OPEN-FILE REPORT O-07-06

COMPILED BY WILLIAM J. BURNS AND YUMEI WANG

2007 LANDSLIDE SYMPOSIUM PROCEEDINGS & FIELD TRIP GUIDE

NEW TOOLS AND TECHNIQUES FOR DEVELOPING REGIONAL HAZARD MAPS AND FUTURE RISK MANAGEMENT PRACTICES

SPONSORED BY DOGAMI/USGS/ASCE/AEG

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

State of Oregon
Department of Geology and Mineral Industries
Vicki S. McConnell, State Geologist

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NEW TOOLS AND TECHNIQUES FOR DEVELOPING REGIONAL HAZARD MAPS AND FUTURE RISK MANAGEMENT PRACTICES

Compiled by
William J. Burns[1] and Yumei Wang[1]

2007

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DISCLAIMER
Maps in this publication depict relative landslide hazard zones on the basis of limited data as described further in the text. The maps cannot serve as a substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from those shown on the maps.

Cover page photos: (top) 2007 Landslide Symposium field trip participants view Johnson Creek landslide scarp. (bottom) 2007 Landslide Symposium field trip leaders, Scott Burns, Jason Hinkle, and William Burns, and participants look at landslide features on the trip to the coast.

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1.0 SUMMARY

On April 26–28, 2007, a symposium and two field trips focusing on landslides in Oregon were sponsored by the Oregon Department of Geology and Mineral Industries (DOGAMI), the U.S. Geological Survey (USGS), the American Society of Civil Engineers (ASCE), and the Association of Engineering Geologists (AEG). The symposium and field trips provided a forum for the exchange of landslide information among geotechnical practitioners, including engineering geologists and engineers from the private sector, government, and academia. Below is an outline of activities that took place over the three days.

Thursday April 26, 2007
8:00 AM to 5:00 PM

Main Program
16 technical talks

Morning focus: DOGAMI/USGS partnership and research; state of practice/art methods

Afternoon focus: "Landslide mapping, FHWA practices, reducing losses and managing risk", and Keynote: "How we can improve landslide practice and management in Oregon: a practitioner's perspective."

5:30 PM to 7:30 PM
Post Symposium Gathering and Poster Session
16 technical posters

Friday April 27, 2007
Field Trip day 1 —
Landslides in and around Oregon City, Oregon

Saturday April 28, 2007
Field Trip day 2 —
Coastal Landslides in Lincoln County, Oregon

The symposium and field trips introduced current research projects by DOGAMI and USGS, including those involving LIDAR, and future map products. It also presented some risk reduction information and possible future risk management practices. Some of the goals were to:

- Provide a forum for the exchange of landslide information between government agencies, academia, and private industry
- Review current DOGAMI/USGS partnership and project directions
- Promote risk management
- Form preliminary statewide landslide advisory group (for reducing damage from landslides)
- Improve state-of-practice regional landslide analyzes and assessments
- Obtain ideas for 2009 Geological Society of America conference in Portland

2.0 INTRODUCTION

Geologic hazards pose a significant threat in many parts of Oregon. Landslides are a major geologic hazard in Oregon, and the impact of landslides on property and life safety for Oregonians will only increase as population increases and development advances into more landslide prone urban peripheries. For a typical year, an estimated $10 million is spent on landslide losses in Oregon (*Landslide loss estimation pilot project in Oregon*, Oregon Department of Geology and Mineral Industries Open-File Report O-02-05, 2002, by Y. Wang, R. D. Summers, and R. J. Hofmeister, 23 p.). In years of heavy rainfall, losses can increase by an order of magnitude. Most of Oregon's landslide damage has been associated with years when heavier than normal rainfall resulted in landslide losses which exceed $100 million in direct damage (such as the February 1996 event—see *February 1996 flooding, landslides, and stream erosion in the State of Oregon*, Federal Emergency Management Agency (FEMA), Region 10, Interagency Hazard Mitigation Team Report DR-1099-OR, 87 p.).

A partnership between the DOGAMI Geohazard Section and the USGS Landslide Group has been developed over the past several years and is intended to extend for several more years. The primary goal of this partnership is to perform collaborative research to increase the understanding of the landslide hazard in Oregon and transfer of technical knowledge from the USGS to DOGAMI. In 2006, a landslide forum was held, which focused on the introduction of the USGS-DOGAMI partnership and planning (Figure 1.0-1). One of the goals of the symposium was to share some of this research and technical knowledge with other government agencies, private consultants, and academics in Oregon.

In order to accomplish these goals, on April 26–28, 2007, a symposium and field trips focusing on landslides in Oregon were held. The symposium and field trips provided a forum for the exchange of landslide information among geotechnical practitioners, including engineering geologists and engineers from the private sector, government, and academia. Some of the other goals were to:

- Provide a forum for the exchange of landslide information between government agencies, academia, and private industry
- Review the current DOGAMI/USGS partnership and project directions
- Promote risk management
- Form a preliminary statewide landslide advisory group (for reducing damage from landslides)
- Improve state-of-practice regional landslide analyzes and assessments
- Obtain ideas for 2009 Geological Society of America conference in Portland

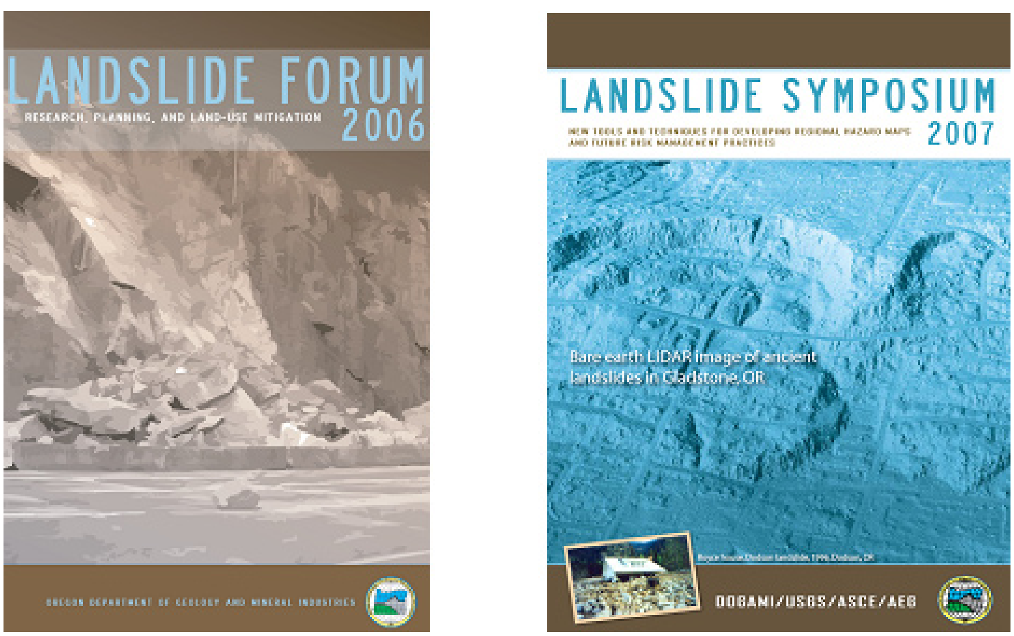

Figure 1. 2006 Landslide Forum and 2007 Landslide Symposium posters.

3.0 PLANNING COMMITTEE AND SPONSORS

A planning committee was formed and met several times to discuss and organize the symposium. The following is an alphabetical list of planning committee members.

- Jeremy Appt
- Roland Brady, lead on poster session
- William Burns, lead co-organizer and field trip co-organizer
- Scott Burns, lead on field trips
- Jason Butler-Brown, lead on securing sponsors
- Jeff Coe
- Steve Dickenson
- Gerry Heslin
- Jason Hinkle, field trip co-organizer
- Brad Hupy
- John Jenkins, lead on post symposium venue
- Steve Palmer
- Tova Peltz, lead on continuing education units
- Gary Peterson
- Marvin Pyles
- David Scofield
- John Seward
- James Roddey, planning and logistics
- Yumei Wang, lead co-organizer
- Michael Zimmerman

The symposium and field trip primary sponsors were:

- Oregon Department of Geology and Mineral Industries (DOGAMI)
- U.S. Geological Survey (USGS grant award 07HQGR0100)
- American Society of Civil Engineers (ASCE)
- Council on Disaster Risk Management (CDRM)
- American Society of Civil Engineers (ASCE) Oregon section's geotechnical group (GG)
- Association of Engineering Geologists (AEG) Oregon chapter

Field trips were co-organized by the AEG Oregon chapter, Portland State University (PSU), and DOGAMI, with co-sponsors USGS, ASCE CDRM, and ASCE GG.

The post symposium gathering and poster session was sponsored by two different levels:

Gold Level Sponsors

- Boart-Longyear
- GeoCon Northwest, Inc.
- Geotech Explorations / Boart-Longyear
- PBS Engineering + Environmental
- Pro Landscape, Inc.
- Subsurface Technologies

Silver Level Sponsors

- AMEC Earth and Environmental
- BCG Geotech
- Foster Gambee
- GeoDesign
- GRI Geotechnical and Environmental Consultants
- Landslide Technologies
- PSI, Inc.
- Shannon &Wilson

Contributors from USGS and DOGAMI management included the following:

- Peter Lyttle, USGS Landslide Hazard Program Coordinator
- Paula Gori, USGS Landslide Hazard Program Assistant Coordinator
- Vicki McConnell, DOGAMI Director
- Don Lewis, DOGAMI Assistant Director
- DOGAMI staff assistance:: Geneva Beck, Carol DuVernois, Marina Drazba, Don Haines, J. Charles Kirby, Tove Larsen, Lina Ma, Ian Madin, Clark Niewendorp, James Roddey, Mark Sanchez, Deb Schueller, Alva Schneff, and Rudie Watzig,

Special thanks to Carol DuVernois and James Roddey, DOGAMI, for their planning, organizing, and logistical assistance.

