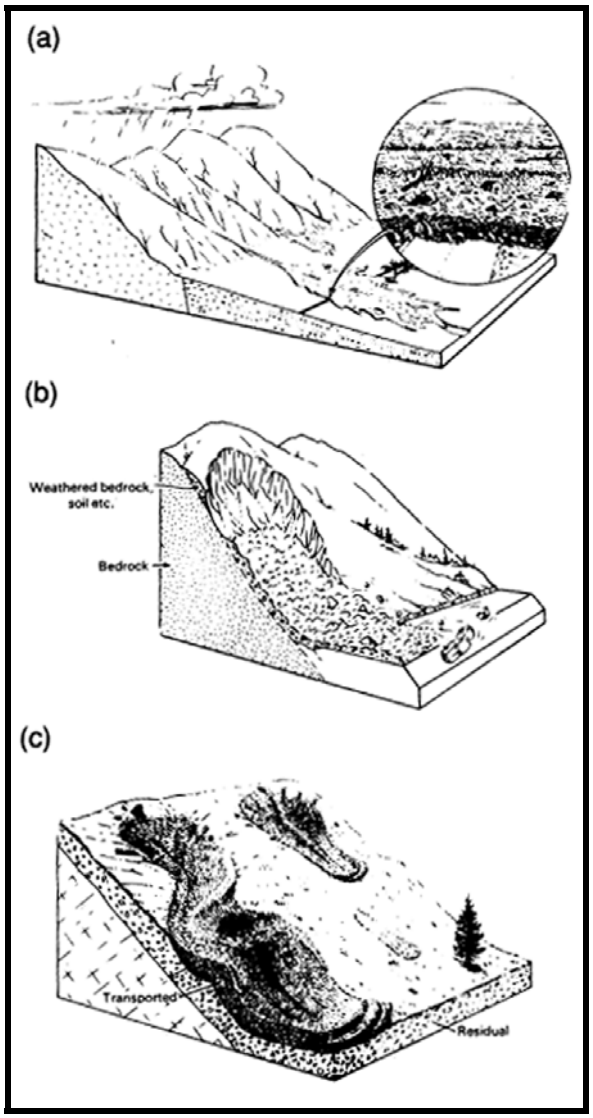


Figure C.12 Chanalized debris flows: (a) debris flow, (b) debris avalanche, and (c) block stream (Cruden and Varnes, 1996)

Spread

Spread is defined as an extension of a cohesive soil or rock mass combined with a general subsidence of the fracture mass of cohesive material into softer underling material. Spread may result from liquefaction, which is triggered from a rapid ground motion such as earthquake or artificial induced vibration.

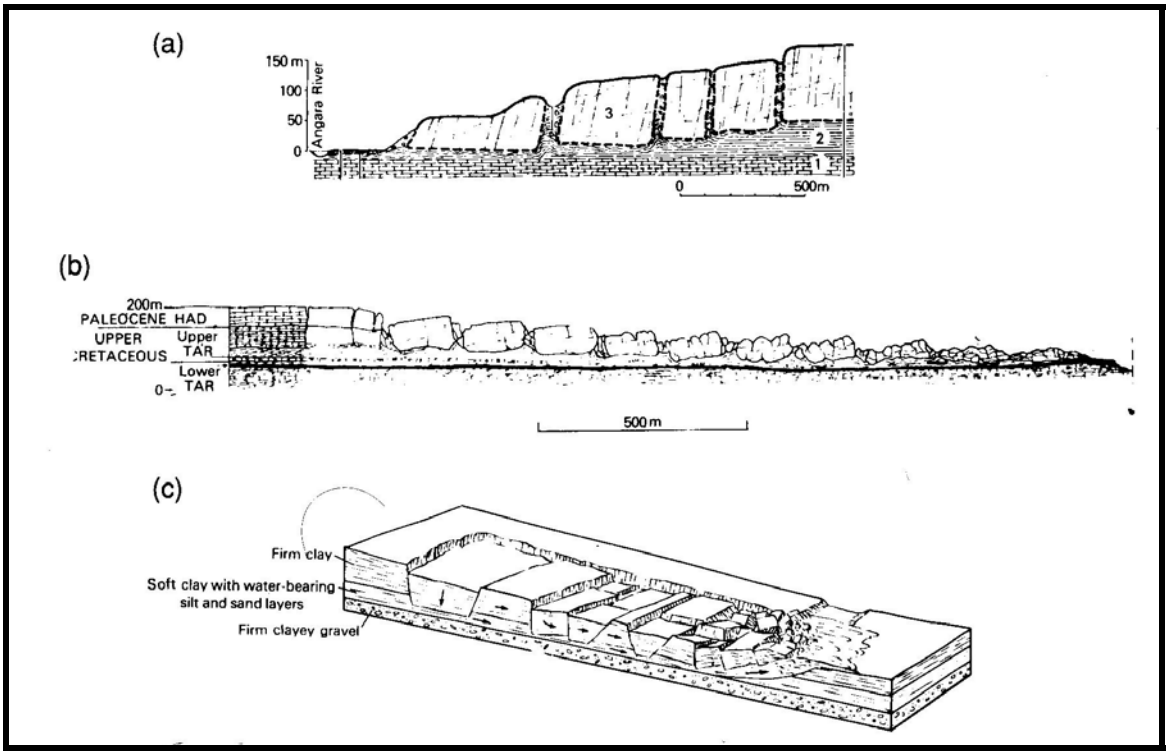


Figure C. 13 Typical rock and earth spreads: (a), (b) rock spreads that have experienced lateral extension without well-defined basal shear surface or zone of plastic flow. (c) Earth spread resulting from liquefaction or plastic flow of subjacent material (Cruden and Varnes, 1996)

10. State of Landslide Activity:

Active landslides are those currently moving.

Inactive landslides are those that last moved more than one annual cycle of season ago.

The detailed differences of active and inactive are shown in the table below.

Table C.1 Features indicating Active and Inactive Landslides (Abramson et al 1996)

ACTIVE	INACTIVE
Scarp, terraces, and crevices with sharp edges	Scarp, terraces, and crevices with round edges
Crevices and depressions without secondary infilling	Crevices and depressions infilled with secondary deposit
Secondary mass movement on scarp faces	No secondary mass movement on scarp faces
Surface of rupture and marginal shear plane show fresh slickenside and striations	Surface of rupture and marginal shear plane show old or no slickenside and striations
Fresh fracture surfaces on blocks	Weathering on fractured surfaces of blocks
Disarranged drainage system; many ponds and undrained depressions	Integrated drainage system
Pressure ridge in contact with side margin	Marginal fissure and abandoned levees
No soil development on exposed surface of rupture	Soil development on exposed surface of rupture
Presence of fast growing vegetation	Presence of slow growing vegetation
Distinct vegetation differences on and off slide	No distinction between vegetation on and off slide
Tilted tree with no vertical growth	Tilted tree with new vertical growth above inclined trunk
No new supportive, secondary tissue on trunks	New supportive, secondary tissue on trunks

APPENDIX D

ADDITIONAL EXAMPLES OF

LANDSLIDE HAZARD ASSESSMENT

(Only parameters based on judgment are discussed)

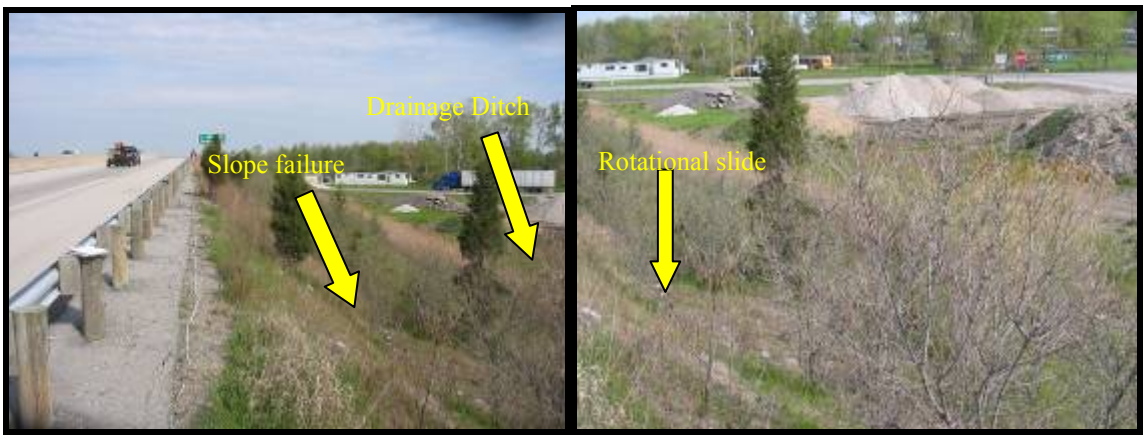
1. Picture set no. 1

Comment on picture set no.1

It was reported that the embankment was excavated by some utility companies many times (interviewing a local resident). Surface erosions were observed on the failed slope. A pond is located near the toe of the embankment but it does not affect the stability of slope. Longitudinal and alligator cracks are found on the roadway but they are not the result of the slope instability.

- **Movement location/impact:** low potential to affect the shoulder/ 3 points
- **Hazard to traveling public:** visible crack or dip no visible drop/ 3 points
- **Maintenance response:** requires observation with periodic maintenance/ 9 points

2. Picture set no. 2



Comment on picture set 2

Several failure locations were found on the slope. The failures were shallow, which were relatively old and inactive. There was a drainage ditch at the toe of the slope with present water. There was no evidence of failure on the roadway surface. This failed slope needs some periodic observations because the failures exist and they may be reactivated after rainfall.

- **Movement location/impact:** low potential to affect the shoulder/ 3 points
- **Hazard to traveling public:** visible crack or dip, no visible drop/ 3 points
- **Maintenance response:** requires observation with periodic maintenance/ 9 points

3. Picture set no. 3

Comment on picture set no. 3

The portion of roadway seemed to continue sliding into a parallel running river. A recent road work (asphalt patching) was observed. The new embankment along the roadway edge was up to 4 feet in thickness. There was no evidence of crack on the roadway surface but the roadway humps still existed as seen in the pictures. The settlement appeared to be severe.

Note: For this site, the maintenance history is important. The newly paved roadway surface might hide the current failure situation from the investigator.

- **Movement location/impact:** On roadway, or on slope with high potential to affect roadway or structure/ 81 points
- **Hazard to traveling public:** > 3 inches of displacement/ 81 points
- **Maintenance response:** Requires routine maintenance/ 27 points

4. Picture set no. 4

Comment on picture set no. 4

There were significant dips that can be seen from long distance. The evidence of the failed slope can be noticed from misalignment of the guardrail. The longitudinal cracks are parallel to the fog line. It was not evident that these cracks were related to the slope movement. The river below might have caused erosion at the toe of the slope. At the tilted guardrail area (affected area), concrete pipes connecting. Water leakage from this pipe could also contribute to erosion.

- **Movement location/impact:** On slope with high potential to affect roadway/ 81 points
- **Hazard to traveling public:** 1-3 inches of displacement/ 81 points
- **Maintenance response:** Requires observation with periodic maintenance/ 9 points

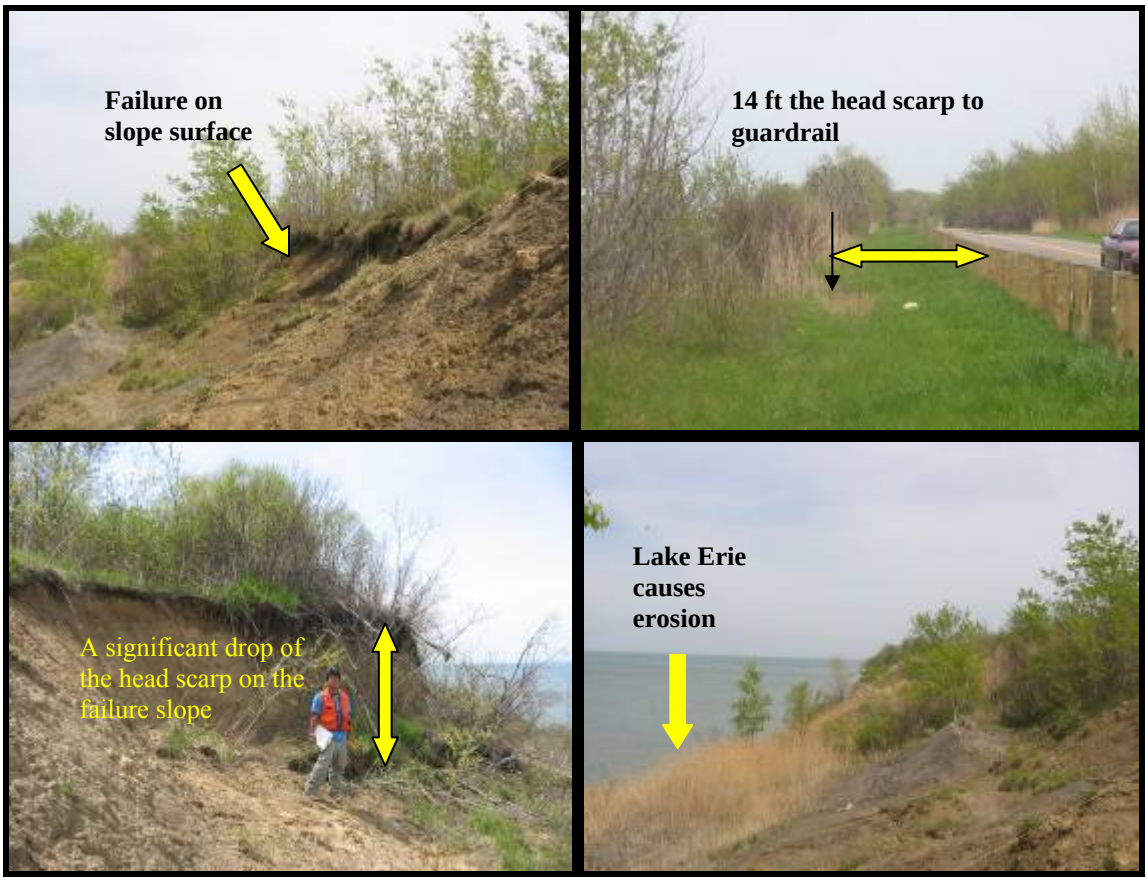
5. Picture set no. 5

Comment on picture set no. 5

The failed slopes were observed on both sides of the cut through slope as seen in the pictures. There existed the evidence of groundwater. The area above the cut was wet and standing water was visible in many places. The ditches at the toe of both sides of slopes were filled with water. There was no evidence of rainfall prior to the day of the site visit. The water may come from the groundwater seepage. The slope on the southbound lane has a catch basin. There was a concrete pipe connecting from the building above the slope and daylighting at the flank of slope. The water from concrete drain pipe may cause slope instability. There were longitudinal cracks on the road but they were not due to the slope failure.

- **Movement location/impact:** On slope with high potential to affect structure beyond right of way/ 81 points
- **Hazard to traveling public:** None / 3 points
- **Maintenance response:** Requires observation with periodic maintenance/ 9 points

6. Picture set no. 6



Comment on picture set no. 6

The wave induced by Lake Erie has caused severe erosion at the toe of this failed slope. Some evidences showed that the roadway had been shifted form the original position several times. The closest head scarp was 14 ft from the guardrail. There was no crack found on the pavement surface. The closest distance between Lake Erie and the roadway at the failed slope location is approximately 200 ft. The roadway surface is approximately 80 ft above the lake. The maximum vertical displacement of the average head scarp was more than 8 ft.

- **Movement location/impact:** On slope with high potential to affect the roadway/ 81 points
- **Hazard to traveling public:** no failure/ 3 points
- **Maintenance response:** Requires observation with periodic maintenance/ 9 points

7. Picture set no. 7

Comment on picture set no. 7

There was no evidence of failure on the roadway surface. The failure type of the failed slope appeared to be related to creep movement. Many areas on the slope surface were saturated with water. The soil type that is found on the slope is soft to medium stiff brown silty clay mixed with gravels. The slope failure was related to poor construction.

- **Movement location/impact:** Failure only found on the slope/ 3 points
- **Hazard to traveling public:** no failure evidence on road/ 3 points
- **Maintenance response:** Requires observation with periodic maintenance/ 9 points

8. Picture set no. 8

Comment on picture set no. 8

This failed slope is a part of a big ancient landslide but remains active. The most active part was located at the toe of the slope because it is adjacent to the river. There were many vertical displacements on the uphill side of the slope, which was approximately 50 to 70 feet above the roadway. No crack was found on the road surface. The toe of the failed slope is cut out in some parts. It is suspected that the displaced mass may have been removed from the roadway because the roadway ditch was found to be recently cleaned.