4.0 SYMPOSIUM MAIN PROGRAM

On Thursday April 26, 2007, the main program was held from 8 AM to 5 PM (Figure 4.0-1). Sixteen technical talks comprised the morning and afternoon sessions. Yumei Wang, DOGAMI, Peter Lyttle, USGS Landslide Hazard Program, opened the symposium with welcoming comments.

Morning Focus: DOGAMI-USGS partnership, state of practice/art methods, DOGAMI-USGS research, including bringing USGS Seattle-based research findings to Western Oregon. Moderator: Tova Peltz (GRI)

Lunch and Raffle: Just prior to lunch, a raffle was held and three publications were raffled:

- *Map of Landslide Geomorphology of Oregon City, Oregon and Vicinity Interpreted from LIDAR Imagery and Aerial Photographs* (DOGAMI Open-File Report O-06-27), Madin and Burns, 2006. (donated by DOGAMI)
- *Landslides in Practice,* Cornforth, 2005 (donated by Cornforth Consultants)

Afternoon focus: "Landslide mapping in Portland, reducing losses and managing risk, what's next." Moderator: Yumei Wang (DOGAMI)

Biographies, abstracts, and slides of Microsoft PowerPoint presentations by the main program speakers are provided on the following pages. Note that some biographies and PowerPoint presentations were not approved and/or permitted for print and therefore are not included in this report. Approved/permitted presentations are also available for download from the DOGAMI website at www.oregongeology.org.

NOTE: Due to possible copyright issues, all PowerPoint presentation slides have been removed from this online version.

Figure 4.0-1. (top left) Peter Lyttle, U.S. Geological Survey, welcomes everyone and talks about the DOGAMI-USGS partnership. (top right) Participants and some of the displays. (bottom left) Yumei Wang, DOGAMI, presents Derek Cornforth with the keynote gift. (bottom right) Ian Madin, DOGAMI Chief Scientist, talks about new applications using LIDAR.

4.1. DOGAMI/USGS partnership on landslide risk reduction: DOGAMI'S landslide efforts

Yumei Wang, Oregon Department of Geology and Mineral Industries, 800 NE Oregon Street, Portland, OR 97232, Yumei.Wang@dogami.state.or.us

BIOGRAPHY: Yumei Wang's expertise is in science, engineering, and technology policy; natural-hazard analyses and risk reduction, and sustainable engineering practices. Since 1994, Ms. Wang has worked as a geotechnical engineer at the Oregon Department of Geology and Mineral Industries (DOGAMI) where she leads the Geohazards Section, and focuses on lowering risks from earthquakes and landslides. Ms. Wang has been influential in enacting public policies in her expertise areas, including in 2000, co-developing earthquake safety laws as chairperson of the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) that was reenacted in 2001. Later, in 2004, she led a diverse task force that culminated into complementary earthquake safety laws in August 2005, which focus on statewide earthquake risk management. She co-led an engineering investigation on the 2004 Sumatra earthquake and tsunami and participated in two subsequent BBC science documentaries. She is a commentator in "Megaquake," which has aired on the Discovery Channel (2005), and "Earthquake Alert" that has aired on the National Geographic channel (2006). In 2007, she was appointed as one of 15 national advisors to the National Earthquake Hazards Reduction Program. In 2006, she was awarded Government Engineer of the Year by the American Society of Civil Engineers (ASCE) Oregon Section. In 2000, Wang served a one-year term as a Congressional Fellow in the U.S. Senate in Washington DC. The ASCE-funded fellowship was hosted by the American Association for the Advancement of Science (AAAS). She has over three-dozen technical publications, serves on local and national advisory commissions and committees, and is a frequent speaker at events. She is adjunct faculty at the Portland State University Civil and Environmental Engineering Department. Before coming to Portland in 1994, she had a geotechnical consulting practice in Oakland, California. She obtained a master's degree in Civil Engineering at the University of California in Berkeley in 1988 and a bachelor's degree in Geological Sciences at the University of California at Santa Barbara in 1985.

Oregon is vulnerable to many geologic hazards, including flooding, landslides, and coastal erosion caused by heavy winter storms every year. Landslides cause tens-to-hundreds of millions of dollars of damage per year in Oregon, and current development practices and continued growth will only contribute to higher losses in the future. DOGAMI's landslide program, including its establishment, goals and selected publications surrounding various landslide issues is discussed. In 2005, the U.S. Geological Survey (USGS) funded DOGAMI to collaborate on the multi-year Western Oregon Landslide Project. This partnership between DOGAMI and the USGS has provided DOGAMI a major opportunity to make significant improvements to its landslide program. A brief description on how the Western Oregon Landslide Project was initiated is given. Last, an overview of DOGAMI's efforts as part of the DOGAMI-USGS partnership is provided.

DOGAMI Landslide Program

Oregon Department of Geology and Mineral Industries (DOGAMI) started the DOGAMI Landslide Program in 1999 as a result 1996-1997 storm damage and state directives. The program goal is to conduct targeted landslide risk reduction through landslide risk management as a means to protect communities from unnecessary danger and property damage. Oregon's landslide risk management strategy includes five parts: 1) engaging stakeholders, 2) landslide hazard identification, 3) risk assessment, 4) risk management through prioritization of risks, and 5) mitigation. Figure 4.1-1 lists these five parts with examples of actions for each part—forming an "Oregon Landslide Workgroup" under "engaging stakeholders" is one example. It also depicts how these five parts are being integrated. Some of the activities of the program include: increasing awareness through education, brochures, field trips, existing landslide and landslide hazard maps; assisting local jurisdictions with technical expertise on sustainable policies and ordinances; and, supporting a statewide landslide warning system. For many years, the activities were sporadic and minimal due to funding limitations.

1996-1997 Storms and State Directives. Severe storms in Oregon in 1996 and 1997 triggered on the order of 10,000 landslides and caused over $100 million in damage (DOGAMI Publication SP-34, Hofmeister, 2000; O-02-05, Wang and others, 2002). The November 1996 storm resulted in five fatalities (refer to government report on www.oregon.gov/LCD/HAZ/docs/landslides/sb12body.PDF). In response to these devastating storms, the Oregon Legislature passed Senate Bill (SB) 1211 (1997) and later SB 12 (1999) as a means to reduce future landslide losses. This legislation resulted in Oregon Revised Statute (ORS) 195.250-275, which requires selected state agencies and other responsible parties to work together to reduce landslide risks. Furthermore, it requires DOGAMI to issue "Further Review Area" (FRA) maps which are to indicate areas that are potentially susceptible to rapidly moving landslides, such as debris flows. Oregon Administrative Rule 632-007-0020, enacted in 2003, stipulates how DOGAMI is to issue these FRA maps.

Figure 4.1-1. The five parts of Oregon's Landslide Risk Management Strategy

By late 1999, DOGAMI began to map debris flow hazards throughout western Oregon in response to these state directives. In 2002, DOGAMI, in partnership with the Oregon Department of Forestry and the Department of Land Conservation and Development, issued preliminary FRA maps (DOGAMI publication IMS 22, Hofmeister and others, 2002). The IMS 22 product includes digital maps that identify potentially hazardous zones and can be used by local communities to screen new development and mandate site-specific studies in potentially high risk and life-threatening areas. Several jurisdictions have voluntarily adopted IMS 22 in their local ordinances, such as the city of Salem and Marion County. Official FRA maps will be forthcoming as funds become available, and as the DOGAMI and ODF develop acceptable FRA mapping techniques. Pilot studies on FRA mapping techniques involve using light detection and ranging data, commonly referred to as LiDAR.

As a result of the 1996-97 storms, DOGAMI increased its effort on promoting landslide awareness, identifying landslide hazards and promoting risk reduction. Below are a few examples of selected efforts and related publications (which are referenced using the DOGAMI publication number).

DOGAMI developed an inventory of landslides that were triggered from the 1996-97 storms as well as estimated the direct losses from the storms.

- SP-34. Slope Failures in OR—GIS Inventory for Three 1996/97 Storm Events, by R.J. Hofmeister, 2000, 20 p. & CD.
- O-02-05, Wang, Y., Summers, R.D., and Hofmeister, J., 2002, Landslide losses in Oregon, 46 pp.
-

DOGAMI worked with local governments and others to improve geotechnical reports and adopting landslide risk reduction ordinances.

- O-00-04. Guidelines for engineering geologic reports & site-specific seismic hazards reports, developed & adopted by OR Bd. of Geologist Examiners, 2000, 8 p.
- SP-31. Mitigating geologic hazards in OR: A technical reference manual, by J.D. Beaulieu & D.L. Olmstead, 2000, 60 p.
-

DOGAMI improved mapping methods for identification of earthquake-triggered landslide hazards, developed landslide hazard maps and mapped existing landslides.

- SP-30. EQ-induced slope instability: Methodology of relative hazard mapping, W. portion of Salem Hills, Marion Co., OR, by R.J. Hofmeister, Y. Wang & D.K. Keefer, 2000, 73 p.
- IMS-17 and IMS-18. EQ-induced slope instability: Relative hazard map, W. portion of Salem Hills, Marion Co., OR, R.J. Hofmeister, Y. Wang & D.K. Keefer, 2000, and E portion of Eola Hills, Polk Co., by R.J. Hofmeister and Y. Wang, 2000, 1:24,000.
- IMS-5 and IMS-6. Water-induced landslide hazards, Eola Hills and Salem Hills, OR, by A. Harvey & G. Peterson, 1998, 1:24,000.
- O-01-05. Prelim. EQ hazard & risk assessment & water-induced landslide hazard in Benton Co., OR, by Z. Wang, G.B. Graham & I.P. Madin.
- O-03-9 and O-03-10. Earthquake and Landslide Hazard maps in Clackamas County, Oregon, by R. J. Hofmeister, C.S. Hasenberg, I.P. Madin & Y. Wang 2003 paper map and CD.