The slope surface appears hummocky with numerous cracks on the surface. Numerous tension cracks were found in the area between the roadway and the river as well. Springs and hydro-plants were found in many places on the upslope side. Material found on slope composes of dense brown clayey sand with numerous sandstone and rock fragments of gravel to boulder size

- **Movement location/impact:** On slope with high potential to affect the roadway/ 81 points
- **Hazard to traveling public:** no evidence of failure on road/ 3 points
- **Maintenance response:** Requires immediate response/ 81 points

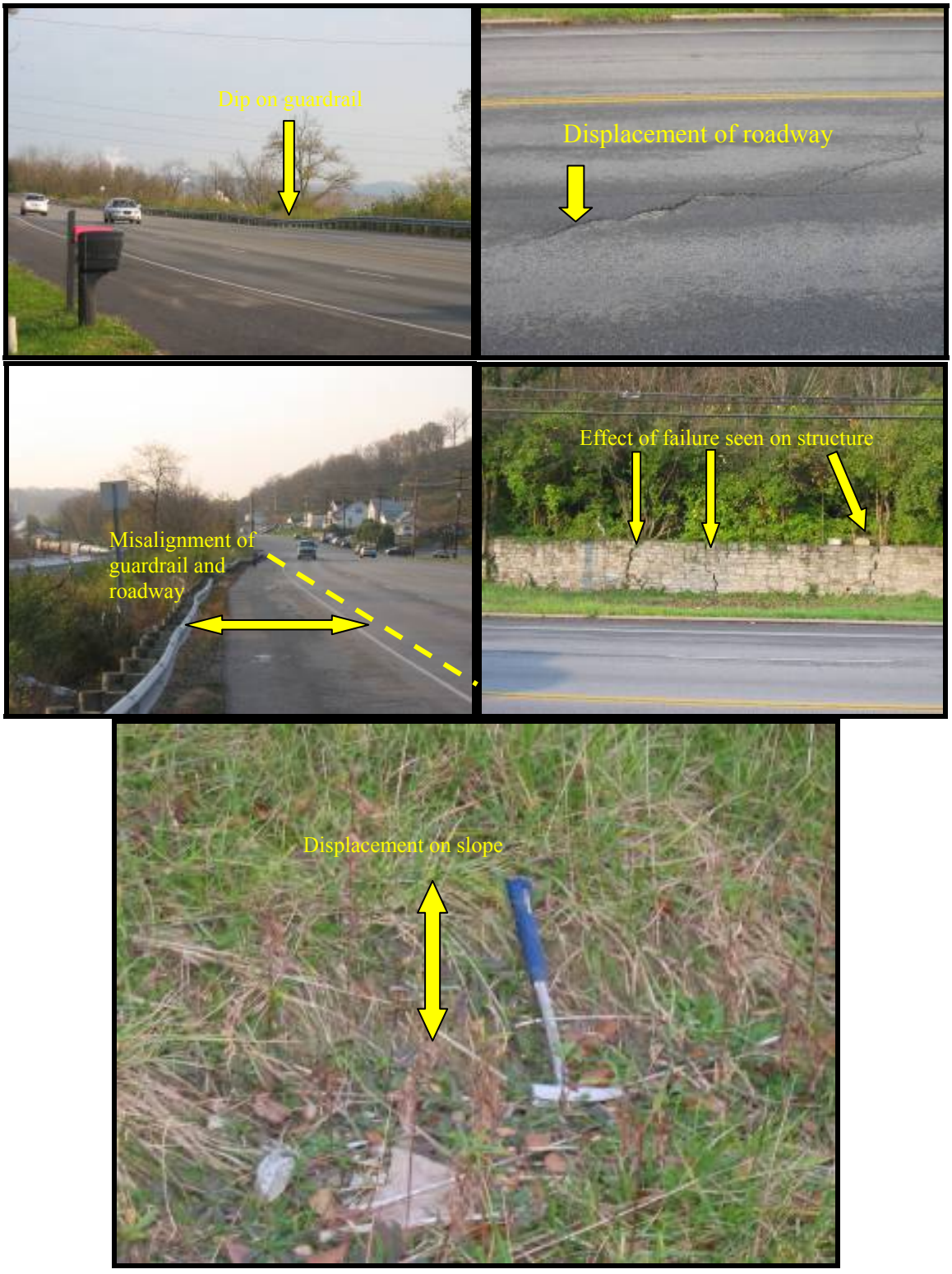
9. Picture set no. 9

Comment on picture set no. 9

Vertical displacements on roadway were noticeable in both directions. These might pose high hazard to the traveling public. Ponding water was found in the roadway median area between two traffic directions. There was no evidence of slope failure on slope. The roadway dip may be caused by creeping of materials on the slope which may cause larger slope movement in the future.

- **Movement location/impact:** On slope with high potential to affect the roadway/ 81 points
- **Hazard to traveling public:** more than 3 inches/ 81 points
- **Maintenance response:** Requires immediate response/ 81 points

10. Picture set no. 10



Comment on picture set no. 10

The roadway and the guardrail have moved downslope for several feet. A railroad is located at the toe of the failure slope. Numerous cracks and vertical displacements (drops) were found on the surface of road. The vertical displacements were approximately greater than 3 inch. The failed slope was thought to be a deep seat landslide. A roadway is located in the middle of the landslide. The head scarp of this failed slope might be located beyond the white brick wall above the roadway. The evidence of failure can be seen on the wall behind the roadway as well.

- **Movement location/impact:** On slope with high potential to affect the roadway/ 81 points
- **Hazard to traveling public:** more than 3 inches/ 81 points
- **Maintenance response:** Requires immediate response/ 81 points

11. Picture set no. 11

Comment on picture set no. 11

The failed slope was located on the side of embankment above the culvert. The failure was found to be a shallow rotational landslide. The failure appeared to have a minor effect to the roadway. The hair line cracks were found on the surface of roadway, which were parallel to the fogline and shoulder. The displacements of these hairline cracks were up to 1 inch. The materials found in the embankment were a combination of silt, weathered shale and clay (medium to stiff). It was speculated that the problem might start from the running water in the creek at the toe of the failed slope, which weakened the soil strength and washed away the materials at the toe of the slope.

- **Movement location/impact:** On slope and low potential to affect shoulder/ 3 points
- **Hazard to traveling public:** More than 1 inch / 9 points
- **Maintenance response:** Requires observation and periodic maintenance / 9 points

12. Picture set no. 12

Comment on picture set no. 12

The failed slope was located at an embankment approach of a bridge. The failure can be clearly seen on the roadway shoulder. The vertical and horizontal displacements were up to 7 inch. The displacement of 2 to 3 inches was also found on the retaining wall at the downslope. A railroad is located next to the retaining wall. The standing water was found behind the retaining wall, which can exert additional water pressure on the wall. The materials on the embankment are composed of silt stone / shale.

- **Movement location/impact:** On slope with high potential to affect roadway/ 81 points
- **Hazard to traveling public:** More than 3 inch / 81 points
- **Maintenance response:** Response is needed immediately / 81points

13. Picture set no. 13

Comment on picture set no. 13

The failed slope was located on the highway embankment along the river. It was a recently paved roadway; however, the displacements were noticeable. It was judged that this failed slope may have experienced a high rate of movement and have been frequently maintained. The thickness of pavement was up to 1.5 ft in some locations. The vertical and horizontal displacements on roadway surface were varied from the hairline cracks up to 4 inch. The undulations of roadway and guardrail were noticeable. The causes of this failed slope were judged to be related to the material degradation and the poor construction quality. Toe erosion may also contribute to slope failure.

- **Movement location/impact:** Failure is on the roadway and have high potential to cause hazard/ 81 points
- **Hazard to traveling public:** more than 3 inch/ 81 points
- **Maintenance response:** Response is needed immediately / 81points

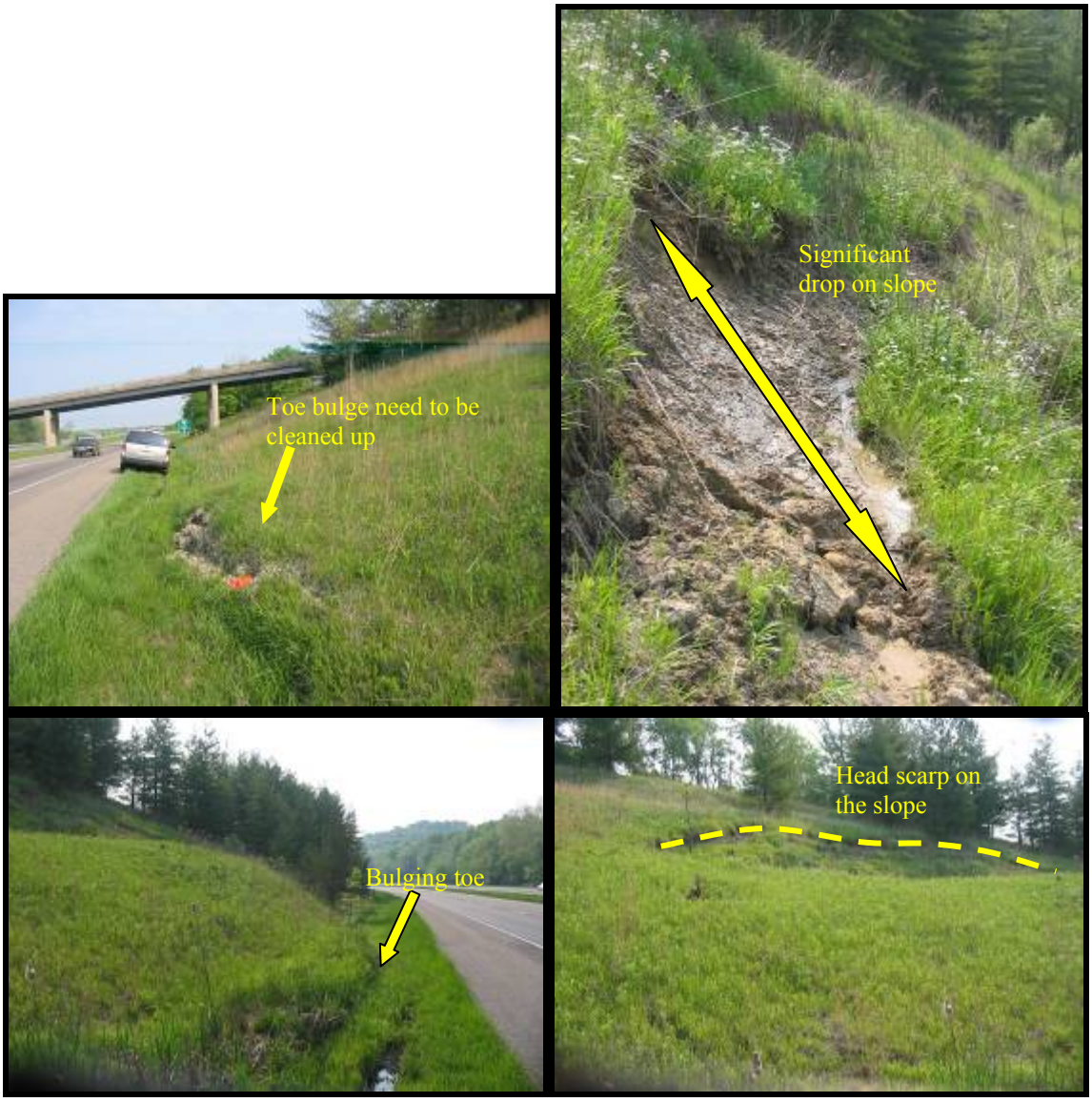
14. Picture set no. 14

Comment on picture set no. 14

A creek was located at the toe of the failed slope. The existing rip-rap was found at the toe for erosion protection. A culvert was found on the other side of the roadway. There was standing water where the culvert daylights. The water was also found at the roadway median. Springs and seeps were found flowing out of the slope at the failed slope location. The slope surface was hummocky. Material found on slope was very soft to medium stiff clay. Cracks were present on the pavement and shoulder with the displacements up to 1.5 inch. It was judged that the failed slope may be the result of malfunction of the drainage system and the effect of the running water from the creek.

- **Movement location/impact:** Failure is on the shoulder with the moderate potential to cause hazard/ 27 points
- **Hazard to traveling public:** less than 3 inches/ 27 points
- **Maintenance response:** Require routine maintenance response/ 81points

15. Picture set no. 15

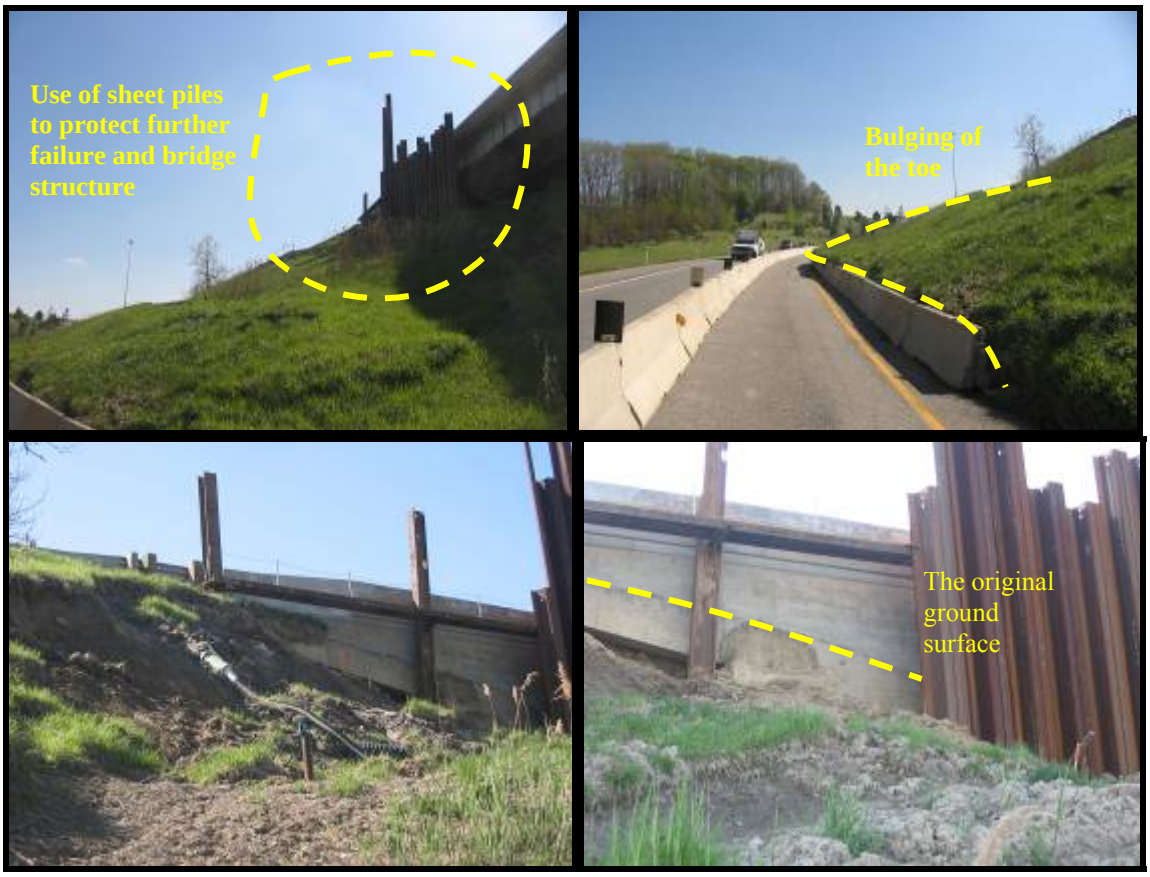


Comment of picture set no. 15

The slope failure was located on the slope above the highway. Groundwater seepage was found throughout the failed slope. There were a small road and a drainage ditch on the top of the slope. The cause of the slope failure was judged to be the result of drainage ditch on the top slope, which may release water to the slope surface. There was no failure found on the roadway.

- **Movement location/impact:** Failure has no effect on the roadway/ 3 points
- **Hazard to traveling public:** No displacement on road/ 3 points
- **Maintenance response:** Require observation and periodic maintenance / 9 points.

16. Picture set no. 16

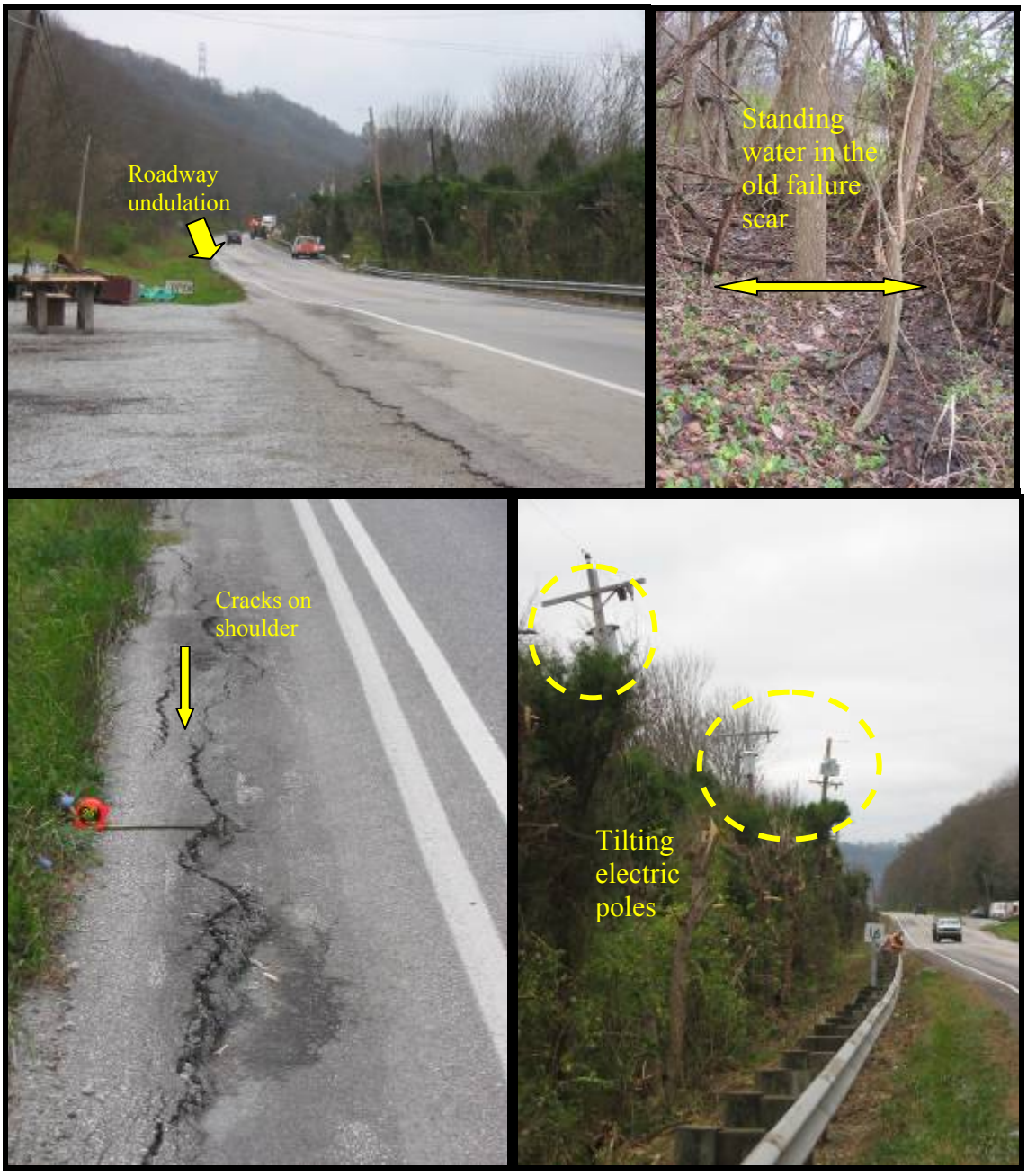


Comment on picture set no. 16

The failed slope was located at a busy four-lane highway intersection. The concrete barriers were placed at the toe of the slope to protect the displaced material from reaching the moving traffic. The sheet piles were driven to protect the slope from the progressive failure. The vertical displacements of the failed slope were large, which can be seen at the exposed bridge structure.

- **Movement location/impact:** Failure affects the highways above and below the slope. It also affects the stability of bridge structure/ 81 points
- **Hazard to traveling public:** Displacement is on the road/ 81 points
- **Maintenance response:** Require immediate response for safety of traveling public and the stability of the bridge structure/ 81 points.

17. Picture set no. 17



Comment on picture set no. 17

The failed slope location is located on a large active rotational landslide. The fluctuation of the Ohio River appeared to aggravate the instability of the failed slope. The evidence of slope movement can easily be seen from the tilting of telephone pole and the misalignment of the guardrail. The vertical and horizontal displacements on roadway as well as cracks and roadway undulations were noticeable. There were active scarps with the depth and width approximately 2-4 feet. The effect of the failed slope may also affect the houses that are located at the toe of the slope.

- **Movement location/impact:** Failure found on the roadway with high potential to affect roadway and structures/ 81 points
- **Hazard to traveling public:** displacement less than 3 inches / 27 points
- **Maintenance response:** Require routine maintenance response / 27 points.

APPENDIX E

THE COLLECTED DATA AND SITE SKETCHES OF EXERCISE EXAMPLES PROVIDED IN CHAPTER IV

LANDSLIDE INFORMATION OF EXAMPLE 1

Landslide Observation Report filed by Highway/construction worker

Name of reporter		Brent Black
Affiliation (District)		11
Date		5/11/2004
Site Location	**County**	Belmont
	Route	S.R. 7
	Mile marker (county basis)	2.31

Description (Visual Inspection)

Landslide material(s)	√ Soil __Rock __Both
Number of lanes (one direction)	√ 1 __2 __3 __4 __5 __6
Posted speed limit (miles/hr)	__15 __20 __25 __30 __35 __40 __45 __50 √ 55 __60 __65 __70
Location of landslide relative to roadway	__Above roadway √ Below roadway __both
Position of impact on roadway	Position of cracks/dips: √ Pavement √ Shoulder __Ditch __None
	Position of earth debris: __ Pavement __Shoulder __Ditch √ None
Impact to adjacent structures or properties	__Roads __Railroads __Residential __Buildings __Commercial √ Bridge __Utilities __Others_____
Vegetation	Barren__% Grass__% Shrub__% Tree 100% Other_____
Presence of surface water	√ Yes __No
Presence of groundwater	√ Yes __No __Unknown
Previous site works (Based on observation at the site)	__Temporary __Failed temporary __Permanent __Failed permanent √ Patching of asphalt __Guardrail work __Other_____
Recent precipitation	__Heavy __Moderate √ Light
Duration	__24-hr __3-d √ 7-d __15-d
Date identifying first evidence of instability	Unknown
Name of verifier (CM/TM)	-
Date of verification	-
Signature	-

Part A filed by Transportation/County Manager

Evaluator's name	Brent Black
Date of observation	5/13/2004

Site Location

Jurisdiction	__County __Turnpike __Municipal √ State __Township __Federal __Private
County	Belmont
District	11
Route system	__**IR**-interstate __**US**-United States route √ **SR**-state route __**CR**-county road __**TR**-township road __**MR**-municipal road __**RA**-ramp __**PA**-park roads __**BK**-bike route
Route number	7
Mile marker (county basis)	Beginning: 2.31 Ending: 2.37
Network linear feature (NLF) (auto generation)	SBELSR007**C
Number of Lanes (one direction)	√ 1 __2 __3 __4 __5 __6
Location of landslide relative to roadway	__Above roadway √ Below roadway __Both

Centroid of Affected Highway (GPS Information)

GPS coordinates	Centroid:	Latitude: 80° 47' 46.44 W Longitude: 39° 52' 28.29 N Elevation: 1714.95 ft
	Beginning point:	Latitude: N.A. Longitude: N.A. Elevation: N.A.
	Ending point:	Latitude: N.A. Longitude: N.A. Elevation: N.A.
State coordinates (Mid-point) (Auto generation)		Zone: South Northing: 209476.250530 Easting: 745744.490229
USGS Quad (Auto generation)		Name: PAWHATAN POINT Number: 39080G7

A.1/3

Landslide vulnerability table

Probability of additional movement	Probability of significant impacts to the roadway, structures, adjacent property or features			
	Very High	***High***	***Moderate***	***Low***
Very High	Very High	Very High	High	Moderate
High	Very High	High	High	Moderate
Moderate	High	High	Moderate	Low
Low	Moderate	Moderate	Low	Low

Remark: A landslide site having "low" vulnerability is non-rated.

General information

General dimensions (Rough estimate)	Length (ft): 252 Width (ft): 352 Estimated maximum depth of sliding surface (ft) ~40-50ft
Preliminary rating (Use landslide vulnerability table)	√ Rated __Non-rated
Inspection frequency	__Hourly __Daily _√ Weekly __Biweekly __Monthly __Quarterly __Yearly __Others_____

Part B filed by Transportation/County Manager

Evaluator's name	Brent Black
Date of observation	5/13/2004

Site Location

Jurisdiction	__County __Turnpike __Municipal √ State __Township __Federal __Private
County	Belmont
District	11
Route system	__**IR**-interstate __**US**-United States route √ **SR**-state route __**CR**-county road __**TR**-township road __**MR**-municipal road __**RA**-ramp __**PA**-park roads __**BK**-bike route
Route number	7
Mile marker (county basis)	Beginning:2.31 Ending: 2.37
Network linear feature (NLF) (auto generation)	SBELSR007**0
Number of lanes (one direction)	√ 1 __2 __3 __4 __5 __6
Location of landslide relative to roadway	__Above roadway √ Below roadway __Both

Site History

Date of original construction (m/d/y)	_____/_____/_____
Date of alignment modifications (m/d/y)	_____/_____/_____
Date of remedial activities (m/d/y)	_____/_____/_____
Past remedial activities	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others unknown
Existing remediation	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others unknown
Annual maintenance frequency (times/year)	unknown
Annual maintenance cost (Average Over the Past 5 to 10 Years) (dollars/year)	unknown
Maintenance response (Based on judgment)	__No response __Require observation with periodic maintenance __Require routine maintenance response to preserve roadway √ Require immediate response for safe travel or to protect adjacent structure

Traffic Data

Average daily traffic (ADT)	Total traffic: 6410 vehicles/day Passenger traffic: unknown vehicles/day Trucks traffic: unknown vehicles/day
Accident history in past 10 years (Number of occurrence)	Number of accident in past 10 years_____ Number of accident without loss_____ Number of accident with vehicle and property damage_____ Number of accident with injury 1 Number of accident with fatality__
Estimated detour route length (miles)	unknown miles
Posted speed limit (miles/hr)	__15 __20 __25 __30 __35 __40 __45 __50 √ 55 __60 __65 __70
Estimated traveling time of detour (hr)	Truck unknown hr Passenger unknown hr

Part C (District Geotechnical Engineer)

Evaluator's name	Brent Black
Date of observation	5/13/2004

Site Location verified by DGTE (provide O.K. click button)

Jurisdiction	__County __Turnpike __Municipal √ State __Township __Federal __Private
County	
District	
Route system	__**IR**-interstate __**US**-United States route √ **SR**-state route __**CR**-county road __**TR**-township road __**MR**-municipal street __**RA**-ramp __**PA**-park roads __**BK**-bike route
Route number	7
Mile marker (county basis)	Beginning: 2.31 Ending: 2.37
Network linear feature (NLF) (auto generation)	SBELSR007**C
Number of lanes (one direction)	√ 1 __2 __3 __4 __5 __6
Location of landslide relative to roadway	__Above roadway √ Below roadway __Both

Centroid of Affected Highway (GPS Information) verified by DGTE (provide O.K. click button)

GPS coordinates	Centroid:	Latitude: 80° 47' 46.44 W Longitude: 39° 52' 28.29 N Elevation: 174.95 ft
	Beginning point:	Latitude: N.A. Longitude: N.A. Elevation: N.A.
	Ending point:	Latitude: N.A. Longitude: N.A. Elevation: N.A.
State coordinates (Mid-point) (Auto generation)	Zone: South Northing: 209476.250530 Easting: 745744.490229	
USGS Quad (Auto generation)	Name: PAWHATAN POINT Number: 3908067	

Part C (continued)

Required information for data collection (use landslide vulnerability table)

Low (0< X ≤ 2 points)	Moderate and High (2< X ≤ 9 points)	Very high (X > 9 points)
• Verify and fill out C.1 • Very rough sketches by CM/TM • Take additional photos C.14	• Verify and fill out C.1 • Fill out C.2 to C.11 • Verify rough sketches by CM/TM • Take additional pictures C.14	• Verify and fill out C.1 • Fill out C.2 to C.13 • Take additional photos C.14

Landslide vulnerability table

Probability of additional movement (A)	Probability of significant impacts to the roadway, structures, adjacent property or features (B)			
	Very High(4)	***High(3)***	***Moderate(2)***	***Low(1)***
Very High(4)	Very High (16)	Very High (12)	High (8)	Moderate (4)
High(3)	Very High (12)	High (9)	High (6)	Moderate (3)
Moderate(2)	High (8)	High (6)	Moderate (4)	Low (2)
Low(1)	Moderate (4)	Moderate (3)	Low (2)	Low (1)

Vulnerability score (X) = A× B

Inspection schedule

Inspection frequency	__Hourly	__Daily	√ Weekly
	__Biweekly	__Monthly	__Quarterly
	__Yearly	__Others_____	

Part C (continued)

Slope Characteristics

Slope type		__Natural __Cut __Fill √ Cut and fill
Average slope angle (α_{ave}°)		$\alpha_{ave} = \frac{\alpha_1 \cdot l_1 + \alpha_2 \cdot l_2 + \ldots \alpha_n \cdot l_n}{L} =$ 25°
Slope surface appearance		__Straight __Concave __Convex √ Hummocky __Terraced __Complex
Vegetation cover		__Grass__% __Shrub__% __Cultivated land__% __Reforestation__% √ Woodland 100% __Other_____
Vegetation density		__Sparse __Moderate √ Dense
Hydrogeology	**Surface water**	**Types of water sources** __Reservoir __Lake __River √ Creek __Pond __Surface drainage __Others_____ __None **Location of water sources that may affect landslide** __Above √ Below __Both
	Groundwater (use visual inspection)	**Groundwater flow** __Into landslide __Off landslide __Both √ Unknown __None **Groundwater condition** __Spring __Seep __Both √ Unknown __None **Location of ground water:** __Above __Below __Middle __None **Presence of monitoring or water well** __Artesian __Flowing artesian __Pooled √ None observed
Erosion area		√ Head __Toe __Flank __Body __None
Possible cause of failure		√ Erosion of the toe __Precipitation __Failure of drainage __Drainage outlet __Surface water √ Weathering of materials __Deforestation __Change of water level
Orientation of slope (Azimuth; The clockwise angle from the north)		N.A. degree
Direction of landslide (Azimuth; The clockwise angle from the north)		N.A. degree

Part C (continued)

Slope Materials (by Visual Inspection and Judgment)

Soil origin	√ Colluvium √ Alluvium __Till __Residual soil √ Weather rock __Unweathered rock √ Fill __Combination __Others
Soil type	__Boulders/cobbles __Stone fragments √ Gravel __Sand __Fine sand __Silty gravel __Silty sand __Clayey gravel __Clayey sand __Silty soil √ Clayey soil __Organic √ Combination √ Others Local called "red dog", Shale
Rock type	√ Shale __Mudstone /claystone __Siltstone __Sandstone __Limestone __Coal __Interbedded __Dolomite __Combination __Others

Landslide Characteristics

Type of Movement (Rockfall is not included.)	**Slide**	__Rotational rock slide __Translational rock slide __Rotational earth slide √ Translational earth block slide __Debris slide __Complex
	Flow	__Slow earth flow __Loess flow __Dry sand flow __Debris avalanche __Debris flow __Block stream __Complex
	Spread	__Rock spread __Earth spread __Complex spread
Rate of movement		____inches/year √ unknown
State of landslide activity		√ Active __Inactive __Mitigated

Observed Remediation

Past remedial activities	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others unknown
Existing remediation	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others None observed

Part C (continued)

Preliminary Determination of Causes of Landslide

Human activities	__Excavation/under cutting __Groundwater pumping __Deforestation __Loading __Defective maintenance __Failure of drainage __Water leakage from pipes __Artificial vibrations __Loose waste dumping √ Construction related __Others
Natural activities	√ Rainfall __Snowmelt __Earthquake __Ground water __Loss of vegetation __Toe erosion √ Inadequate long term strength __Surface water level change/rapid drawdown √ Degradation of construction material __Others
Comment (limit no more than 50 words)	

Observed Traffic Information

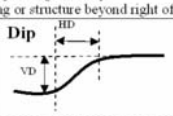
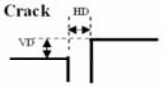
Actual sight distance (ASD) (ft.)	300 ft
Percent decision sight distance (%DSD) %DSD=(ASD/DSD)*100	34 %

Decision sight distance (DSD)

Posted speed limit (mph)	Decision sight distance (ft)
25	375
30	450
35	525
40	600
45	675
50	750
55	875
60	1000
65	1050
70	1100

Part C (continued)