In addition, DOGAMI addresses various landslide-related issues as special needs arise, such as:

- Landslide warning press releases in coordination with the Oregon Department of Forestry, Oregon Emergency Management, and Oregon Department of Transportation (ODOT). These press releases were issued to warn the public of rapidly moving landslide hazards and are a result of the directives from the 1996-97 storms.
- O-04-05. Geotechnical Investigation Johnson Creek Landslide, Lincoln County, Oregon, by Landslide Technology, 115 p., 2004 CD only. This originated as a ODOT-funded DOGAMI research project along U.S. Highway 101, and recently expanded to include USGS collaboration.
- O-00-03. Memo: Cape Cove landslide, findings from field visit, February 10 & March 10, 2000, by G. R. Priest, 2000, 14 p. This was an emergency situation with the state's request for DOGAMI's technical assistance.
- O-04-08. Geologic Hazard Study for the Columbia River Transportation Corridor, by Y. Wang & A. Chaker, 2004 CD only. This included a preliminary assessment of the economic importance of this critically important multimodal transportation corridor.
- Oregon City LiDAR landslide map O-06-27. Map of Landslide Geomorphology of Oregon City, Oregon, and vicinity interpreted from LiDAR Imagery and Aerial photographs, Clackamas County, OR, by I.P. Madin & W.J. Burns, 2006, CD. This map includes existing landslides and is a product of the DOGAMI-USGS partnership on the Western Oregon Landslide Project.

Although progress had been made on several fronts, which is supported by the above publications, much needed improvements are necessary in order to curb future losses. In late 2004, DOGAMI and the USGS began a partnership which led to a marked increase in DOGAMI's efforts on landslide issues. This will be discussed in the next sections "Western Oregon Landslide Project" and "Current DOGAMI-USGS Efforts."

Western Oregon Landslide Project

Since 1995, DOGAMI has been collaborating with the USGS to improve the understanding of earthquake triggered landslide hazards. In 2001, the USGS funded DOGAMI to collect information on landslide losses. These collaborative efforts led to DOGAMI hosting a National Academies meeting in Portland Oregon in late 2001. At that time, the National Research Council (NRC), which is part of the National Academies, was conducting a study to determine how the USGS could improve its landslide hazards program. DOGAMI explained that state geologic surveys need more support from the USGS in order to better understand and manage landslide risk, and stronger partnerships are necessary. The NRC agreed that more partnerships are needed for effective risk reduction. In 2004, they published a landmark report with their complete findings (National Research Council, 2004)

Armed with the NRC's findings, DOGAMI and the USGS sought ways to improve its partnership. It was agreed that a stronger partnership would include collaborative research projects that would benefit the landslide professional community and geologic state surveys-at-large. DOGAMI supported USGS efforts to increase funding for the USGS Landslide Hazard Program in fiscal year 2005 (FY05). When Congress increased the FY05 funding to the USGS's Landslide Hazard Program, the USGS began to fund DOGAMI for a multi-year project, called the "Western Oregon Landslide Project". A portion of DOGAMI's proposal to the USGS of the "Western Oregon Landslide Project" is shown in Figure 4.1-2. Since this time, DOGAMI and the USGS have developed a strong collaborative partnership on a number of research projects.

Current DOGAMI-USGS Efforts

As part of the Western Oregon Landslide Project, DOGAMI is currently collaborating with the USGS on several projects and efforts. Both DOGAMI and the USGS also have agency-specific projects and efforts in which each agency has a lead role. For these projects, there is a varying amount of collaboration. In general, the USGS research projects are largely aimed to benefit DOGAMI's goals and, in turn, the DOGAMI projects are largely aimed to reduce risk to the public. As an example, one of the USGS projects is to better characterize debris flow entrainment behavior. Modeling of entrainment is needed for the forthcoming DOGAMI FRA maps. For a summary of the current USGS efforts, please refer directly to the USGS Landslide Hazard Program.

The current projects that DOGAMI has taken the lead role and have substantial USGS support focus on:

- Educating and increasing awareness, including:
    - DOGAMI and USGS co-organized the April 26-28, 2007 symposium with co-sponsorship from the American Society of Civil Engineers and the Association of Engineering Geologists. DOGAMI and USGS researchers are sharing information on current Western Oregon Landslide Project research and are facilitating an exchange of technological advancements with landslide experts including geotechnical consultants.
    - DOGAMI organized a landslide forum in 2006 that was a 10-yr commemoration of the 1996-97 storms. USGS personnel provided talks at this forum, which included a broad audience.
- Engaging stakeholders. DOGAMI is forming the Oregon Landslide Workgroup (OLW), which will include a broad spectrum of stakeholders, including technical landslide experts. The primary goals are to promote collaborative efforts to reduce damage and losses with both private and public sector partners. The USGS, geotechnical consultants and others will be represented on OLW.
- Evaluating mapping techniques, including multiple types of remote sensing data
- Improving mapping techniques using LiDAR
- Developing risk management strategies

Western Oregon Landslide Project

"The National Landslide Hazard Mitigation Program must play a vital role in evaluating methods, setting standards and advancing procedures and guidelines for landslide hazard maps and assessments."

Taken from "**National Research Council's** Partnerships for Reducing Landslide Risk: Assessment of the National Landslide Hazards Mitigation Strategy" (2004)

The NRC recently recommended "that the USGS—in close partnership with other relevant agencies—produce the implementation and management plans that will provide the practical basis for an effective national strategy that can be applied at the local level." In accordance with this and other NRC recommendations, the Oregon Department of Geology and Mineral Industries (DOGAMI) proposes that the USGS launch its first concentrated landslide efforts in a collaborative "Western Oregon Landslide Project." The proposed Project Scope, Funding and Schedule, Location and Background, Available Data, Contacts and Potential Partners are outlined.

Project Scope: Areas of Comprehensive Study

- Improve field and aerial mapping techniques, especially beneath densely forested areas
- Advance characterization of landslide types (life threatening, property damage, reactivation of large slide complexes, hydrogeologic characterization, forest lands, storm-induced, earthquake-triggered, fire-related, weather-related and future climate trends)
- Integrate remote sensing, climatological and hydrological analyses into landslide studies
- Conduct state of the art analytical research and improve procedures; piggyback on Johnson Creek Landslide Research Project (DOGAMI has a secure budget of $500,000)
- Advance landslide monitoring and warning systems by upgrading existing instrumented landslides
- Improve hazard identification and hazard mapping
- Research active soil creep rates into salmon bearing streams and sustainability of spawning beds
- Advance identification of landslide-induced turbidity events into rivers and public water supply
- Quantify loss, investigative, and mitigation costs and integrate into improved tracking and benefit-cost analyses
- Improve guidelines, standards, risk analyses, risk reduction, and mitigation
- Provide sound public policy options on risk and loss reduction
- Launch public education campaign
- Co-organize and co-sponsor advance landslide workshop in Fall 2005 (see attachment)

Figure 4.1-2. A portion of the "Western Oregon Landslide Project" proposal.

- Mapping existing landslides using LiDAR in the Portland Hills area
- Developing pilot landslide susceptibility and hazard maps using LiDAR, in Oregon City
- Developing a Statewide Landslide database, called "SLIDO" (statewide landslide information database of Oregon)

Future efforts may involve:

- Co-organizing landslide sessions at Geological Society of America (GSA) conference in Portland 2009 to further share information on DOGAMI and USGS research projects and facilitate an exchange in technological advancements with landslide experts including local geotechnical consultants
- Conducting technology transfer to cities and counties (e.g., understanding landslide triggers, hazard maps, policies, guidelines, ordinances)
- Sharing and exchanging technological knowledge with other state geology surveys (e.g., seek collaborative research, mapping with LiDAR, developing stakeholder workgroups, promoting risk reduction involving sustainable practices, creating web-based landslide databases)
- Producing risk assessment studies
- Establishing an interactive landslide website
- Improving the statewide landslide warning system (and possibly involve the National Weather Service)
- Conducting landslide mitigation projects

Since 1996-97, some landslide risk reduction progress has been made but clearly not enough to reduce future damage in a significant manner. Similar storms will trigger landslides and future damage and losses will continue to occur. As the population increases and assuming current land use and construction practices, losses are expected to increase both in developed areas and in the areas of new development. This includes vulnerable hill slopes, and near stream banks and ocean bluffs.

Increasingly, Oregon is employing practices geared toward minimizing geohazard-related disasters. For example, building of essential facilities requires site-specific seismic hazard studies to ensure that appropriate design and construction are employed (i.e., mandated by ORS 455.447). Also, construction of these facilities within mapped tsunami inundation zones is restricted (ORS 455.446). Landslide-, earthquake-, and tsunami- hazard maps can be integrated into local government comprehensive plans. DOGAMI has been assisting counties and cities with maps, risk studies and developing disaster recovery plans; however, a much stronger effort targeted towards landslide risk reduction is needed.

In order to effectively manage landslide risks, the geotechnical landslide community needs to become more proactive to help increase landslide awareness, landslide identification, hazard mapping in landslide prone areas, risk assessments, sustainable practices in risk reduction and mitigation efforts. The geotechnical landslide community needs to engage other stakeholders, including local government planners, building officials, realtors, decision makers and many others. Only then will there be a significant reduction in landslide risks to Oregonians.

4.2. Overview of the USGS landslide research in Oregon

Jeffrey A. Coe, jcoe@usgs.gov, Rex L. Baum, William L. Ellis, Jonathan W. Godt, Edwin L. Harp, Lynn M. Highland, Jonathan P. McKenna, and William H. Schulz, U.S. Geological Survey, Denver, Colorado, and Mark E. Reid, U.S. Geological Survey, Menlo Park, California

ABSTRACT: In late 2004, the Landslide Hazards Program of the USGS began a multi-year, collaborative research program on landslides in Oregon. Collaborating organizations include the Oregon Departments of Geology and Mineral Industries, Forestry, and Transportation; the US Forest Service and Bureau of Land Management, Portland State University, and the USGS Cascades Volcano Observatory.

Several collaborative research topics have been identified so far, most of which are in the early stages of data collection. These topics include (1) the study of sediment entrainment by rapidly moving landslides (i.e., debris flows), (2) an examination of how hillslope hydrology affects landslide occurrence and reactivation, and (3) landslide hazard assessments of selected urban areas and transportation corridors in western Oregon. Study areas include coastal, Coast Range, and inland settings.

The study of sediment entrainment will utilize detailed sediment budgets determined from field and photogrammetric measurements of natural channels, as well as from experiments at the USGS debris-flow flume near Eugene. The hydrologic studies can be further subdivided into research on (1) rainfall intensity and antecedent soil wetness for the occurrence of landslides and (2) the relationship between rainfall, pore-pressure rise, and movement of landslides. The hydrologic research relies on a combination of instrumental monitoring, laboratory experiments, numerical modeling, and statistical analysis. The hazard assessment work will utilize airborne LiDAR data acquired during the winter and spring of 2007 and will incorporate results from our other research.

Our collaborative research seeks to develop landslide-hazard information and hazard assessment tools that are applicable to Oregon and transferable to other areas of the United States to reduce the loss of life and damage caused by landslides.

4.3. State of practice and state of the art predictive tools and future direction

Stephen Dickenson, Associate Professor, Department of Civil, Construction, and Environmental Engineering, Oregon State University, 220 Owen Hall, Corvallis, OR 97331-3212, Stephen.dickenson@oregonstate.edu, and Jack Gordon, Department of Civil, Construction, and Environmental Engineering, Oregon State University

BIOGRAPHY: Stephan Dickenson has been active in geotechnical education, research, and consulting for almost 20 years. His areas of research specialization have focused primarily on ground failures and soil-structure interaction, with an emphasis on seismically-induced soil deformations. He has greatly enjoyed working with talented students and geo-professionals on a variety of slope stability projects including the performance of earth dams and native slopes during rapid drawdown conditions, stability of Columbia River levees during flood and earthquake events, landslide initiation in shallow forest slopes of the Oregon Coast Range, mechanics of slope deformation for coastal landslides, the initiation of submarine landslides, and the seismic performance of waterfront slopes and rubble mound breakwaters at ports. Dr. Dickenson and his students have employed a variety of numerical tools for modeling the static and dynamic performance of slopes. The results of this applied research have culminated in numerous technical papers, reports, and design guidelines for engineers. A notable example is the ASCE-TCLEE monograph "Instrumentation for Monitoring the Performance of Port and Coastal Infrastructure," which includes guidance on integrated instrumentation programs for monitoring of waterfront slopes during daily operations and extreme events. Dr. Dickenson served as co-author and editor of this book, which is scheduled for publication by ASCE during the summer of 2007.

ABSTRACT: The increasing adoption of reliability analysis and performance-based design concepts by organizations that manage and maintain transportation systems requires the quantification of uncertainties associated with current procedures for simulating the performance of earth structures, excavated slopes, and natural slopes. Specific applications include the development of LRFD methods for geotechnical aspects of surface transportation projects, and the application of performance-based design standards by numerous ports and agencies within the maritime transportation system. In both cases the predictive capabilities of widely-used models for evaluating slope stability and permanent ground deformations, the latter of which is more important in most cases involving soil-structure interaction, is widely varying. This presentation will focus on the application of numerical models for several projects in the Pacific Northwest and address the strengths and limitations of these tools.

Attempts to gauge the directions for applied research are made in response to perceived limitations of the current tools for simulating the field performance of slopes and earth structures. The presenter believes that while incremental enhancement to existing predictive tools can be made with improvements to constitutive models, 3D modeling procedures, and methods of visualization, more broad ranging improvements in slope modeling can be made by developing methods for the direct integration of field data (survey, geophysics, and geotechnical) into the numerical models. Advances in the use of surveying techniques such as LIDAR represent a worthwhile step in this direction. The development of methods for inputting geo-spatial data directly into 3D numerical models is a goal that has been expressed by several agencies. The latter portion of the presentation will address recommendations for integrated site characterization and monitoring with the goal of increasing the reliability of numerical modeling efforts.

4.4. Research investigation at the Johnson Creek landslide, a cooperative effort of private, state, and federal partners

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BIOGRAPHY: George R. Priest has a doctorate in geology from Oregon State University and has worked for the Oregon Department of Geology and Mineral Industries (DOGAMI) since 1979 managing at various times geothermal, earthquake and coastal research programs. Prior to the DOGAMI position he worked as an assistant professor at Portland State University and as an exploration geologist in the mineral and geothermal industries. He currently works part time in the DOGAMI Coastal Field Office in Newport.

ABSTRACT: The Johnson Creek Landslide is a large translational slide in seaward-dipping Astoria Formation that cuts the coastal bluff 6 km north of Newport, Oregon. The slide is the subject of a five-year research project started in the fall of 2002 and supported by the Oregon Department of Transportation (ODOT) Research Program, utilizing a Federal Highway Administration (FHWA) grant. The project aimed to find out what makes this and similar slides move and determine the most cost effective means of slowing or stopping movement. In 2002, a line of six borings with piezometers and inclinometers were completed east-west across the west-directed slide. Later, manual extensometers were installed in the inclinometer borings when slide movement made it impossible to conduct inclinometer surveys through the basal slip zone. A rain gauge was also installed. Rain gauge and piezometer data were recorded hourly by individual data loggers, but the extensometers were measured manually and at irregular intervals. Precise correlation of rainfall, pore pressure, and landslide movement was therefore not possible because the extensometer data was not recorded simultaneously with the other hourly data.

In November 2004, the U.S. Geological Survey (USGS) Landslide Hazards Program installed new data loggers at the site and connected electronic transducers to the extensometer cables so that all of the instruments could be recorded concurrently. The dataloggers were later equipped with cell-phone telemetry such that data could be collected remotely and at regular and more frequent intervals. In the fall of 2006, additional piezometers were installed to better characterize the hydrology of the slide. This paper summarizes data and interpretations compiled before the 2004 installation of USGS instruments and draws heavily from Priest and others (2006). The companion paper by Ellis and others (2007) summarizes the later data.

The central part of the landslide has a total displacement of ~28 m horizontal and 6 m vertical based on a balanced cross section. Offset of the Old Coast Highway since its abandonment in 1943 until 2004 is 3.35 0.6 m horizontal and 0.91 0.05 m vertical, indicating a mean movement rate of 5.4 1 cm/yr horizontal and ~1.5 0.08 cm/yr vertical. The slide plane dips seaward, cutting though weak siltstone units and generally deflecting along the top of more competent sandstone and zeolitized tuff beds. In the northern 85 percent of the slide, the slide plane reaches below sea level and then curves upward at the toe of the slide, rotating the westernmost slide block backward and overriding slide talus on the beach. In the southern 15 percent of the slide, the slide plane at the toe is relatively flat but still has a back-rotated slide block at the sea cliff. Six slide movements were recorded by inclinometers or extensometers between 2002 and spring of 2004, all correlating with intense rainfall events that trigger large increases in piezometric head.

The largest single slide movement so far observed occurred at the end of January 2003. At the latitude of the bore holes the slide moved a maximum of ~24 cm during this event. Only minor offset of the Highway 101 occurred at the northern slide margin during the January event, but a re-survey in April 2003 of marker pins emplaced October 2002 revealed that movement increased toward the southwest to values as large as ~130 cm at the toe of the slide. The slide at the southwest toe is flat rather than forming an east-inclined buttress as it does to the north.

Extensometer and resurvey data revealed that interior blocks within the slide moved at different rates during the January 2003 event, creating areas of extension, compression, and lateral movement within the slide. Later events in2003-2004 were all slow creeping movements each of <4 centimeters lateral (<1 cm vertical) that caused only minor highway damage. Marker

nails monitored around the slide perimeter and data from extensometers in the center of the slide during the slow movement event in March 2003 revealed that the slide moved approximately equal amounts in the center and at the north, south, and east margins.

These data indicate two distinctive styles of slide movement, slow and fast, with differential offset within the slide occurring principally during the fast movements. Only 1.5-2.7 m of head separates slow versus fast slide movement, so lowering of piezometric head by ~3 m would probably eliminate the most dangerous, highly damaging slide movements.

Piezometric elevation head in a sand pack 3-6 m below the slide plane is 4-6 m lower than head at the slide plane, illustrating the lack of hydraulic communication into relatively unfractured Astoria Formation at these depths below. Installation in 2006 of piezometers ~1 m below the slide plane allowed water pressure closer to the slide plane to be measured (see companion paper by Ellis and others, 2007, for results). Hourly piezometer data from above the slide plane reveals that spikes in pressure head occur progressively from east to west (down the hydraulic gradient) over a period of 30-44 hours in response to large rainfall events.

About 90 mm of hourly head rise occurs for each millimeter of hourly rainfall at a piezometer located in marine terrace sand near the head of the slide. Intergranular void space in the terrace sand is~40 percent, but the large rise in piezometric head (90 times the rainfall) can be accommodated only if the voids being filled comprise ~1.1 percent of the terrace sand. Field estimates of fracture voids in a structural position within the slide identical to this drill site were also ~1.1 percent. These data and field observations of the slide fracture system are consistent with pressure head "spikes" at the head of the slide being caused by downward percolation of rain into ~1 percent fractures spaced ~0.3m apart in the slide mass.

Since movement is triggered by rainfall and correlative water pressure increases, dewatering should be an effective re-mediation option. A significant amount of the water in the slide is from direct rainfall percolating into well-connected, fractures that appear to effectively drain groundwater after each rainfall event, so dewatering schemes should be efficient. Modeling of slide forces revealed that dewatering and slowing or eliminating toe erosion is important in achieving an increase in the factor of safety (Landslide Technology, 2004). Erosion has been monitored since May 2004 through ground based LIDAR surveys, one in October 2006 and another in April 2007. Other remediation options such as buttressing, tied-back shear pile wall, or draining the upper part of the slide with perforated pipes were also examined by Landslide Technology (2004) but were found to be too high in cost relative to maintenance of the road.