Impact assessment on roadway and beyond right of way

Current and potential impact of landslide on roadway	__On slope with a low potential to affect shoulder __On slope with a low potential to affect roadway __On shoulder or on slope with a moderate potential to affect roadway √ On roadway, or on slope with a high potential to affect roadway or structure	
Current and potential impact of landslide on the area beyond right of way	__On slope with a low potential to impact area beyond right of way __On slope with a moderate potential to impact area beyond right of way __On slope with a high potential to impact area beyond right of way __On slope with a high potential to impact building or structure beyond right of way	
Evidence of impact on roadway	**Dip** √ Yes __No **Maximum displacement of dip** Vertical displacement (VD) (inch) ≥3 Horizontal displacement (HD) (inch) ≥3	
	Crack √ Yes __No **Maximum displacement of crack** Vertical displacement (VD) (inch) ≥3 Horizontal displacement (HD) (inch) ≥3	
	Earth debris on roadway __Yes √ No Estimated volume (Yd^3)_____	

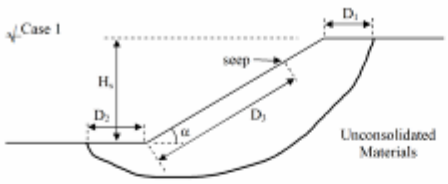
Adjacent Structures and Areas

Adjacent structures	__Roads __Railroads __Residential __Buildings √ Bridge __Utilities __Others_____
Surrounding area	√ Forest __Agriculture √ Rural __Urban __Housing development __Others_____

Part C (continued)

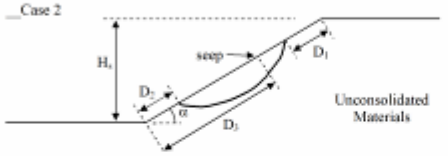
Information for estimation of landslide repair cost

√ Case 1



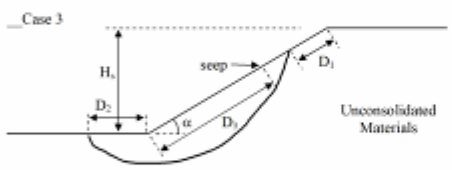
1. Average slope angle, α, ≥5°
2. Height of slope, H_s (ft) ≤5'
3. Length of slope repair, L, parallel to highway (ft) ≥50
4. Distance from crest of slope to failure surface, D_1(ft) ≤0
5. Distance from toe of slope to failure surface, D_2 (ft) ≤0
6. Distance along slope (measured from toe) to groundwater seeps, D_3, and approximate quantities of groundwater (ft) unknown

__Case 2



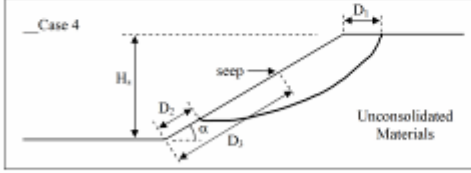
1. α_____
2. H_s (ft)_____
3. L(ft)_____
4. D_1(ft)_____
5. D_2(ft)_____
6. D_3(ft)_____

__Case 3



1. α_____
2. H_s (ft)_____
3. L(ft)_____
4. D_1(ft)_____
5. D_2(ft)_____
6. D_3(ft)_____

__Case 4



1. α_____
2. H_s (ft)_____
3. L(ft)_____
4. D_1(ft)_____
5. D_2(ft)_____
6. D_3(ft)_____

Cost Estimate

Repair cost	unknown
Benefit cost ratio	unknown
Estimated time required for remediation (days)	unknown days

Part C (continued)

Suggested Remediation Measure

- √ Benching & regarding
- √ Counter berm & regrading
- __ Flattening Slope
- __ Soil Drainage
- __ Bedrock Drainage
- __ Retaining Walls
- __ Light Weight Fills
- __ Dynamic Compaction
- __ Bio-engineering
- __ Geofabrics
- __ Sheet Piling
- __ H Piling
- __ Drilled Piling
- __ Soil Nailing
- __ Tieback Walls
- __ Remove & Replace
- __ Shear Key
- __ Chemical Treatment
- __ Relocation
- __ Bridge
- __ Change Line or Grade
- __ Other_____

Part C (continued)

Sources of Supplemental Information

__ Aerial photos	√ Field visit
__ Satellite imaginary	__ Local people
__ County-ODOT	__ Dist-ODOT
√ State-ODOT	__ City and county engineer
__ Soil/Rock/Water samples	__ GPS features
__ Folder/ File location	__ Academia with engineering or geology program
__ USGS publications and files	__ USGS Quadrangles

- __ USGS open file map series #78-1057 "Landslide related features"
- __ Division of geological survey (ODNR)
- __ Division of mineral resource management (ODNR)
- __ Division of soil and water (ODNR)
- __ Others_____

Part C (continued)

Landslide hazard rating matrix

CATEGORY		RATING CRITERIA and SCORE				Total Item Scores
		Points 3	Points 9	Points 27	Points 81	
Movement location/ impact (select higher score)	Current and potential impact of landslide on roadway	On slope with a low potential to affect shoulder	On slope with a low potential to affect roadway	On shoulder, or on slope with a moderate potential to affect roadway	On roadway, or On slope with a high potential to affect roadway or structure	81
	Current and potential impact of landslide on area beyond right of way	On slope with a low potential to impact area beyond right of way	On slope with moderate potential to impact area beyond right of way	On slope with high potential to impact area beyond right of way	On slope with high potential to impact structure beyond right of way	
Hazard to traveling public (Select higher score)	Rate of displacement in roadway if known	<1-inch/year	1 to 3-inches/year No single event ≥1-inch	3 to 6-inches/year No single event ≥3-inches	>6-inches/year Single event ≥3-inches	81
	Evidence of displacement in roadway	Visible crack or dip no vertical drop	≤1-inch of displacement	1 to 3-inches of displacement	≥ 3-inches of displacement	
Maintenance (Select higher score)	Maintenance frequency	None to rare	Annually (one time/year)	Seasonal (1 to 3 times/ year)	Continuous throughout year (> 3 times/year)	81
	Maintenance response	No response	Requires observation with periodic maintenance	Requires routine maintenance response to preserve roadway	Requires immediate response for safe travel or to protect adjacent structure	
%Decision Sight Distance (%DSD)		≥ 90	89 -50	49-35	< 34	81
ADT		<2000	2001-5000	5001-15000	>15001	27
Accident history (Related to landslide)		No accident	Vehicle or property damage	Injury	Fatality	27
					Total Score	378

Part C (continued)

Hazard calculation sheet

Hazard category	Explanation	Item Scores
1. Movement Location/ Impact	The impact of slope failure is observed on both traffic lanes. Dips and cracks are noticeable on both traffic directions. Significant drops and separation between the fill material and bridge structure are noticeable as well as misalignment of guardrail.	81
2. Hazard to Traveling Public	The rate of movement is not available at the time that the investigation is conducted. The displacement observed on road is used. It is about a foot separation between bridge structure and fill material. Due to the recent pave roadway surface, the displacement on road is not visible.	81
3. Maintenance	The maintenance history is also not available. However, some cracks on the bridge substructure and separation between the fill material and the bridge are observed. The response for maintenance is judged to be high, which requires the immediate response.	81
4. %DSD	The speed limit at the site location is 55 miles/hr. The actual sight distance is approximately 300 ft. The calculated DSD is about 34%.	81
5. ADT	10,110 cars/ day	27
6. Accident history (Related to landslide)	Injury	27
	Total score	378

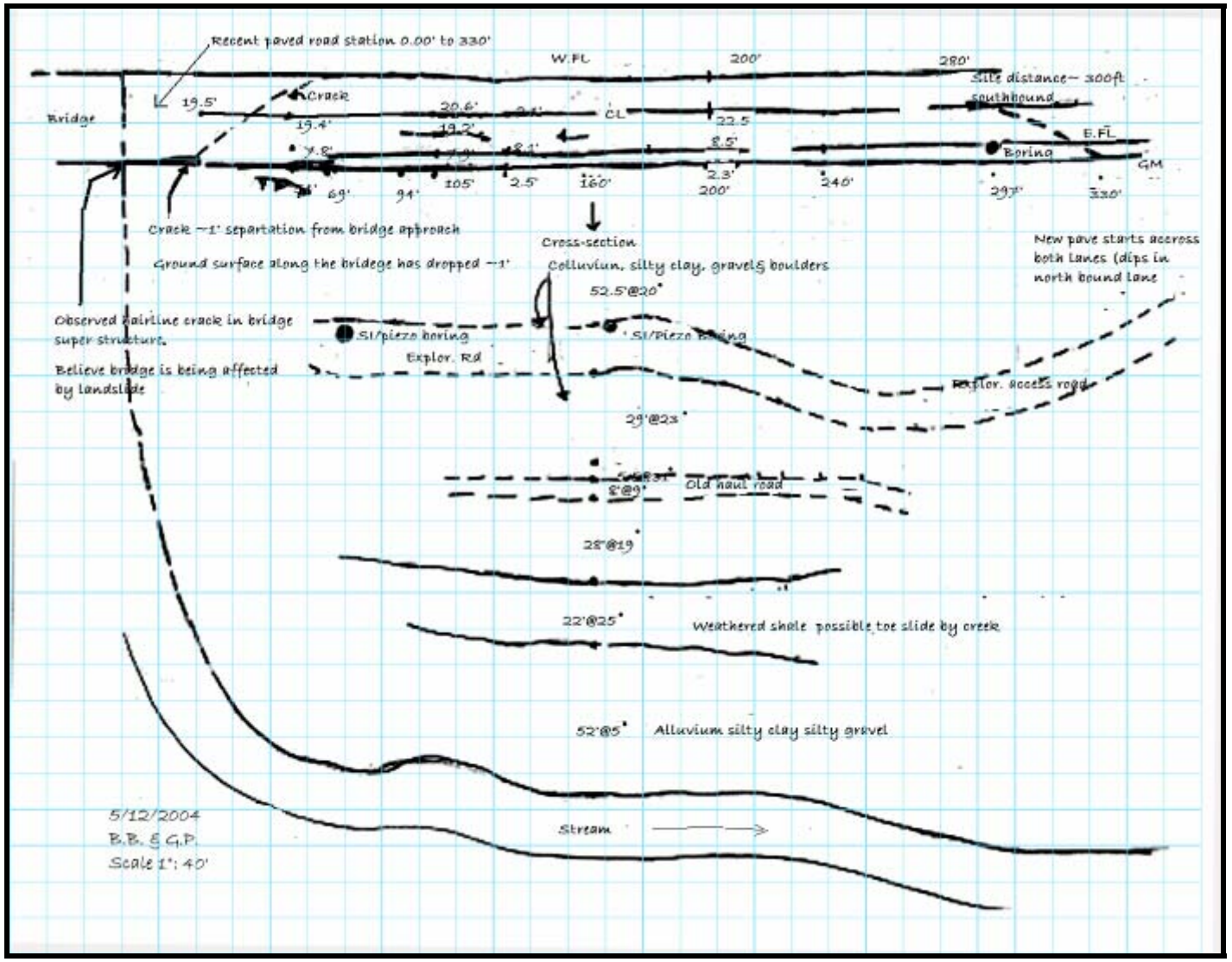


Figure E.1 A plan sketch of Example 1

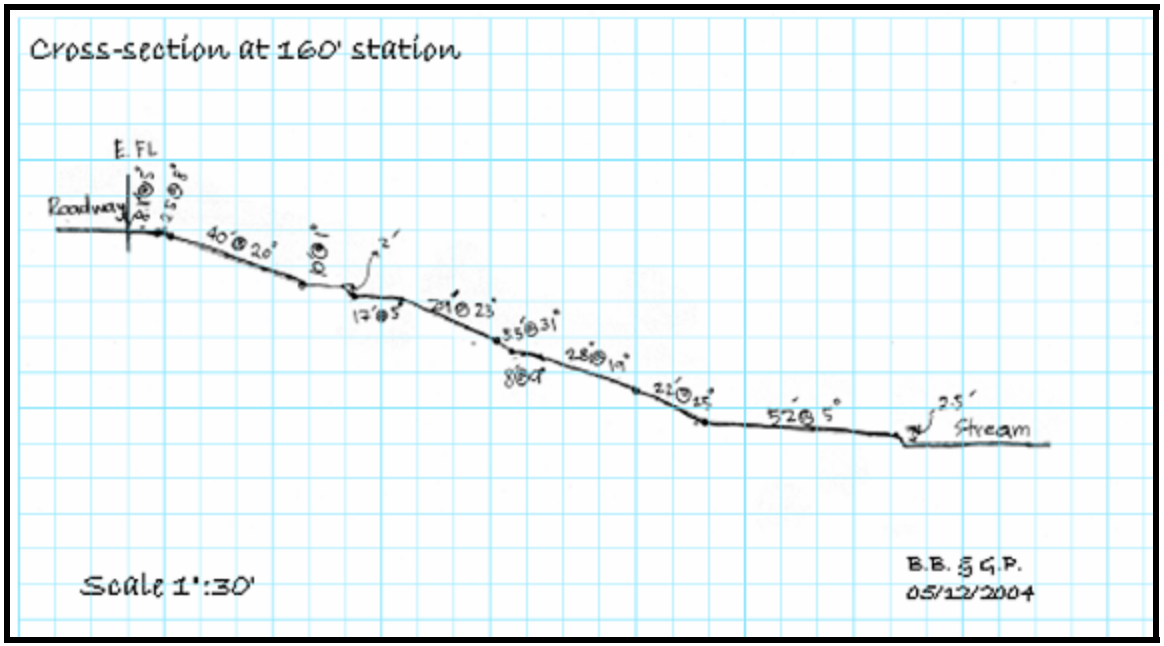


Figure E.2 A cross-section sketch of Example 1

LANDSLIDE INFORMATION OF EXAMPLE 2

Landslide Observation Report filed by Highway/construction worker

Name of reporter		Brent Black
Affiliation (District)		2
Date		5/04/2004
Site Location	**County**	Ottawa
	Route	S.R. 2
	Mile marker (county basis)	17.71

Description (Visual Inspection)

Landslide material(s)	√Soil __Rock __Both
Number of lanes (one direction)	_1 √2 __3 __4 __5 __6
Posted speed limit (miles/hr)	__15 __20 __25 __30 __35 __40 __45 __50 __55 __60 √ 65 __70
Location of landslide relative to roadway	__Above roadway √Below roadway __both
Position of impact on roadway	Position of cracks/dips: _Pavement √Shoulder __Ditch __None Position of earth debris: __ Pavement __Shoulder __Ditch √None
Impact to adjacent structures or properties	__Roads __Railroads __Residential __Buildings __Commercial __Bridge __Utilities __Others no adjacent structure
Vegetation	Barren__% Grass 100% Shrub__% Tree ___% Other_____
Presence of surface water	√Yes __No
Presence of groundwater	√Yes __No __Unknown
Previous site works (Based on observation at the site)	__Temporary __Failed temporary __Permanent __Failed permanent √Patching of asphalt __Guardrail work __Other_____
Recent precipitation	__Heavy __Moderate √ Light
Duration	__24-hr __3-d √ 7-d __15-d
Date identifying first evidence of instability	Unknown
Name of verifier (CM/TM)	-
Date of verification	-
Signature	-

L.1/1

Part A filed by Transportation/County Manager

Evaluator's name	Brent Black
Date of observation	5/03/2004

Site Location

Jurisdiction	__County __Turnpike __Municipal √State __Township __Federal __Private
County	S.R.
District	2
Route system	__**IR**-interstate __**US**-United States route √ **SR**-state route __**CR**-county road __**TR**-township road __**MR**-municipal road __**RA**-ramp __**PA**-park roads __**BK**-bike route
Route number	2
Mile marker (county basis)	Beginning: 17.71 Ending: 17.72
Network linear feature (NLF) (auto generation)	SOTTSR00002**C
Number of Lanes (one direction)	__1 √2 __3 __4 __5 __6
Location of landslide relative to roadway	__Above roadway √Below roadway __Both

Centroid of Affected Highway (GPS Information)

GPS coordinates	Centroid: Latitude: 23° 0' 10.56 W Longitude: 41° 31' 13.2 N Elevation: 142.97 ft
	Beginning point: Latitude: N.A. Longitude: N.A. Elevation: N.A.
	Ending point: Latitude: N.A. Longitude: N.A. Elevation: N.A.
State coordinates (Mid-point) (Auto generation)	Zone: North Northing: 391024.863750 Easting: 557993.661026
USGS Quad (Auto generation)	Name: LACARNE Number: 41083E1

A.1/3

Landslide vulnerability table

Probability of additional movement	Probability of significant impacts to the roadway, structures, adjacent property or features			
	Very High	***High***	***Moderate***	***Low***
Very High	Very High	Very High	High	Moderate
High	Very High	High	High	Moderate
Moderate	High	High	Moderate	Low
Low	Moderate	Moderate	Low	Low

Remark: A landslide site having "low" vulnerability is non-rated.