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4.5. Hydrogeologic investigations of the Johnson Creek landslide — Recent data, results and future plans

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ABSTRACT: Near real-time monitoring of the Johnson Creek landslide, located on the Oregon coast about 7 km north of Newport, has provided detailed data on the geohydrology and movement behavior of the landslide. In November, 2004, new data acquisition systems were installed to monitor existing instrumentation at the site and new instrumentation was added that allowed, for the first time, the simultaneous recording of precipitation, groundwater pressure, and landslide movement. In early 2006, cellular modems were incorporated into the data acquisition systems so that the data could be accessed remotely and more frequently. In November 2006, fourteen additional piezometers were installed in four new boreholes. Two vertical arrays of six piezometers each were installed using the grout-in method in two boreholes, and single piezometers were installed inside slotted casing near the bottom of two additional boreholes. The vertical-array piezometers were installed to determine groundwater pressures at different levels within, and just below, the landslide. The single-piezometer installations are for monitoring water levels and may be used for future hydrologic testing. Shallow soil-moisture sensors were also installed at two locations near the data acquisition systems on the landslide.

Between March 2003 and December 2005, a period that corresponded to unusually dry climatic conditions for the region, no measured movement of the landslide occurred. With the return of more characteristic rainfall conditions in the winter of 2005-2006, several episodes of landslide movement totaling a few centimeters occurred that yielded detailed data on the relationship between precipitation, groundwater pressure, and the onset of movement on time intervals as short as fifteen minutes. Although an approximate groundwater-pressure threshold for landslide movement could be identified for each movement episode, the threshold was not always consistent between episodes and sometimes decreased with later episodes. Additionally, the timing and variation of groundwater-pressure response to rainfall between three locations on the landslide was found to vary temporally, even when there was no measurable landslide movement. In the winter of 2006-2007, intense rainfall events again produced several episodes of minor movement. The groundwater pressure thresholds at which these movements occurred were similar to those of the previous year, but the peak groundwater pressures were less than recorded in the previous winter. The total landslide movement in 2006-2007 was also less than in 2005-2006, although the total yearly rainfall amounts were similar.

Data from the vertical piezometer arrays installed in late 2006 indicate approximately slide-base parallel groundwater flow and a very weak vertical hydraulic gradient, even across the basal shear zone. This observation contradicts previous observations in 2003 that indicated groundwater pressure beneath the basal shear was significantly less than groundwater pressures just above the shear zone. The vertical piezometer arrays also indicate that groundwater-pressure increases occur almost simultaneously at all elevations within the saturated zone following significant rainfall events, verifying previous interpretations of a high effective hydraulic conductivity within the landslide mass. Although the piezometers in the unsaturated zone detect some apparent surface infiltration, the timing of the pressure increases suggest that vertical infiltration is not the primary cause of groundwater pressure increases where the water table is relatively deep. Instead, infiltration near the head of the slide, where the water table is near the surface, appears to produce lateral pressure transmission and groundwater flow that is the primary cause of groundwater pressure increases throughout the landslide. The groundwater flow gradient is also observed to be greatest between two locations in the central part of the landslide where previous geologic interpretations indicated the possible presence of a near-vertical fault.

Based on recent observations of minor movement, the following sequence of events typically occurs. Significant rainfall causes a rapid increase of the groundwater pressure near the head of the landslide, which is followed by a progressively more gradual and delayed increase in groundwater pressures at locations farther down the landslide. This is consistent with earlier observations that groundwater pressure increases travel from east to west (headscarp toward the toe). When the basal

shear-zone groundwater pressure near the center of the landslide reaches an approximate threshold value, the landslide begins to creep almost uniformly. Groundwater pressures near the center of the landslide therefore seem to be the critical factor in controlling landslide movement.

Potential future work includes continued monitoring of the landslide and further interpretation and analysis of the data. Ideally a rapid landslide movement event could be captured in future monitoring efforts to determine groundwater pressures at the onset of rapid movement. Hydrologic testing may be conducted during the summer months using the existing boreholes and instrumentation to help quantify the hydrologic properties of the landslide mass. The potential influence of toe erosion on triggering landslide movement is also an area of needed future research, as is the degree of similarity between behavior of the Johnson Creek landslide and other coastal landslides.

4.6. Assessing regional instability using 3-D groundwater flow and 3-D slope-stability analyses

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ABSTRACT: Deep-seated, large landslides are driven by the interplay between gravitational stresses induced by complex topography and the three-dimensional (3-D) subsurface distribution of soil or rock shear strength. In addition, saturated groundwater flow patterns in hillslopes commonly produce 3-D distributions of pore-fluid pressure and locally elevated positive pore pressures are typically destabilizing. One-dimensional methods are inadequate to fully capture all of these effects. We have developed a 3-D slope-stability model, SCOOPS, that allows us to search a digital elevation model (DEM) and determine the least-stable areas. We use a 3-D version of Bishop's simplified limit-equilibrium analysis that incorporates 3-D arcuate potential failure surfaces, 3-D variations in material properties, 3-D pore-fluid pressures, and pseudo-static earthquake shaking effects to determine regions of minimum stability. By computing the stability of millions of potential failure surfaces, we can map the relative stability of all regions of a landscape. Moreover, unlike 1-D or 2-D analyses, our 3-D model can calculate the volume of potential failures, making it particularly useful for quantitative hazard analyses.

We successfully applied this approach to volcano edifices prone to massive flank collapse and to coastal bluff landslides affected by regional 3-D groundwater flow. For the Mount St. Helens volcano edifice with relatively uniform material properties, a 3-D analysis using topography alone provides a good post-failure assessment of the location and volume of the catastrophic 1980 collapse. At Mount Rainier volcano, both topography and a 3-D distribution of weaker, hydrothermally altered rocks are needed to adequately identify regions of past instability. In Seattle, Washington, we analyzed the 3-D slope stability of coastal bluffs using pore pressures from a 3-D groundwater flow model, constructed using MODFLOW, combined with 3-D heterogeneous strength properties. Groundwater flow patterns were calibrated using observed water level data. Here, groundwater flow is 3-D, resulting in a perched shallow groundwater table and groundwater convergence in coastal re-entrants; both effects create regions of lower stability. In all these cases, the 3-D effects of topography, strength, and pore pressure determine the location and size of potential landslides.

4.7. Modeling transient rainfall-induced pore pressure and slope instability

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ABSTRACT: Precipitation is one of the most common external factors in the occurrence of landslides and debris flows in western Oregon and throughout the U.S. Seasonal and long-term precipitation raise soil moisture and groundwater levels and thereby contribute to landslide occurrence or reactivation, but intense precipitation induces (or triggers) most shallow and many deep landslides. Predicting the timing of rainfall-induced landslide movement is an important aspect of landslide hazard assessment. Understanding and predicting the magnitude and timing of rainfall-induced pore pressure changes in landslides and steep slopes can be aided by real-time monitoring and by mathematical models that represent the physical processes of rainfall infiltration and pore-pressure transmission below the water table.

The transient effects of rainfall can be represented by vertical flow superimposed on the initial flow field. We modeled the infiltration process using a two-layer system that consists of an unsaturated zone above a saturated zone, and then implemented this model in a GIS framework. The model joins analytical solutions for transient, unsaturated, vertical infiltration above the water table to pressure-diffusion solutions for pressure changes below the water table. Pore pressure rise that occurs as water accumulates at the base of the unsaturated zone drives pressure diffusion below the initial water table. This scheme, though limited to simplified soil-water characteristics and moist initial conditions, greatly improves computational efficiency over numerical models in spatially distributed modeling applications. Pore pressures computed by these models are subsequently used in slope-stability computations to estimate the timing and locations of slope failures.

Preliminary model results indicate that the unsaturated layer attenuates and delays the rainfall-induced pore-pressure response at depth when compared with results of linear models for suction-saturated initial conditions, consistent with observations at instrumented hillsides. For shallow landslides, the attenuation reduces the area of false-positive predictions of slope instability in distributed application of the model over an area. Modeling indicates that initial wetness of the hillside materials affects the intensity and duration of rainfall required to induce shallow landslides and, consequently, the timing of their occurrence, a result that is consistent with observations of landslide occurrence in the Seattle area. Beyond aiding our understanding of the mechanisms and timing of shallow landslides, the model can be applied to forecasting landslide occurrence using real-time precipitation data and quantitative precipitation forecasts. The model also can be used for deterministic modeling of rainfall thresholds based on topography, mechanical and hydraulic properties of hillside materials, and rainfall patterns. Preliminary results also indicate that a similar modeling approach can explain the timing of rainfall-induced pore-pressure rise in certain deep landslides.

4.8. Comparison of mapping techniques in the Portland hills pilot study area

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BIOGRAPHY: William Burns is a registered Professional Geologist (RPG) and Certified Engineering Geologist (CEG) in Oregon and Washington. He spent roughly 10 years consulting as an engineering geologist in Oregon and Washington before his current position as Landslide Geotechnical Specialist at the Oregon Department of Geology and Mineral Industries (DOGAMI). His areas of expertise include engineering geology, geomorphology, landslide hazards mapping, and landslide hazard susceptibility.

ABSTRACT: Many parts of Oregon are highly susceptible to landslides, particularly in the portions of the state with moderate to steep slopes and a wet climate; landslides pose significant threats to people and infrastructure. As population growth continues to expand and development into steeper terrain occurs, greater losses from landslides are likely to result.

DOGAMI is working on collaborative landslide research with the US Geological Survey (USGS) to identify and understand landslides in Oregon. In order to begin the extensive undertaking of mapping the existing landslides throughout Oregon, a pilot project area was selected to compare remote sensing data/images for effectiveness. In order to compare the remote sensing datasets, six individual mappers with landslide mapping experience participated in the study. One mapper used all five datasets and the five other mappers each used one dataset a piece to located landslides and provide some basic information (Table 1). The remote sensing datasets compared include:

1. 30 m digital elevation model (DEM) from the Shuttle Radar Topography Mission,
2. 10 m DEM derived from the USGS topographic quadrangles,
3. photogrammatic and ground based 5 ft interval contour data set,
4. stereo aerial photographs from 1936 to 2000, and
5. light detection and ranging (LIDAR) with an average of 1 bare-earth data point per m^2 and 15 cm vertical accuracy.

Four preliminary key findings were:

1. the use of the LIDAR data resulted in the identification of between 3 to 200 times the number of landslides found with the other data sets,
2. the LIDAR data resulted in consistently finding small landslides,
3. the accuracy of the spatial extent of the landslides identified was greatly improved with the LIDAR data, and
4. the results varied with the individual mappers.

In general, the results strongly suggest the necessity of LIDAR data in order to merely locate many of the smaller landslides and to accurately locate all landslides. However, LIDAR alone is not enough data to produce a quantitative and qualitative landslide map. Several strategies were formed while working on this study which will aid in the development of a procedure for mapping landslides in Oregon and other places similar to Oregon including:

1. The compilation of all previously identified landslides from geologic maps, previous landslide studies, and other local sources is a critical starting point.
2. The mapper should have experience identifying all types and ages of landslides within the area being studied.
3. LIDAR data should be used to identify landslides and accurately locate the extents of the previously mapped landslides from step 1.
4. An orthophoto of similar age to the LIDAR data should be used in combination to minimize the identification of man-made cuts and fills as landslides.
5. The mapper should use at least one set of historic stereo-pair aerial photography to located landslides in the area being studied.
6. Non-spatial data should also be collected at the time of the mapping so that a comprehensive database can be formed
7. A comprehensive check of the data including some field checks should be developed and implemented.

These strategies are not alone enough to produce a quantitative and qualitative landslide map, but will aid in reaching this goal. DOGAMI is currently working on creating a landslide map of the study area and most of the Portland Hills using the above minimal requirements.

Table 1. Comparison of the general results of the landslides located using all data sets by a single mapper and each data set by individual mappers.

	Dataset	USGS 10 m DEM	City PDX Data	Stereo-Pair Aerial Photograph (1973)	LIDAR
Single Mapper	Time (hours)	6	10	21	37
	Smallest Landslide (m^2)	106,988	5,330	2,019	80
	Largest Landslide (m^2)	7,208,710	7,216,927	6,048,897	5,993,277
	Total Number of Landslides	**11**	**34**	**31**	**211**
Individual Mappers	Time (hours)	8	11	10	39
	Smallest Landslide (m^2)	34,693	1,694	8,111	28
	Largest Landslide (m^2)	309,185	3,050,746	959,016	92,640
	Total Number of Landslides	6	69	18	151
	Average Landslides / Hour	**1.2**	**4.9**	**1.6**	**4.8**

This project was funded through the USGS Landslide Hazard Program Partnership for the Western Oregon Landslide Project, with special thanks to Peter Lyttle, Paula Gori, and Rex Baum. The author is very grateful to the individual mappers who provided valuable information along with the contribution of many hours of time identifying landslides in the study area.

4.9. Use of landslide inventories for hazard and risk assessment, some recent examples from the western U.S.

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ABSTRACT: Regional landslide inventories are often the first product needed for landslide hazard and risk assessments because they provide ground truth data that can be used to calibrate and validate landslide prediction models. In the western U.S., numerous regional landslide inventories have been compiled, many by state agencies and the USGS. The type and quality of inventory data vary considerably as a function of the needs of the group, or groups, doing the compilation. The most useful inventories are usually those that were compiled with specific goals in mind before starting the inventory process, or those that were compiled or coordinated by single agencies, rather than by multiple agencies with different interests and agendas.

The spatial components of inventories are typically one-dimensional points or two-dimensional polygons. Point data have been used successfully in Seattle to estimate landslide initiation and probability, and in San Francisco to estimate future economic losses from landslides. Inventories composed of points are rarely useful for studies of landslide travel distances or volumes. Two-dimensional polygons offer an improvement over point data in that they account for both landslide initiation locations and total travel distances. The primary limitation of polygons is that the initiating landslide, transport paths, erosion and entrainment, and deposits are often lumped together, making studies of individual landslide components difficult. Two-dimensional data have been used successfully for landslide hazard studies in Colorado, California, Washington, and Oregon, but these studies often focus on landslide initiation, rather than travel distance or landslide volume.

Debris flows and deep-seated slides are the types of landslides that seem to cause most problems in Oregon. An extensive inventory of predominantly shallow slides and debris flows was compiled following extreme precipitation in Oregon in 1996 and 1997. This inventory was compiled by various government, academic, and private sources, and therefore covers a large area, but is somewhat inconsistent in the types of data that were recorded. This inventory formed a partial basis for the fast-moving landslide (debris flow) prediction maps that are currently available on the web. Currently, DOGAMI has a major ongoing effort to compile a state-wide, deep-seated landslide inventory map from existing geologic maps, as well as from newly acquired LiDAR data. Inventories of debris flows, however, are more difficult to compile (compared to inventories of deep-seated landslides) for several reasons. First, because debris flows tend to be relatively small, large-scale regional mapping is needed to adequately portray individual flows in the inventory. Second, an important feature of Oregon debris flows is that they often initiate as small slides that increase in volume (i.e., “bulk up”) by eroding and entraining large amounts of hillslope and/or channel debris. Therefore, a typical two-dimensional polygonal portrayal of debris flows does not adequately capture locations of erosion and entrainment that seem essential for hazard analyses and assessments. Third, because volume bulking is a typical characteristic of Oregon debris flows, inventories should attempt to quantify bulking in the form of a volumetric sediment budget, wherever possible.

One of the objectives of the recently started USGS work in Oregon is to gain a better understanding of debris flows that grow by erosion and entrainment. The existing landslide database in Oregon is difficult to use for entrainment studies because it generally doesn’t include volume estimates from erosion and entrainment locations. Our approach has 3 major components:

1. experimental entrainment studies at the USGS flume near Eugene;
2. two-dimensional inventory mapping which distinguishes between landslide source, erosion, transport, and deposition; and
3. three dimensional inventories (volumetric sediment budgets) of specific debris flows where erosion and entrainment have occurred.

The USGS is currently mapping a debris-flow inventory in the central Coast Range on both sides of Highway 38 between Reedsport and Elkton at a scale of 1:12,000. Mapping is being done using 1:12,000-scale, 1997 aerial photographs and a photogrammetric stereo plotter. The central Coast Range also provides an ideal location to attempt inventory and volumetric studies because:

1. debris flows occur frequently and therefore provide many potential study sites,

2. 1:12,000 scale aerial photos are flown about every 5 years and therefore provide an excellent data source for pre- and post-flow measurements of topographic profiles and Digital Elevation Models (using an analytical stereoplotter) for estimating sediment budgets, and
3. large parts of the area are industrial forest and are routinely clear cut, making it easy to see the ground in pre- and post-flow aerial photos.

The critical importance of clear cuts for sediment budget work was impressed upon us when we attempted to use pre- and post-event aerial photographs to determine a sediment budget for the 1996 Dodson debris flow in the Columbia River Gorge. We were able to measure a post-flow DEM of the entire debris flow area, but were not able to measure a pre-flow DEM because trees prevented us from seeing portions of the ground. We were able, however, to measure pre- and post-flow topographic profiles along the debris flow path. Preliminary results from a comparison of the two profiles indicate that about 50% of the total debris-flow volume was generated through entrainment of channel sediment at and near the head of the debris fan. Average incision at the head of the fan was about 4.5 m and the maximum incision was about 6 m. Thus far, observations made during inventory mapping near Reedsport indicate that entrainment locations for debris flows in the Coast Range are not at the heads of fans, but rather in steep channel reaches between slide source areas and fan heads. This presentation will include a short summary of preliminary results from the Gorge and Coast Range studies.

4.10. Estimating landslide susceptibility on a regional basis using LIDAR imagery and historical landslide records

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ABSTRACT: Landslides have posed a significant hazard in Seattle, Washington since at least the late 1800s, in part because many landslide features are obscured by dense vegetation. LIDAR-derived imagery can reveal these features and was used to map Seattle landslides and landslide-related landforms. Imagery used for mapping included shaded relief maps with various sun orientations and vertical exaggeration, slope maps, curvature maps, and topographic contour maps. Vertical exaggeration was not useful for mapping, and shaded relief maps were best used in tandem because features on a given relief map that are washed out or heavily shaded should be revealed on a relief map with a different sun orientation. Topographic contour maps were the most useful for identifying landslide features. LIDAR aided in the identification of 173 landslides and associated headscarps, which is nearly four times the number identified by previous mapping efforts that used field and photogrammetric methods. Most of the LIDAR-mapped landslides and head-scarps are complexes consisting of multiple smaller landslides. Mapped landslides are therefore referred to as the landslide deposit landform and mapped headscarps are referred to as the scarp landform. Many Seattle hillsides lack discernible landslide deposits but the LIDAR imagery shows evidence of landsliding; landslide deposits on these hillsides appear to have been eroded by wave action or streams. These hillsides were also mapped using LIDAR imagery and are referred to as the denuded slope landform. The area of Seattle outside of the landslide-related landforms is referred to as the glacial landform.