General information

General dimensions (Rough estimate)	Length (ft): 80 Width (ft): ~148 Estimated maximum depth of sliding surface (ft) ~15.20ft
Preliminary rating (Use landslide vulnerability table)	√ Rated __Non-rated
Inspection frequency	__Hourly __Daily __Weekly √Biweekly __Monthly __Quarterly __Yearly __Others_____

Part B filed by Transportation/County Manager

Evaluator's name	Brent Black
Date of observation	5/03/2004

Site Location

Jurisdiction	__County __Turnpike __Municipal √ State __Township __Federal __Private
County	S.R.
District	2
Route system	__**IR**-interstate __**US**-United States route √ **SR**-state route __**CR**-county road __**TR**-township road __**MR**-municipal road __**RA**-ramp __**PA**-park roads __**BK**-bike route
Route number	2
Mile marker (county basis)	Beginning: 17.71 Ending: 17.72
Network linear feature (NLF) (auto generation)	SOTTSR00002**C
Number of lanes (one direction)	__1 √2 __3 __4 __5 __6
Location of landslide relative to roadway	__Above roadway √Below roadway __Both

Site History

Date of original construction (m/d/y)	_____/_____/_____
Date of alignment modifications (m/d/y)	_____/_____/_____
Date of remedial activities (m/d/y)	_____/_____/_____
Past remedial activities	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others unknown
Existing remediation	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others unknown
Annual maintenance frequency (times/year)	unknown
Annual maintenance cost (Average Over the Past 5 to 10 Years) (dollars/year)	unknown
Maintenance response (Based on judgment)	__No response __Require observation with periodic maintenance __Require routine maintenance response to preserve roadway √Require immediate response for safe travel or to protect adjacent structure

Traffic Data

Average daily traffic (ADT)	Total traffic: 16330 vehicles/day Passenger traffic: unknown vehicles/day Trucks traffic: unknown vehicles/day
Accident history in past 10 years (Number of occurrence)	Number of accident in past 10 years_____ Number of accident without loss_____ Number of accident with vehicle and property damage_____ Number of accident with injury __ Number of accident with fatality__
Estimated detour route length (miles)	unknown miles
Posted speed limit (miles/hr)	__15 __20 __25 __30 __35 __40 __45 __50 __55 __60 √ 65 __70
Estimated traveling time of detour (hr)	Truck unknown hr Passenger unknown hr

Part C (District Geotechnical Engineer)

Evaluator's name	Brent Black
Date of observation	5/03/2004

Site Location verified by DGTE

Jurisdiction	__County __Turnpike __Municipal √ State __Township __Federal __Private
County	S.R.
District	2
Route system	__**IR**-interstate __**US**-United States route √ **SR**-state route __**CR**-county road __**TR**-township road __**MR**-municipal road __**RA**-ramp __**PA**-park roads __**BK**-bike route
Route number	2
Mile marker (county basis)	Beginning: 17.71 Ending: 17.72
Network linear feature (NLF) (auto generation)	SOTTSR00002**C
Number of lanes (one direction)	__1 √ 2 __3 __4 __5 __6
Location of landslide relative to roadway	__Above roadway √ Below roadway __Both

Centroid of Affected Highway (GPS Information) verified by DGTE (provide O.K. click button)

GPS coordinates	Centroid: Latitude: 83° 0' 10.56 W Longitude: 41° 31' 13.2 N Elevation: 1429.97 ft
	Beginning point: Latitude: N.A. Longitude: N.A. Elevation: N.A.
	Ending point: Latitude: N.A. Longitude: N.A. Elevation: N.A.
State coordinates (Mid-point) (Auto generation)	Zone: North Northing: 391024.863750 Easting: 557993.661026
USGS Quad (Auto generation)	Name: LACARNE Number: 41083E1

Part C (continued)

Required information for data collection (use landslide vulnerability table)

Low (0< X ≤ 2 points)	Moderate and High (2< X ≤ 9 points)	Very high (X > 9 points)
• Verify and fill out C.1 • Very rough sketches by CM/TM • Take additional photos C.14	• Verify and fill out C.1 • Fill out C.2 to C.11 • Verify rough sketches by CM/TM • Take additional pictures C.14	• Verify and fill out C.1 • Fill out C.2 to C.13 • Take additional photos C.14

Landslide vulnerability table

Probability of additional movement (A)	Probability of significant impacts to the roadway, structures, adjacent property or features (B)			
	Very High(4)	***High(3)***	***Moderate(2)***	***Low(1)***
Very High(4)	Very High (16)	Very High (12)	High (8)	Moderate (4)
High(3)	Very High (12)	High (9)	High (6)	Moderate (3)
Moderate(2)	High (8)	High (6)	Moderate (4)	Low (2)
Low(1)	Moderate (4)	Moderate (3)	Low (2)	Low (1)

Vulnerability score (X) = A× B

Inspection schedule

Inspection frequency	__Hourly	__Daily	_Weekly
	√_Biweekly	__Monthly	_Quarterly
	__Yearly	__Others_____	

Part C (continued)

Slope Characteristics

Slope type		__Natural __Cut √_Fill __Cut and fill
Average slope angle (α_{ave}°)		$\alpha_{ave} = \frac{\alpha_1 \cdot l_1 + \alpha_2 \cdot l_2 + \ldots \alpha_n \cdot l_n}{L} = \underline{25^{\circ}}$
Slope surface appearance		√_Straight __Concave __Convex __ Hummocky __Terraced __Complex
Vegetation cover		√ Grass 100% __Shrub__% __Cultivated land__% __Reforestation__% __Woodland__% __Other _____
Vegetation density		__Sparse __Moderate √_Dense
Hydrogeology	**Surface water**	**Types of water sources** __Reservoir √_Lake __River __Creek __Pond __Surface drainage __Others_____ __None **Location of water sources that may affect landslide** __Above √_Below __Both
	Groundwater (use visual inspection)	**Groundwater flow** __Into landslide __ Off landslide __Both √_Unknown __None **Groundwater condition** __Spring __Seep __Both √_Unknown __None **Location of ground water:** __Above √_Below __Middle __None **Presence of monitoring or water well** __Artesian __Flowing artesian __Pooled √_None observed
Erosion area		√_Head __Toe __Flank __Body __None
Possible cause of failure		__Erosion of the toe __Precipitation √_Failure of drainage __Drainage outlet √_Surface water √_Weathering of materials __Deforestation √_Change of water level
Orientation of slope (Azimuth; The clockwise angle from the north)		N.A. degree
Direction of landslide (Azimuth; The clockwise angle from the north)		N.A. degree

Part C (continued)

Slope Materials (by Visual Inspection and Judgment)

Soil origin	__Colluvium __Alluvium __Till __Residual soil __Weather rock __Unweathered rock √ Fill __Combination __Others
Soil type	__Boulders/cobbles __Stone fragments √ Gravel __Sand __Fine sand __Silty gravel __Silty sand __Clayey gravel __Clayey sand __Silty soil √ Clayey soil __Organic √ Combination √ Others Silty clay with gravel
Rock type	__Shale __Mudstone /claystone __Siltstone __Sandstone __Limestone __Coal __Interbedded __Dolomite __Combination __Others N.A.

Landslide Characteristics

Type of Movement (Rockfall is not included.)	**Slide**	__Rotational rock slide √ Rotational earth slide __Debris slide	__Translational rock slide __Translational earth block slide __Complex
	Flow	__Slow earth flow __Dry sand flow __Debris flow __Complex	__Loess flow __Debris avalanche __Block stream
	Spread	__Rock spread __Complex spread	__Earth spread
Rate of movement		____inches/year	√ unknown
State of landslide activity		√ Active __Inactive	__Mitigated

Observed Remediation

Past remedial activities	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others Unknown
Existing remediation	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others None observed

Part C (continued)

Preliminary Determination of Causes of Landslide

Human activities	__Excavation/under cutting __Groundwater pumping __Deforestation __Loading __Defective maintenance √ Failure of drainage √ Water leakage from pipes __Artificial vibrations __Loose waste dumping √ Construction related __Others
Natural activities	√ Rainfall __Snowmelt __Earthquake √ Ground water __Loss of vegetation __Toe erosion √ Inadequate long term strength √ Surface water level change/rapid drawdown √ Degradation of construction material __Others
Comment (limit no more than 50 words)	

Observed Traffic Information

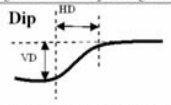
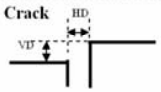
Actual sight distance (ASD) (ft.)	1,000 ft
Percent decision sight distance (%DSD) %DSD=(ASD/DSD)*100	100 %

Decision sight distance (DSD)

Posted speed limit (mph)	Decision sight distance (ft)
25	375
30	450
35	525
40	600
45	675
50	750
55	875
60	1000
65	1050
70	1100

Part C (continued)

Impact assessment on roadway and beyond right of way

Current and potential impact of landslide on roadway	__On slope with a low potential to affect shoulder __On slope with a low potential to affect roadway √ On shoulder or on slope with a moderate potential to affect roadway __On roadway, or on slope with a high potential to affect roadway or structure	
Current and potential impact of landslide on the area beyond right of way	__On slope with a low potential to impact area beyond right of way __On slope with a moderate potential to impact area beyond right of way __On slope with a high potential to impact area beyond right of way __On slope with a high potential to impact building or structure beyond right of way	
Evidence of impact on roadway	**Dip** __Yes √ No **Maximum displacement of dip** Vertical displacement (VD) (inch) ≥3 Horizontal displacement (HD) (inch) ≥3	
	Crack √ Yes __No **Maximum displacement of crack** Vertical displacement (VD) (inch) ≥3 Horizontal displacement (HD) (inch) ≥3	
	Earth debris on roadway __Yes √ No Estimated volume (Yd^3) _____	

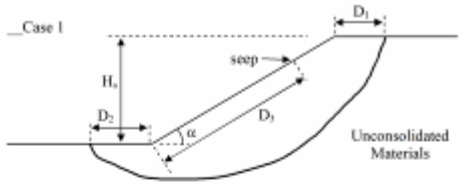
Adjacent Structures and Areas

Adjacent structures	__Roads __Railroads __Residential __Buildings √ Bridge __Utilities __Others_____
Surrounding area	__Forest __Agriculture √ Rural __Urban __Housing development __Others_____

Part C (continued)

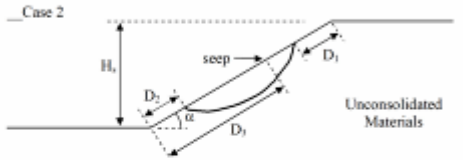
Information for estimation of landslide repair cost

__Case 1



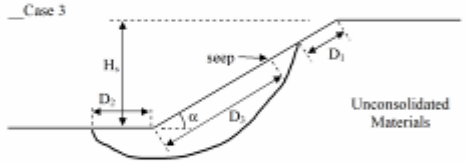
1. Average slope angle, α, _____
2. Height of slope, H_s (ft) _____
3. Length of slope repair, L, parallel to highway (ft) _____
4. Distance from crest of slope to failure surface, D_1(ft) _____
5. Distance from toe of slope to failure surface, D_2 (ft) _____
6. Distance along slope (measured from toe) to groundwater seeps, D_3, and approximate quantities of groundwater (ft) _____

__Case 2



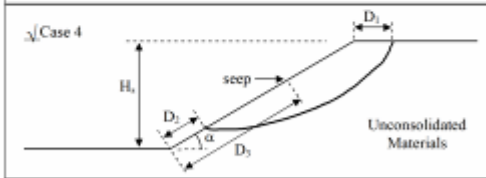
1. α, _____
2. H_s (ft)_____
3. L(ft)_____
4. D_1(ft)_____
5. D_2(ft)_____
6. D_3(ft)_____

__Case 3



1. α, _____
2. H_s (ft)_____
3. L(ft)_____
4. D_1(ft)_____
5. D_2(ft)_____
6. D_3(ft)_____

√ Case 4



1. α, 25
2. H_s (ft) 30
3. L(ft) 150
4. D_1(ft) 13
5. D_2(ft) 0
6. D_3(ft) 50

Cost Estimate

Repair cost	unknown
Benefit cost ratio	unknown
Estimated time required for remediation (days)	unknown days

Part C (continued)

Suggested Remediation Measure

√ Benching & regarding
√ Counter berm & regrading
__Flattening Slope
__Soil Drainage
__Bedrock Drainage
__Retaining Walls
__Light Weight Fills
__Dynamic Compaction
__Bio-engineering
__Geofabrics
__Sheet Piling
__H Piling
__Drilled Piling
__Soil Nailing
__Tieback Walls
__Remove & Replace
__Shear Key
__Chemical Treatment
__Relocation
__Bridge
__Change Line or Grade
__Other_____

Part C (continued)

Sources of Supplemental Information

__Aerial photos	√ Field visit
__Satellite imaginary	__Local people
__County-ODOT	__Dist-ODOT
√ State-ODOT	__City and county engineer
__Soil/Rock/Water samples	__GPS features
__Folder/ File location	__Academia with engineering or geology program
__USGS publications and files	__USGS Quadrangles

__USGS open file map series #78-1057 "Landslide related features"

__Division of geological survey (ODNR)

__Division of mineral resource management (ODNR)

__Division of soil and water (ODNR)

__Others_____

Part C (continued)

Landslide hazard rating matrix

CATEGORY		RATING CRITERIA and SCORE				Total Item Scores
		Points 3	Points 9	Points 27	Points 81	
Movement location/ impact (select higher score)	Current and potential impact of landslide on roadway	On slope with a low potential to affect shoulder	On slope with a low potential to affect roadway	On shoulder, or on slope with a moderate potential to affect roadway	On roadway, or On slope with a high potential to affect roadway or structure	27
	Current and potential impact of landslide on area beyond right of way	On slope with a low potential to impact area beyond right of way	On slope with moderate potential to impact area beyond right of way	On slope with high potential to impact area beyond right of way	On slope with high potential to impact structure beyond right of way	
Hazard to traveling public (Select higher score)	Rate of displacement in roadway if known	<1-inch/year	1 to 3-inches/year No single event ≥1-inch	3 to 6-inches/year No single event ≥3-inches	>6-inches/year Single event ≥3-inches	81
	Evidence of displacement in roadway	Visible crack or dip no vertical drop	≤1-inch of displacement	1 to 3-inches of displacement	≥ 3-inches of displacement	
Maintenance (Select higher score)	Maintenance frequency	None to rare	Annually (one time/year)	Seasonal (1 to 3 times/ year)	Continuous throughout year (> 3 times/year)	27
	Maintenance response	No response	Requires observation with periodic maintenance	Requires routine maintenance response to preserve roadway	Requires immediate response for safe travel or to protect adjacent structure	
%Decision Sight Distance (%DSD)		≥ 90	89 -50	49-35	< 34	3
ADT		<2000	2001-5000	5001-15000	>15001	81
Accident history (Related to landslide)		No accident	Vehicle or property damage	Injury	Fatality	3
					Total Score	222

OHIO LANDSLIDE HAZARD RATING SYSTEM

Part C (continued)

Hazard calculation sheet

Hazard category	Explanation	Item Scores
1. Movement Location/ Impact	The impact of slope failure is observed on the roadway shoulder.	27
2. Hazard to Traveling Public	The rate of movement is not available. The displacement observed on road is used. It is more than 3 inch displacement found on the roadway shoulder.	81
3. Maintenance	The maintenance for this site requires the routine maintenance response as the cracks were significant, and somewhat close to the traffic lane.	27
4. %DSD	The speed limit at the site location is 55 miles/hr. The actual sight distance is longer than 1000 ft. The calculated DSD is about 100%.	3
5. ADT	16,330 cars/ day	81
6. Accident history (Related to landslide)	None	3
	Total score	222

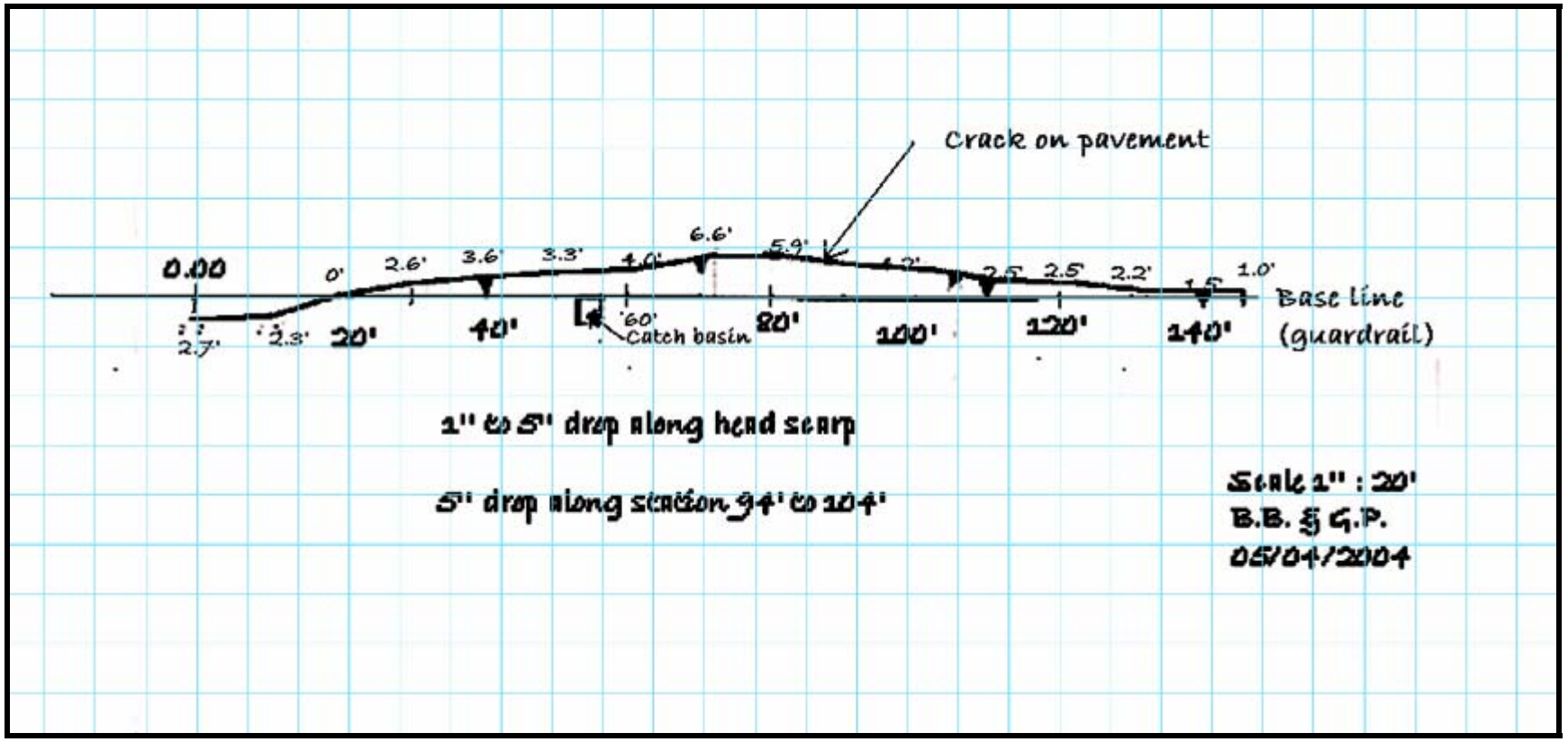


Figure E.3 A Plan sketch of Example 2

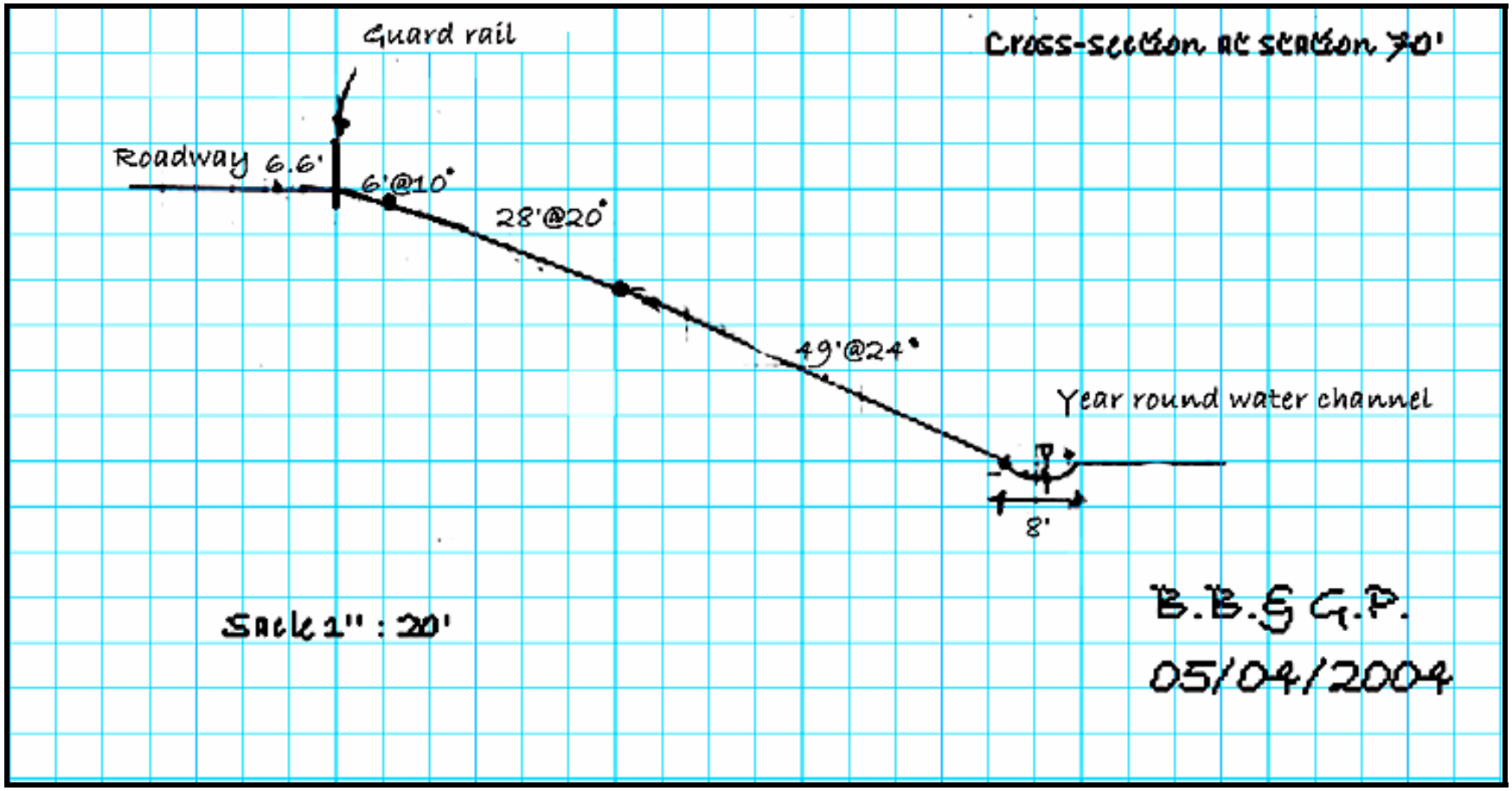


Figure E.4 A cross-section sketch of Example

LANDSLIDE INFORMATION OF EXAMPLE 3

Landslide Observation Report filed by Highway/construction worker

Name of reporter		Brent Black
Affiliation (District)		10
Date		5/11/2004
Site Location	**County**	Morgan
	Route	S.R. 78
	Mile marker (county basis)	23.00

Description (Visual Inspection)

Landslide material(s)	√Soil __Rock __Both
Number of lanes (one direction)	_1 √2 __3 __4 __5 __6
Posted speed limit (miles/hr)	__15 __20 __25 __30 __35 __40 __45 __50 √55 __60 __65 __70
Location of landslide relative to roadway	__Above roadway √Below roadway __both
Position of impact on roadway	Position of cracks/dips: __Pavement √Shoulder __Ditch __None
	Position of earth debris: __ Pavement __Shoulder __Ditch √None
Impact to adjacent structures or properties	__Roads __Railroads __Residential __Buildings __Commercial __Bridge __Utilities __Others no adjacent structure
Vegetation	Barren__% Grass 100% Shrub__% Tree___% Other_____
Presence of surface water	√Yes __No
Presence of groundwater	√Yes __No __Unknown
Previous site works (Based on observation at the site)	__Temporary __Failed temporary __Permanent __Failed permanent √Patching of asphalt __Guardrail work __Other
Recent precipitation	__Heavy __Moderate √Light
Duration	__24-hr __3-d √7-d __15-d
Date identifying first evidence of instability	Unknown
Name of verifier (CM/TM)	-
Date of verification	-
Signature	-

L.1/1

Part A filed by Transportation/County Manager

Evaluator's name	Brent Black
Date of observation	5/11/2004

Site Location

Jurisdiction	__County __Turnpike __Municipal √State __Township __Federal __Private
County	S.R.
District	10
Route system	__IR-interstate __US-United States route √ SR-state route __CR-county road __TR-township road __MR-municipal road __RA-ramp __PA-park roads __BK-bike route
Route number	78
Mile marker (county basis)	Beginning: 23.00 Ending: 23.16
Network linear feature (NLF) (auto generation)	SMRGSR00078***0
Number of Lanes (one direction)	√1 __2 __3 __4 __5 __6
Location of landslide relative to roadway	__Above roadway √Below roadway __Both

Centroid of Affected Highway (GPS Information)

GPS coordinates	Centroid:	Latitude: 81°48'25.09 W Longitude: 39°41'19.59N Elevation: 218.05 ft
	Beginning point:	Latitude: N.A. Longitude: N.A. Elevation: N.A.
	Ending point:	Latitude: N.A. Longitude: N.A. Elevation: N.A.
State coordinates (Mid-point) (Auto generation)	Zone: South Northing: 187709.351617 Easting: 659444.7770236	
USGS Quad (Auto generation)	Name: MCCONNELSVILLE Number: 39081F7	

A.1/3

Landslide vulnerability table

Probability of additional movement	Probability of significant impacts to the roadway, structures, adjacent property or features			
	Very High	***High***	***Moderate***	***Low***
Very High	Very High	Very High	High	Moderate
High	Very High	High	High	Moderate
Moderate	High	High	Moderate	Low
Low	Moderate	Moderate	Low	Low

Remark: A landslide site having "low" vulnerability is non-rated.

General information

General dimensions (Rough estimate)	Length (ft): 130 Width (ft): 850 Estimated maximum depth of sliding surface (ft) ~15-20ft
Preliminary rating (Use landslide vulnerability table)	√ Rated __ Non-rated
Inspection frequency	__ Hourly __ Daily __ Weekly __ Biweekly √ Monthly __ Quarterly __ Yearly __ Others_____

Part B filed by Transportation/County Manager

Evaluator's name	Brent Black
Date of observation	5/11/2004

Site Location

Jurisdiction	__ **County** __ **Turnpike** __ **Municipal** √ **State** __ **Township** __ **Federal** __ **Private**
County	S.R.
District	10
Route system	__ **IR**-interstate __ **US**-United States route √ **SR**-state route __ **CR**-county road __ **TR**-township road __ **MR**-municipal road __ **RA**-ramp __ **PA**-park roads __ **BK**-bike route
Route number	78
Mile marker (county basis)	Beginning: 23.00 Ending: 23.16
Network linear feature (NLF) (auto generation)	SMRGSR000078**C
Number of lanes (one direction)	√ 1 __ 2 __ 3 __ 4 __ 5 __ 6
Location of landslide relative to roadway	__ Above roadway √ Below roadway __ Both

Site History

Date of original construction (m/d/y)	____/____/____
Date of alignment modifications (m/d/y)	____/____/____
Date of remedial activities (m/d/y)	____/____/____
Past remedial activities	__ Drainage __ Bio-stabilization __ Slope geometry correction __ Retaining structures __ Internal slope reinforcement __ Erosion control __ Chemical stabilization __ Others unknown
Existing remediation	__ Drainage __ Bio-stabilization __ Slope geometry correction __ Retaining structures __ Internal slope reinforcement __ Erosion control __ Chemical stabilization __ Others unknown
Annual maintenance frequency (times/year)	unknown
Annual maintenance cost (Average Over the Past 5 to 10 Years) (dollars/year)	unknown
Maintenance response (Based on judgment)	__ No response __ Require observation with periodic maintenance __ Require routine maintenance response to preserve roadway √ Require immediate response for safe travel or to protect adjacent structure

Traffic Data

Average daily traffic (ADT)	Total traffic: 1160 vehicles/day Passenger traffic: unknown vehicles/day Trucks traffic: unknown vehicles/day
Accident history in past 10 years (Number of occurrence)	Number of accident in past 10 years unknown Number of accident without loss_____ Number of accident with vehicle and property damage_____ Number of accident with injury __ Number of accident with fatality__
Estimated detour route length (miles)	unknown miles
Posted speed limit (miles/hr)	__15 __20 __25 __30 __35 __40 __45 __50 √ 55 __60 __65 __70
Estimated traveling time of detour (hr)	Truck unknown hr Passenger unknown hr

Part C (District Geotechnical Engineer)

Evaluator's name	Brent Black
Date of observation	5/11/2004

Site Location verified by DGTE

Jurisdiction	__County __Turnpike __Municipal √ State __Township __Federal __Private
County	S.R.
District	10
Route system	__IR-interstate __US-United States route √ SR-state route __CR-county road __TR-township road __MR-municipal road __RA-ramp __PA-park roads __BK-bike route
Route number	78
Mile marker (county basis)	Beginning: 23.00 Ending: 23.16
Network linear feature (NLF) (auto generation)	SMRGSR000078**C
Number of lanes (one direction)	√ 1 __2 __3 __4 __5 __6
Location of landslide relative to roadway	__Above roadway √ Below roadway __Both

Centroid of Affected Highway (GPS Information) verified by DGTE (provide O.K. click button)

GPS coordinates	Centroid: Latitude: 81° 48' 25.09" W Longitude: 39° 41' 19.59" N Elevation: 218.05 ft
	Beginning point: Latitude: N.A. Longitude: N.A. Elevation: N.A.
	Ending point: Latitude: N.A. Longitude: N.A. Elevation: N.A.
State coordinates (Mid-point) (Auto generation)	Zone: South Northing: 187709.351617 Easting: 659444.7770236
USGS Quad (Auto generation)	Name: MCCONNELSVILLE Number: 39081F7

Part C (continued)

Required information for data collection (use landslide vulnerability table)

Low (0< X ≤ 2 points)	Moderate and High (2< X ≤ 9 points)	Very high (X > 9 points)
• Verify and fill out C.1 • Very rough sketches by CM/TM • Take additional photos C.14	• Verify and fill out C.1 • Fill out C.2 to C.11 • Verify rough sketches by CM/TM • Take additional pictures C.14	• Verify and fill out C.1 • Fill out C.2 to C.13 • Take additional photos C.14

Landslide vulnerability table

Probability of additional movement (A)	Probability of significant impacts to the roadway, structures, adjacent property or features (B)			
	Very High(4)	***High(3)***	***Moderate(2)***	***Low(1)***
Very High(4)	Very High (16)	Very High (12)	High (8)	Moderate (4)
High(3)	Very High (12)	High (9)	High (6)	Moderate (3)
Moderate(2)	High (8)	High (6)	Moderate (4)	Low (2)
Low(1)	Moderate (4)	Moderate (3)	Low (2)	Low (1)

Vulnerability score (X) = A× B

Inspection schedule

Inspection frequency	__Hourly	__Daily	_Weekly
	__Biweekly	√ Monthly	__Quarterly
	__Yearly	__Others_____	

Part C (continued)

Slope Characteristics

Slope type		__Natural __Cut √ Fill √ Cut and fill
Average slope angle (α_{ave}°)		$\alpha_{ave} = \frac{\alpha_1 \cdot l_1 + \alpha_2 \cdot l_2 + \ldots \alpha_n \cdot l_n}{L} =$ 20°
Slope surface appearance		__Straight __Concave __Convex √ Hummocky __Terraced __Complex
Vegetation cover		√ Grass 80% √ Shrub 20 % __Cultivated land __% __Reforestation __% __Woodland __% __Other _____
Vegetation density		__Sparse √ Moderate √ Dense
Hydrogeology	**Surface water**	**Types of water sources** __Reservoir __Lake __River √ Creek __Pond __Surface drainage __Others_____ __None **Location of water sources that may affect landslide** __Above √ Below __Both
	Groundwater (use visual inspection)	**Groundwater flow** __Into landslide __Off landslide __Both √ Unknown __None **Groundwater condition** __Spring __Seep __Both √ Unknown __None **Location of ground water:** __Above √ Below __Middle __None **Presence of monitoring or water well** __Artesian __Flowing artesian __Pooled √ None observed
Erosion area		√ Head √ Toe __Flank __Body __None
Possible cause of failure		__Erosion of the toe __Precipitation __Failure of drainage __Drainage outlet √ Surface water √ Weathering of materials __Deforestation √ Change of water level
Orientation of slope (Azimuth; The clockwise angle from the north)		N.A. degree
Direction of landslide (Azimuth; The clockwise angle from the north)		N.A. degree

Part C (continued)

Slope Materials (by Visual Inspection and Judgment)