The locations of 93% of 1,308 cataloged historical landslides coincide with landslide-related landforms mapped using LIDAR imagery, and all of the historical landslides that occurred naturally were located on these landforms. The landslide-related landforms and historical landslides occur in locations where post-glacial erosion has been concentrated. Most of this erosion has been by wave action on Puget Sound and Lake Washington and stream incision. Manmade structures now prevent nearly all coastal erosion and stream incision, yet landslides are still common. The spatial distribution of historical landslides above former glacial-lake shorelines and along glacial melt-water channels suggests that thousands of years are required for Seattle hillsides to naturally stabilize in the absence of toe erosion.

The spatial distribution and size of historical landslides within landslide-related landforms mapped using LIDAR indicate that most of the landslides that created these landforms were prehistoric. Since both historical and prehistoric landslides are concentrated on the landslide-related landforms, future landslides will likely be concentrated on these landforms. Therefore, the spatial densities of historical landslides on the landforms (including the glacial landform) provide reasonable estimates of the relative susceptibilities of the landforms to future landslides. These densities and the mapped landform boundaries were used to create a relative landslide susceptibility map. Historical landslide characteristics and causes correlate with landform type so the susceptibility map provides relative susceptibilities to landslides with certain characteristics and causes. For example, the relative susceptibility of the scarp landform to shallow landslides is 3 to 237 times greater than on the other landforms, and the relative susceptibility of the glacial landform to human-caused landslides is 19 times greater than the susceptibility of this area to natural landslides. The map can be useful for regional planning and provides background data for site-specific investigations.

4.11. LIDAR and landslides — New technology supports a new landslide hazard mapping program

Ian P. Madin, Oregon Department of Geology and Mineral Industries, 800 NE Oregon Street, Portland, OR 97232, ian.madin@dogami.state.or.us

BIOGRAPHY: Ian Madin joined the Oregon Department of Geology and Mineral Industries in 1987 as the Seismic Hazard Geologist for the State of Oregon. In 1994 he transferred to the Baker City field office. After 4 years in Baker City making geologic maps, Mr. Madin returned to the Portland office of DOGAMI as the geologic mapping team leader, and in2004 became Chief Scientist for the agency. Ian's current research in the Portland Area includes geologic and geophysical investigations of potentially active faults, the development of detailed geologic models for improved hazard mapping, and the use of LIDAR data for mapping geology and geologic hazards.

ABSTRACT: Starting in 2004, high resolution bare-earth DEM's generated from high accuracy LIDAR data became available for parts of the Portland Metropolitan area as part of a USGS-funded program to search for active faults. These DEM's proved to be a powerful tool for mapping landslides in heavily urbanized and forested areas, and led DOGAMI to develop a new strategy to develop statewide landslide susceptibility maps. Sophisticated visualizations of the LIDAR DEM's make it possible to systematically map existing deep-seated and shallow landslides, and debris flow fans and deposits with unprecedented precision and completeness.

As a result of this powerful new tool, DOGAMI is planning to systematically prepare landslide susceptibility maps for the inhabited parts of Western Oregon. We will develop a complete digital map and database of existing landslides from published maps and reports and interpretation of LIDAR data as it becomes available. With the complete database in hand we will then prepare and calibrate susceptibility maps using a standard set of analytical models that are being developed with pilot projects in the Portland METRO area as part of the DOGAMI-USGS landslide program. A key to this program will be working with local governments to develop appropriate regulations and policies as we develop the maps.

Clearly, a critical element in this plan is to obtain LIDAR data for the inhabited areas of western Oregon. To date there are about 500 square miles of public domain LIDAR data available in the Portland Hills, Oregon City and along the lower Columbia River. A survey currently underway will add 2200 square miles in a swath centered on the Portland METRO area and extending from Hood River County to the coast at Tillamook. DOGAMI is working to develop consortia to collect data for a further 10,000 square miles to provide complete coverage of the inhabited areas of western Oregon.

4.12. Hydrologic conditions leading to shallow landslide occurrence on the Puget Sound bluffs near Edmonds, Washington

Jonathan Godt, Rex Baum, Jonathan McKenna, and Ed Harp, U.S. Geological Survey Geologic Hazards Team MS 966 Denver Federal Center, Denver, Colorado 80225, jgodt@usgs.gov

ABSTRACT: In 2001, the USGS, in cooperation with BNSF and its consultant, Shannon and Wilson Inc., installed a system of instruments at two sites near Everett and Edmonds, Washington to monitor the hydrologic response of hillside materials to rainfall. The instrumentation supports USGS research on rainfall-induced landslide initiation and the applicability of field monitoring for anticipating landslide activity. On January 14, 2006 a shallow translational landslide occurred at one instrumented site on an unstable coastal bluff near Edmonds, Washington. The landslide failed in colluvium on a 45 degree slope, about 24 long, 10 m wide, and less than 2 m thick. This landslide was one of several that occurred during the winter season of 2005-2006 along a section of the Burlington Northern Santa Fe Railway (BNSF) between Seattle and Everett, Washington. Shallow landslides are common in the deposits and colluvium that mantle many of the steep bluffs along the Puget Sound and are often triggered by heavy rainfall or rapidly-melting snow. The bluffs at the instrumented sites are underlain by subhorizontally bedded glacial and interglacial sediments, which include glacial outwash sand and glaciolacustrine silt deposits. The well-consolidated glacial deposits readily weather mechanically to form a loose, highly permeable, colluvium.

The instrument array at each site has varied over the monitoring period with equipment upgrades and replacements. The original systems consisted of rain gauges, water content reflectometers, soil temperature sensors, and shallow (12 m) open-tube piezometers. Positive head was never measured in the open-tube piezometers and they were thus abandoned. In 2003, two soil-water content profilers that provide measurements at eight depths to 2 m below the ground surface and two tensiometer nests of six instruments at similar depths were added to the Edmonds site. Data were collected and transmitted via commercial line-of-site networks and uploaded to the Internet, processed at USGS offices in Golden, CO, and finally made available in near real time on public USGS web pages.

Data collected during the five winter seasons the systems operated provide valuable insight into the hydrologic conditions associated with shallow landslide occurrence. Instrumental observations show that infiltration of rainwater was dominantly vertical and the pore-water response to rainfall at depths below about 1 m was highly dependent on initial soil-moisture conditions. For example, record 24-hour rainfall on initially dry soils (~12% soil-water content at 0.8 m depth) in the fall of 2003 led to a small increase in pressure head and water content which peaked nearly six days after the storm. However, once initial water contents reached about 20% (typically between late October and early December) the response at depth was much greater and occurred within hours of the beginning of rainfall. About 200 mm of rain was recorded at the Edmonds field site between late December 2005 and the middle of January 2006. By the New Year period soil-water contents at depths below 1 m exceeded 30%. In the following days, the BNSF rail corridor was closed several times because of landslide activity.

Preliminary slope stability analyses using laboratory measured shear strength parameters, observed pore pressure conditions, and field measured topographic profiles indicate that the landslide at the Edmonds site occurred under partially saturated or unsaturated conditions. Under the conditions of prolonged rainfall from late December 2005 through mid-January 2006, overall wetness of the colluvium increased with depth. The progressive downward wetting apparently resulted in a gradual reduction of apparent cohesion and increased the weight of the soil, which in turn resulted in ground failure on the morning of January 14.

4.13. FHWA's efforts to raise the standard for analysis, mitigation and management of landslides

Scott A. Anderson, Ph.D., P.E., Geotechnical Discipline Leader, Federal Lands Highway, Federal Highway Administration, Lakewood, CO, Scott.Anderson@fhwa.dot.gov

BIOGRAPHY: Scott Anderson is a geotechnical engineer and geologist with more than 20 years experience in academia, consulting, and with the FHWA. He graduated in geology from the University of Colorado (B.A.) and Colorado State (M.S.), and in civil engineering from U.C. Berkeley (M.S., Ph.D.). He was assistant professor of civil engineering at the University of Hawaii after completing his PhD and was employed by Woodward-Clyde Consultants and URS Corporation through school and prior to joining the FHWA 5 years ago. The Federal Highway Administration (FHWA) strives to improve safety and mobility while minimizing expenditure and protecting the environment. It is in this context that the FHWA has interest in landslide analysis, mitigation and management. Responsibilities of the FHWA include research and development, technology deployment, technology transfer, stewardship, and oversight on roads ranging in size and daily traffic from interstate highways to single-lane, gravel-surfaced roads on federal lands - such as national parks and forests. The number of miles of highway and slopes traversed, natural and man-made, stable and unstable is tremendous.

ABSTRACT: Since at least the mid-1970's, the FHWA has sponsored technology deployment, hosted training, and implemented new technologies to raise the bar with respect to slope stability analysis and landslide mitigation and management. Recent activities in these areas are the subject of this presentation. Examples that address safety, mobility, asset management, and environmentally context-sensitive solutions are as follows:

Recent FHWA sponsored technology deployment

- LIDAR for mapping rock outcrops and safely designing safe rock cuts
- InSAR for monitoring slopes and landslide movement
- Risk-based framework for rock slope and rockfall mitigation design
- Hollow-Bar-Anchors; are these self-drilling anchors the next generation soil nail?