Soil origin	__Colluvium __Alluvium __Till __Residual soil __Weather rock __Unweathered rock √ Fill __Combination __Others
Soil type	__Boulders/cobbles __Stone fragments √ Gravel __Sand __Fine sand __Silty gravel __Silty sand __Clayey gravel __Clayey sand __Silty soil √ Clayey soil __Organic √ Combination __Others
Rock type	__Shale __Mudstone /claystone __Siltstone √ Sandstone __Limestone __Coal __Interbedded __Dolomite __Combination __Others Boulders in creek

Landslide Characteristics

Type of Movement (Rockfall is not included.)	**Slide**	__Rotational rock slide __Translational rock slide √ Rotational earth slide __Translational earth block slide __Debris slide __Complex
	Flow	__Slow earth flow __Loess flow __Dry sand flow __Debris avalanche __Debris flow __Block stream __Complex
	Spread	__Rock spread __Earth spread __Complex spread
Rate of movement		_____inches/year √ unknown
State of landslide activity		√ Active __Inactive __Mitigated

Observed Remediation

Past remedial activities	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others unknown
Existing remediation	__Drainage __Bio-stabilization __Slope geometry correction __Retaining structures __Internal slope reinforcement __Erosion control __Chemical stabilization __Others None observed

Part C (continued)

Preliminary Determination of Causes of Landslide

Human activities	__Excavation/under cutting __Groundwater pumping __Deforestation __Loading __Defective maintenance __Failure of drainage __Water leakage from pipes __Artificial vibrations __Loose waste dumping √ Construction related __Others
Natural activities	√ Rainfall __Snowmelt __Earthquake √ Ground water __Loss of vegetation __Toe erosion √ Inadequate long term strength √ Surface water level change/rapid drawdown √ Degradation of construction material __Others
Comment (limit no more than 50 words)	

Observed Traffic Information

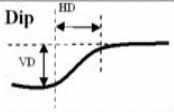
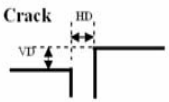
Actual sight distance (ASD) (ft.)	300 ft
Percent decision sight distance (%DSD) %DSD=(ASD/DSD)*100	34 %

Decision sight distance (DSD)

Posted speed limit (mph)	Decision sight distance (ft)
25	375
30	450
35	525
40	600
45	675
50	750
55	875
60	1000
65	1050
70	1100

Part C (continued)

Impact assessment on roadway and beyond right of way

Current and potential impact of landslide on roadway	__On slope with a low potential to affect shoulder __On slope with a low potential to affect roadway __On shoulder or on slope with a moderate potential to affect roadway √ On roadway, or on slope with a high potential to affect roadway or structure	
Current and potential impact of landslide on the area beyond right of way	__On slope with a low potential to impact area beyond right of way __On slope with a moderate potential to impact area beyond right of way __On slope with a high potential to impact area beyond right of way __On slope with a high potential to impact building or structure beyond right of way	
Evidence of impact on roadway	**Dip** __Yes √ No **Maximum displacement of dip** Vertical displacement (VD) (inch) ___ Horizontal displacement (HD) (inch) ___	
	Crack √ Yes __No **Maximum displacement of crack** Vertical displacement (VD) (inch) 0 Horizontal displacement (HD) (inch) 0	
	Earth debris on roadway __Yes √ No Estimated volume (Yd^3) _____	

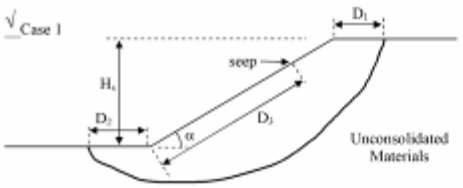
Adjacent Structures and Areas

Adjacent structures	__Roads __Railroads __Residential __Buildings __Bridge __Utilities __Others_____
Surrounding area	√ Forest __Agriculture √ Rural __Urban __Housing development __Others_____

Part C (continued)

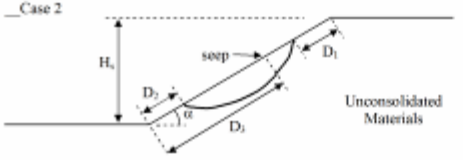
Information for estimation of landslide repair cost

√ Case 1



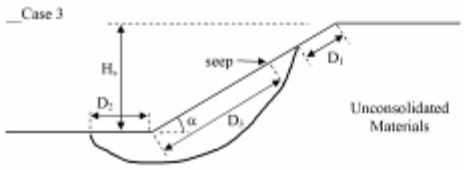
1. Average slope angle, α, 20°
2. Height of slope, H_s (ft) 25
3. Length of slope repair, L, parallel to highway (ft) 250
4. Distance from crest of slope to failure surface, D_1(ft) 15
5. Distance from toe of slope to failure surface, D_2 (ft) unknown
6. Distance along slope (measured from toe) to groundwater seeps, D_3, and approximate quantities of groundwater (ft) unknown

__Case 2



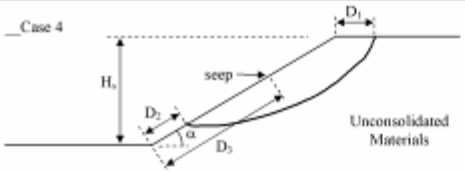
1. α_____
2. H_s (ft)_____
3. L(ft)_____
4. D_1(ft)_____
5. D_2(ft)_____
6. D_3(ft)_____

__Case 3



1. α_____
2. H_s (ft)_____
3. L(ft)_____
4. D_1(ft)_____
5. D_2(ft)_____
6. D_3(ft)_____

__Case 4



1. α_____
2. H_s (ft)_____
3. L(ft)_____
4. D_1(ft)_____
5. D_2(ft)_____
6. D_3(ft)_____

Cost Estimate

Repair cost	unknown
Benefit cost ratio	unknown
Estimated time required for remediation (days)	unknown days

Part C (continued)

Suggested Remediation Measure

- √ Benching & regarding
- √ Counter berm & regrading
- __ Flattening Slope
- __ Soil Drainage
- __ Bedrock Drainage
- __ Retaining Walls
- __ Light Weight Fills
- __ Dynamic Compaction
- __ Bio-engineering
- __ Geofabrics
- __ Sheet Piling
- __ H Piling
- __ Drilled Piling
- __ Soil Nailing
- __ Tieback Walls
- __ Remove & Replace
- __ Shear Key
- __ Chemical Treatment
- __ Relocation
- __ Bridge
- __ Change Line or Grade
- __ Other_____

C.8/14

Part C (continued)

Sources of Supplemental Information

__ Aerial photos	√ Field visit
__ Satellite imaginary	__ Local people
__ County-ODOT	__ Dist-ODOT
√ State-ODOT	__ City and county engineer
__ Soil/Rock/Water samples	__ GPS features
__ Folder/ File location	__ Academia with engineering or geology program
__ USGS publications and files	__ USGS Quadrangles

__ USGS open file map series #78-1057 "Landslide related features"

__ Division of geological survey (ODNR)

__ Division of mineral resource management (ODNR)

__ Division of soil and water (ODNR)

__ Others_____

C.9/14

Part C (continued)

Landslide hazard rating matrix

CATEGORY		RATING CRITERIA and SCORE				Total Item Scores
		Points 3	Points 9	Points 27	Points 81	
Movement location/ impact (select higher score)	Current and potential impact of landslide on roadway	On slope with a low potential to affect shoulder	On slope with a low potential to affect roadway	On shoulder, or on slope with a moderate potential to affect roadway	On roadway, or On slope with a high potential to affect roadway or structure	81
	Current and potential impact of landslide on area beyond right of way	On slope with a low potential to impact area beyond right of way	On slope with moderate potential to impact area beyond right of way	On slope with high potential to impact area beyond right of way	On slope with high potential to impact structure beyond right of way	
Hazard to traveling public (Select higher score)	Rate of displacement in roadway if known	<1-inch/year	1 to 3-inches/year No single event ≥1-inch	3 to 6-inches/year No single event ≥3-inches	>6-inches/year Single event ≥3-inches	3
	Evidence of displacement in roadway	Visible crack or dip no vertical drop	≤1-inch of displacement	1 to 3-inches of displacement	≥ 3-inches of displacement	
Maintenance (Select higher score)	Maintenance frequency	None to rare	Annually (one time/year)	Seasonal (1 to 3 times/ year)	Continuous throughout year (> 3 times/year)	9
	Maintenance response	No response	Requires observation with periodic maintenance	Requires routine maintenance response to preserve roadway	Requires immediate response for safe travel or to protect adjacent structure	
%Decision Sight Distance (%DSD)		≥ 90	89 -50	49-35	< 34	81
ADT		<2000	2001-5000	5001-15000	>15001	3
Accident history (Related to landslide)		No accident	Vehicle or property damage	Injury	Fatality	3
					Total Score	180

Part C (continued)

Hazard calculation sheet

Hazard category	Explanation	Item Scores
1. Movement Location/ Impact	The impact of slope failure is observed on traffic lanes.	81
2. Hazard to Traveling Public	The rate of movement is not available. Only hairline cracks are observed on roadway.	3
3. Maintenance	The maintenance for this site requires periodic observation.	9
4. %DSD	The speed limit at the site location is 55 miles/hr. The actual sight distance is approximately 300 ft. The calculated DSD is 34%.	81
5. ADT	1160 cars/ day	3
6. Accident history (Related to landslide)	None	3
	Total score	180

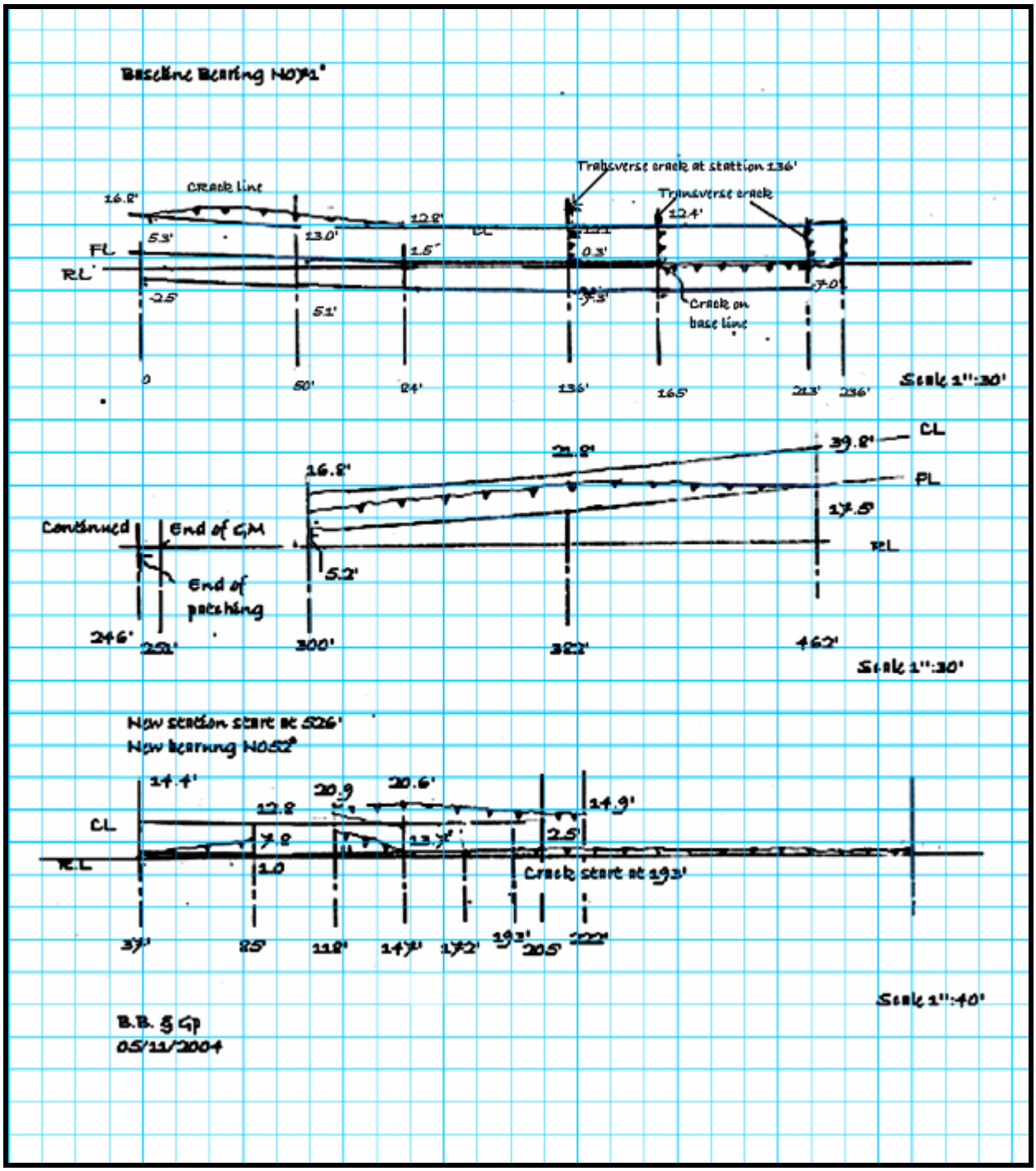


Figure E.5 A plan sketch of Example 3

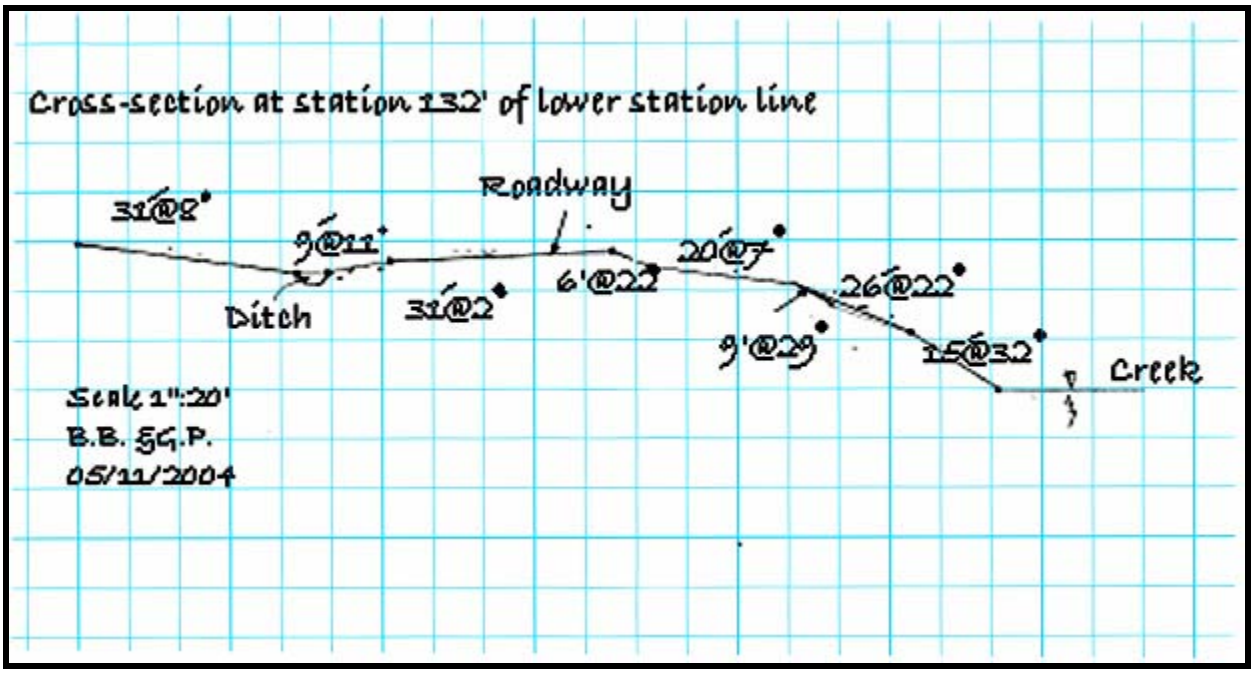


Figure E. 6 A cross-section sketch of Example 3

APPENDIX F

CONTACTS

AND

SUPPLEMENTAL INFORMATION

Ohio Department of Transportation
Districts

District 1
1885 N. McCullough St.
Lima, OH 45801-0040
419-222-9055
fax: 419-222-0438

District 2
317 East Poe Rd.
Bowling Green, OH 43402-1330
419-353-8131
fax: 419-353-1468

District 3
906 North Clark St.
Ashland, OH 44805-1989
800-276-4188 or 419-281-0513
fax: 419-281-0874

District 4
2088 S. Arlington Rd.
Akron, OH 44306
800-603-1054 or 330-786-3100
fax: 330-786-2232

District 5
9600 Jacksontown Rd., S.E.
PO Box 306
Jacksontown, OH 43030
740-323-4400
fax: 740-323-3715

District 6
400 East William St.
Delaware, OH 43015
800-372-7714 or 740-363-1251
fax: 740-369-7437

District 7
1001 St. Marys Ave.
SR 29 PO Box 969
Sidney, OH 45365-0969
937-492-1141
fax: 937-497-9734

District 8
505 South SR 741
Lebanon, OH 45036-9518
800-831-2142 or 513-932-3030
fax: 513-932-7651

Central Office
1980 W. Broad Street
Columbus, OH 43223
614-466-7170
fax: 614-644-8662
ODOT Web Site:
http://www.dot.state.oh.us

District 9
650 Eastern Ave. PO Box 467
Chillicothe, OH 45601
740-773-2691
fax: 740-775-4889

District 10
338 Muskingum Dr. PO Box 658
Marietta, OH 45750
800-845-0226 or 740-373-0212
fax: 740-373-7317

District 11
2201 Reiser Ave.
New Philadelphia, OH 44663
330-339-6633
fax: 330-308-3942

District 12
5500 Transportation Blvd.
Garfield Heights, OH 44125-5396
866-737-8112 or 216-581-2100
fax: 216-587-1730

LISTING OF COUNTY CODES AND DISTRICT

County	*Code*	*District*		*County*	*Code*	*District*
Adams	ADA	9		Licking	LIC	5
Allen	ALL	1		Logan	LOG	7
Ashland	ASD	3		Lorain	LOR	3
Ashtabula	ATB	4		Lucas	LUC	2
Athens	ATH	10		Madison	MAD	6
Auglaize	AUG	7		Mahoning	MAH	4
Belmont	BEL	11		Marion	MAR	6
Brown	BRO	9		Medina	MED	3
Butler	BUT	8		Meigs	MEG	10
Carroll	CAR	11		Mercer	MER	7
Champaign	CHP	7		Miami	MIA	7
Clark	CLA	7		Monroe	MOE	10
Clermont	CLE	8		Montgomery	MOT	7
Clinton	CLI	8		Morgan	MRG	10
Columbiana	COL	11		Morrow	MRW	6
Coshocton	COS	5		Muskingum	MUS	5
Crawford	CRA	3		Noble	NOB	10
Cuyahoga	CUY	12		Ottawa	OTT	2
Darke	DAR	7		Paulding	PAU	1
Defiance	DEF	1		Perry	PER	5
Delaware	DEL	6		Pickaway	PIC	6
Erie	ERI	3		Pike	PIK	9
Fairfield	FAI	5		Portage	POR	4
Fayette	FAY	6		Preble	PRE	8
Franklin	FRA	6		Putnam	PUT	1
Fulton	FUL	2		Richland	RIC	3
Gallia	GAL	10		Ross	ROS	9
Geauga	GEA	12		Sandusky	SAN	2
Greene	GRE	8		Scioto	SCI	9
Guernsey	GUE	5		Seneca	SEN	2
Hamilton	HAM	8		Shelby	SHE	7
Hancock	HAN	1		Stark	STA	4
Hardin	HAR	1		Summit	SUM	4
Harrison	HAS	11		Trumbull	TRU	4
Henry	HEN	2		Tuscarawas	TUS	11
Highland	HIG	9		Union	UNI	6
Hocking	HOC	10		Van Wert	VAN	1
Holms	HOL	11		Vinton	VIN	10
Huron	HUR	3		Warren	WAR	8
Jackson	JAC	9		Washington	WAS	10
Jefferson	JEF	11		Wayne	WAY	3
Knox	KNO	5		Williams	WIL	2
Lake	LAK	12		Wood	WOO	2
Lawrence	LAW	9		Wyandot	WAY	1

DISTRICT AND COUNTY CONTACT

District 1: 1885 N. McCullough St. Lima, OH 45801-0040, Tel: 419-222-9055, fax: 419-222-0438			
District Geotechnical Engineer: Russ Slonecker (419) 999-6882 Russ.Slonecker@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Allen	Robert Gehr	419-228-6385	robert.gehr@dot.state.oh.us
Defiance	Bob Steffel	419-782-2826	bob.steffel@dot.state.oh.us
Hancock	Ron Kear	419-422-2451	ron.kear@dot.state.oh.us
Hardin	Tom Berning	419-673-4218	Tom.berning@dot.state.oh.us
Paulding	Doug Smalley	419-399-2746	doug.smalley@dot.state.oh.us
Putnam	Michael Pollock	419-523-3750	michael.pollock@dot.state.oh.us
Van Wert	Don Taylor	419-2385424	don.taylor@dot.state.oh.us
Wyandot	Tom Vaughn	419-294-2383	tom.vaughn@dot.state.oh.us

District 2: 317 East Poe Rd., Bowling Green, OH 43402-1330, Tel: 419-353-8131, Fax: 419-353-1468			
District Geotechnical Engineer: Doug Rogers (419) 373-4397 Doug.Rogers@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Henry	Craig Schneiderbager	419-592-1838	Craig.Schneiderbauer@dot.state.oh.us
Fulton	Toby Hines	419-335-8941	Toby.Hines@dot.state.oh.us
Lucas	Terry Leach	419-382-2681	Terry.Leach@dot.state.oh.us
Ottawa	Steve Durnwald	419-683-8870	Steve.Durnwald@dot.state.oh.us
Sandusky	Jeff Oneal	419-332-1585	Jeffery.Oneal@dot.state.oh.us
Seneca	Curt Tusing	419-477-0967	Curt.Tusing@dot.state.oh.us
Williams	Lee Anderson	419-485-3505	Lee.Anderson@dot.state.oh.us
Wood	Violet Courtney	419-353-0866	Violet.Courtney@dot.state.oh.us

District 3: 906 North Clark St., Ashland, OH 44805-1989, Tel: 800-276-4188 or 419-281-0513 Fax: 419-281-0874			
District Geotechnical Engineer: Dave Baraty (419) 207-7052 Dave.Baraty@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Ashland	Mark Blair	419-281-6501	Mark.Blair@dot.state.oh.us
Crawford	Al Baker	419-562-8931	Al.Baker@dot.state.oh.us
Erie	Karen Capizzi	419-499-2351	Karen.Capizzi@dot.state.oh.us
Huron	Tim Coleman	419-668-5102	Tim.Coleman@dot.state.oh.us
Lorain	Bill Krueger	440-774-6681	Bill.Krueger@dot.state.oh.us
Medina	Kimberly Conklin	330-723-0091	Kimberly.Conklin@dot.state.oh.us
Richland	Ed Meehan	419-529-3626	Edward.Meehan@dot.state.oh.us
Wayne	Tom Vogel	330-262-2821	Tom.Vogel@dot.state.oh.us

District 4: 2088 S. Arlington Rd., Akron, OH 44306, Tel: 800-603-1054 or 330-786-3100 Fax: 330-786-2232			
District Geotechnical Engineer: Alex Bredikhin (330)786-3100 Alex.Bredikhin@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Ashtabula	Alan Moore	440-997-2276 ext. 457/458	Alan.Moore@dot.state.oh.us
Mahoning	Joseph Maslach	330-533-4351 ext. 459/460	Joseph.Maslach@dot.state.oh.us
Portage	Mike Rahach	330-325-7997 ext. 461/462	Mike.Rahach@dot.state.oh.us
Stark	Jim Murray	330-452-0365	James.Murray@dot.state.oh.us
Summit	Frank Phillips	330-650-1300	Frank.Phillips@dot.state.oh.us
Trumbull	Greg Solarz	330-637-5951 ext. 469/470	Greg.Solarz@dot.state.oh.us

District 5: 9600 Jacksontown Rd., S.E., PO Box 306, Jacksontown, OH 43030, Tel: 740-323-4400 Fax: 740-323-3715			
District Geotechnical Engineer: Nikunj Kadaki (740) 232-5114 Nikunj.Kadakia@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Coshocton	Bill Sullivan	740-622-2741	Bill.Sullivan@dot.state.oh.us
Fairfield	Troy Dunlap	740-653-5961	Troy.Dunlap@dot.state.oh.us
Guernsey	Darrel Fawcett	740-432-7586	Darrel.Fawcett@dot.state.oh.us
Knox	Brian Hunter	740-392-3066	Brian.Hunter@dot.state.oh.us
Licking	Jim Valentine	740-323-5230	Jim.Valentine@dot.state.oh.us
Muskingum	Phil Newman	740-452-1421	Phil.Newman@dot.state.oh.us
Perry	Ray Dailey	740-342-2247	Ray.Dailey@dot.state.oh.us

District 6: 400 East William St., Delaware, OH 43015, Tel: 800-372-7714 or 740-363-1251 Fax: 740-369-7437			
District Geotechnical Engineer: Qi Unterreiner -740 363-1251 x457 Qi.Unterreiner@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Delaware	Robert Lloyd	740-363-3713	Bob.Lloyd@dot.state.oh.us
Fayette	Jason Little	740-335-1800	Jason.Little@dot.state.oh.us
Franklin	Jack Marshall	614-387-2520	Jack.Marshall@dot.state.oh.us
Madison	Mitch Blackford	740-852-9854	Mitch.Blackford@dot.state.oh.us
Marion	Scott Kurz	740-382-0624	Scott.Kurz@dot.state.oh.us
Morrow	William Young	419-946-2921	William.Young@dot.state.oh.us
Pickaway	Jerry Reibel	740-477-3371	Jerry.Riebel@dot.state.oh.us
Union	Dan Wise	937-642-1986	Dan.Wise@dot.state.oh.us

District 7: 1001 St. Marys Ave., SR 29 PO Box 969, Sidney, OH 45365-0969, Tel: 937-492-1141 Fax: 937-497-9734			
District Geotechnical Engineer: Michelle Poor (937) 492-1141 Michelle.Poor@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Auglaize	Ted Hemleben	419-738-4214	Ted.Hemleben@dot.state.oh.us
Champaign	Mark Lewis	937-653-4614	Mark.Lewis@dot.state.oh.us
Clark	John Henry Blazer	937-325-4573	@dot.state.oh.us
Darke	Shawn Anverse	937-548-3015	Shawn.Anverse@dot.state.oh.us
Logan	Randy Sanders	937-592-6911	Randy.Sanders@dot.state.oh.us
Mercer	Steve Zehringer	419-586-4269	Steve.Zehringer@dot.state.oh.us
Miami	Stan Johnston	937-339-1921	Stan.Johnston@dot.state.oh.us
Montgomery	John Glover	937-832-1824	John.Glover@dot.state.oh.us
Shelby	Dave Fisher	937-497-1297	Dave.Fisher@dot.state.oh.us

District 8: 505 South SR 741, Lebanon, OH 45036-9518, Tel: 800-831-2142 or 513-932-3030, Fax: 513-932-7651			
District Geotechnical Engineer: Joe Smithson (513) 932-3030 Joe.Smithson@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Butler	Jim Armstrong	513-933-6719	Jim.Armstrong@dot.state.oh.us
Clermont	Ron Kilburn	513-933-6660	Ron.Kilburn@dot.state.oh.us
Clinton	Chris Beam	513-933-6777	Chris.Beam@dot.state.oh.us
Hamilton	Abell Fuller	513-933-6120	Abnell.Fuller@dot.state.oh.us
Greene	Terry Gill	513-933-6160	Terry.Gill@dot.state.oh.us
Preble	Bill Rigsby	513-933-6140	Bill.Rigsby@dot.state.oh.us
Warren	Mike Brown	513-933-6740	Mike.Brown@dot.state.oh.us

District 9: 650 Eastern Ave. PO Box 467, Chillicothe, OH 45601, Tel: 740-773-2691, Fax: 740-775-4889			
District Geotechnical Engineer: Chad Mitten (740)774-8978 Chad.Mitten@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Adams	Bob Osman	937-544-3131	Bob.Osman@dot.state.oh.us
Brown	Barry Daniels	937-378-6709	Barry.Daniels@dot.state.oh.us
Highland	Dan Nartker	937-393-0229	Daniel.Nartker@dot.state.oh.us
Jackson	Mike Kinnison	740-286-2504	Mike.Kinnison@dot.state.oh.us
Lawrence	Cecil Townsend	740-532-1636	Cecil.Townsend@dot.state.oh.us
Pike	Steve Jenkins	740-289-2650	Steve.Jenkins@dot.state.oh.us
Ross	Aaron Mitten	740-773-3191	Aaron.Mitten@dot.state.oh.us
Scioto	Troy Huff	740-259-2071	Troy.Huff@dot.state.oh.us

District 10 338 Muskingum Dr. PO Box 658, Marietta, OH 45750, Tel: 800-845-0226 or 740-373-0212 Fax: 740-373-7317			
District Geotechnical Engineer: Jason Wise (740)737-0212 x404 Jason.Wise@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Athens	Larry Burnette	740-593-7933	Larry.Burnette@dot.state.oh.us
Gallia	Jeff Phillips	740-446-1553	Jeff.Phillips@dot.state.oh.us
Hocking	John Pallo	740-385-2629	John.Pallo@dot.state.oh.us
Meigs	Brett Jones	740-992-2501	Brett.Jones@dot.state.oh.us
Monroe	Jeff Schenerlein	740-472-0921	Jeff.Schenerlein@dot.state.oh.us
Morgan	Pat Tornes	740-962-4665	Pat.Tornes@dot.state.oh.us
Noble	Jim Wharton	740-732-4504	Jim.Wharton@dot.state.oh.us
Vinton	Dana Peters	740-596-5532	Dana.Peters@dot.state.oh.us
Washington	Doug Clifton	740-373-0536	Doug.Clifton@dot.state.oh.us

District 11: 2201 Reiser Ave., New Philadelphia, OH 44663, Tel: 330-339-6633, Fax: 330-308-3942			
District Geotechnical Engineer: Jim Graham (330)308-3980 Jim.Graham@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Belmont	Dave Schafer	740-782-1641	Dave.Schafer@dot.state.oh.us
Carroll	Barry McCarty	330-627-4660	Barry.Mccarty@dot.state.oh.us
Columbiana	Barry Miner	330-424-7253	Barry.Miner@dot.state.oh.us
Harrison	Christopher Wood	740-942-4201	Christopher.Wood@dot.state.oh.us
Holmes	Randy Ramsey	330-674-1906	Randy.Ramsey@dot.state.oh.us
Jefferson	Thomas Corey	740-264-1722	Thomas.Corey@dot.state.oh.us
Tuscarawas	Jeff Bonomo	330-339-5050	Jeff.Bonomo@dot.state.oh.us

District 12: 5500 Transportation Blvd. Garfield Heights, OH 44125-5396, Tel: 866-737-8112 or 216-581-2100, Fax: 216-587-1730			
District Geotechnical Engineer: James Marszal (216)584-2128 James.Marszal@dot.state.oh.us			
County	County Manager	Phone Number	e-mail address
Cuyahoga			
Geauga			
Lake			

The ODOT District Locals and contact information can be obtained at:
http://www.dot.state.oh.us/dist.asp

Digital Photologs can be obtained at:
http://tscww012.dot.state.oh.us/OTS_Intranet/digilog/
OR
Contact Technical Services for ODOT Mainframe Access or DVD's at:
http://www.dot.state.oh.us/techservsite/Contact_Info.htm

Digital orthophoto quad sheets can be obtained at:
http://www.dot.state.oh.us/aerial/Glossary.asp?Item=Orthophotos
http://seamless.usgs.gov/
http://topomaps.usgs.gov/drg/

Aerial photographs including stereopairs can be obtained at:
http://www.dot.state.oh.us/aerial/

Roadway Type
http://www.dot.state.oh.us/planning/functional%20class/FunctionalClassmaps.htm

ADT, AVT, ATT
http://www.dot.state.oh.us/techservsite/availpro/Traffic_Survey/TSR_Report/default.htm

Roadway width, median
http://www.dot.state.oh.us/techservsite/availpro/Road_%20Infor/SLD/default.htm

AADT
http://www.dot.state.oh.us/techservsite/availpro/Traffic_Survey/Ann_Adj_Fctrs/Adj_Fctr04.PDF

Median Type and width, surface width
http://www.dot.state.oh.us/techservsite/availpro/Road_%20Infor/State_RI06/statemap.htm

General geological data can be contacted at:
http://www.dnr.state.oh.us/geosurvey/default.htm

Abandoned Mine Locator
http://www.dnr.state.oh.us/website/geosurvey/omsiua/viewer.htm

Active Mineral Industries
http://www.dnr.state.oh.us/geosurvey/oimimap/oimimap.htm

SLM for each state and interstate route can be obtained at:
http://www.dot.state.oh.us/techservsite/availpro/Road_%20Infor/SLD/default.htm.

Precipitation Data Information can be collected at the following sites:
ODNR:
http://www.dnr.ohio.gov/water/waterinv/precip_frequency.htm

NOAA:
http://www.ncdc.noaa.gov/oa/climate/climatedata.html