Current training on slopes and slope retention

- Interactive CD-based training on soil nail and ground anchor inspection
- Multimedia presentation of rockfall catchment design (w/Oregon DOT)
- Existing NHI offerings on soil slopes and embankments, reinforced soil slopes, and rock slopes, abbreviated offerings
- Update of Highway Slope Maintenance and Slide Restoration training course

Recent implementations with published findings

- Application of satellite borne InSAR for route selection and slide monitoring
- Patterned ground anchors for landslide stabilization
- Quantitative risk assessment of landslide mitigation strategies
- Retaining wall inventory and assessment

4.14. Landslide risk assessment and management strategies: Some European and Japanese experiences

Mihail E. Popescu, Ph.D., P.E., Eur Ing, Wang Engineering, Inc. / Illinois Institute of Technology, Chicago, IL, mepopescu@usa.com

BIOGRAPHY: Mihail E. Popescu has more than 30 years of experience in geotechnical engineering research, consulting, and education. Conducted fundamental and applied research on a variety of geotechnical topics. Main research interests: slope instability and stabilization, expansive and collapsible soils, soil – structure interaction, computer modeling, and geotechnical hazards compilation and assessment. Responsible for geotechnical design and functional design criteria for a wide variety of engineering projects including the Danube – Black Sea Navigable Canal. Interfaced with major international consultants and contractors. Director of five landslide related workshops and short courses including the NATO Advanced Workshop on Prevention and Remediation of Landslide Related Hazards in the Black Sea Region, in 1998. Professor and Visiting Professor at University of Civil Engineering, Bucharest, Romania, University of Edinburgh, U.K., University of Tokushima, Japan, University of Natal, Durban, South Africa, Norwegian University of Science and Technology, Trondheim, Norway, and Illinois Institute of Technology, Chicago, USA. Leader of the Commissions on Landslide Causal Factors and Landslide Remediation of the UNESCO Working Party on World Landslide Inventory (1988-2000). Member of the ISSMGE-IAEG-ISRM Joint Technical Committee on Landslides (2001-present).

ABSTRACT: Landslides are frequently responsible for considerable losses of both money and lives. In view of above consideration, it is not surprising that slope instability phenomena are rapidly becoming the focus of major scientific research, engineering study and practices, and land-use policy throughout the world.

Despite the development of risk prevention, social structures seem paradoxically less prepared to face disasters and alleviate their effects. It is noted that the approaches developed have not managed to successfully reduce the impact of the natural hazards including landslides. This is due to the fact that risk management has remained for too long concentrated on the strict analysis of the physical processes and favors technical solutions and structural measures rather than more qualitative and more global solutions. It too often focuses on the short term and on the management of the crisis and dismisses local know-how. Risk management policies should adopt an integrated approach, involving all the stakeholders, from global to local, on the basis of a full diagnosis of the area, far beyond the problems of natural risks alone.

Landslide risk assessment and management strategies differ from country to country. The way how the society is organized, its economic strength and historical traditions, among other factors, determine the type of response to the threat caused by landslides. This might explain the difficulties in developing standard terminology and procedures for quantitative hazard and risk assessment and management.

After reviewing landslide risk assessment key elements and principles, the presentation discusses the acceptable risk strategies in different countries. The example of landslide management strategy adopted in Isle of Wight, U.K. for the largest urban landslide complex in north-western Europe is used to illustrate the tools and challenges of living with landslides in a reasonably safe way. Then the example of Jizukiyama Landslide in Nagano is presented in the context of the Japanese Landslide Prevention and Control Program. Finally, landslide management in Alpine countries is briefly discussed.

4.15. Public awareness and participation in reduction of landslide risk—Hong Kong experience

Albert T. Yeung, BSc(Eng)(Hon) MS PhD FICE MHKIE FASCE RPE (Civil, Environmental, Geotechnical) CEngPE, University of Hong Kong, Hong Kong, China, yeungat@hku.hk

BIOGRAPHY: Albert T. Yeung is an Associate Professor at the Department of Civil Engineering, The University of Hong Kong. He received his BSc (Eng) degree in civil engineering with First Class Honours from The University of Hong Kong in1982. He had worked for the former Binnie & Partners International (now Black & Veatch Hong Kong Limited) for two years before he pursued his graduate study on a Rotary Foundation International Graduate Scholarship 19841985 and an Earth Technology Corporation Fellowship 1987-1989 at the University of California, Berkeley. He received his MS and PhD degrees from UC-Berkeley in 1985 and 1990, respectively. He was on the civil engineering faculty at Northeastern University in Boston, Massachusetts and Texas A&M University in College Station, Texas for a total of seven and a half years. Before his return to academia in 2003, he served as Chief Engineer of Black & Veatch Hong Kong Limited and Assistant Secretary for Financial Services and the Treasury of the Hong Kong Special Administrative Region Government. He is a Registered Professional Engineer (Civil, Environmental & Geotechnical) of Hong Kong, a Chartered Engineer of the United Kingdom, and a Registered Professional Engineer of Texas, U.S.A.

ABSTRACT: The total area of the Hong Kong Special Administrative Region (HKSAR), China is approximately 1,100 km^2, accommodating a population of 6.9 million and one of the world's largest trading economies. However, most of the population is being housed in 215 km^2 of urban development because of steep natural terrain and stringent planning controls. Over 400 km^2 have been designated as protected areas including country parks, special areas, and conservation zonings. The concentration of population and economic activities in such a small area exert intense pressures on the demand of usable land.

Throughout the years, many cut or fill slopes have been constructed to cope with the rapid economic development of Hong Kong. There are more than 57,000 sizable man-made and natural slopes in Hong Kong. As many constructed facilities are in close vicinity of man-made or natural slopes, the consequence of any major slope failures can be disastrous. In fact, large-scale landslides causing heavy casualties and severe damage of properties did happen in Hong Kong. There has been an on-going concerted effort of the Government and the public to prevent slope disasters in Hong Kong for decades.

The most important objective of any slope disaster management program is to reduce the loss of lives, casualties, and damage to properties in the event of any unpredictable landslides. Methodologies to achieve the objective can be broadly divided into three categories:

1. technological improvement of to increase slope stability or to mitigate the damage caused by debris flow in case of landslide;
2. routine maintenance to detect and repair any distress of slopes, and to maintain drainage paths functional; and
3. isolation of the public from landslides.

The theme of this presentation is on the Hong Kong experience on public awareness and participation to reduce landslide risk including:

1. systematic categorizing of more than 57,000 sizeable slopes in Hong Kong to provide the most updated slope information to the public and slope professionals through the internet;
2. delineation of slope maintenance responsibility between the Government and private parties to avoid unnecessary ambiguity;
3. provision of administrative and regulatory framework to enforce necessary slope maintenance; and
4. education of the public on how to maintain slopes within their properties, what they should or should not do so as not to deteriorate stability of slopes, how they can prepare themselves for landslides to minimize potential losses, how they can get the most updated information of landslides, and what they should and can do to protect themselves during landslides.

4.16. Keynote: How we can improve landslide practice and management in Oregon: A practitioner's perspective

Derek H. Cornforth, PhD, PE, Cornforth Consultants, 10250 SW Greenburg Road, Portland, OR 97223

BIOGRAPHY: Derek Cornforth has practiced as a geotechnical consulting engineer in the Pacific Northwest for almost 40 years. He was a principal with Shannon & Wilson, for 15 years before founding Cornforth Consultants, Inc. and its Landslide Technology division in 1983. In 2005, his textbook Landslides in Practice was published by Wiley. Derek has a Ph.D. from London University where he studied under Skempton and Bishop, two pioneers in slope stability and landslide analysis.

ABSTRACT: Three types of landslide hazard/risk maps have been produced in the Pacific Northwest over the past 40 years, namely:

(1) conventional geological hazard maps;
(2) landslide occurrence maps, and
(3) perceived landslide risk maps.

Each type of map will be illustrated, and their relative benefits and weaknesses for landslide reduction will be discussed.

The second part of the talk will focus on suggested ways to provide more useful information on such maps, and the need to obtain reports on landslide occurrences for future reference. The talk will conclude with specific procedures recommended for basic research on Oregon's widespread ancient landslide terrain.

4.17. Introduction to the Oregon Landslide Workgroup (OLW) and concluding remarks

William J. Burns, DOGAMI

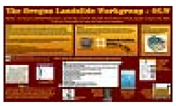
In order to reduce future landslide damages in Oregon, a diverse group of people is needed to collaboratively determine possible risk-reduction steps. To address this need, the Oregon Department of Geology and Mineral Industries (DOGAMI) has begun forming a preliminary landslide working group, titled the Oregon Landslide Workgroup (OLW). See section 5.0 for more details.

5.0 POST-SYMPOSIUM GATHERING AND POSTER SESSION

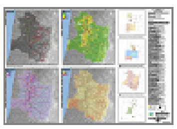
NOTE: Due to possible copyright issues, all poster images have been removed from this online version.

On Thursday April 26, 2007 the main program was followed with a post-symposium gathering and poster session from 5:30 Pm to 7:30 PM which consisted of an open opportunity to discuss questions and 16 technical posters.

Posters included with this publication are shown with the abstracts in the following pages. ***To view a full-size poster, click on the poster image that appears with the abstract or on a thumbnail image below.***



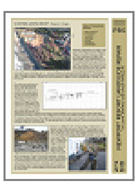
5.1. A new working group in Oregon: The Oregon Landslide Workgroup (OLW) William J. Burns and Yumei Wang



5.2. Relative earthquake induced hazard maps and identified landslide hazard map for six counties in the mid-Willamette Valley, including Yamhill, Marion, Polk, Benton, Linn, and Lane counties, Oregon William J. Burns, R. Jon Hofmeister, and Yumei Wang

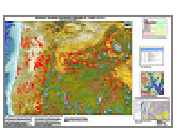
5.3. Modeling the landslide risk for the BPA transmission system John Eidinger, Donald Wells, Leon Kempner, and Jared Perez

5.4. US Highway 26 emergency landslide repair, milepost 24, Clatsop County, Oregon George Freitag, Stanley Kelsay, and Thomas Braibish



5.5. Schooner Landing Resort landslide Newport, Oregon field examination and mitigation design John Jenkins

5.6. Giant landslides in the Coburg Hills: Implications to urban rural development Ian P. Madin and Robert B. Murray

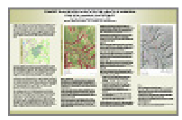


5.7. A new landslide database for Oregon Ian P. Madin and William J. Burns

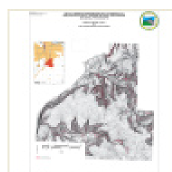
5.8. Asset management – based unstable slope rating system for Oregon highways Curran Mohney and Jamie Schick

5.9. Soil engineering properties of landslide and debris flow initiation sites, Coast Range, Oregon Jonathan P. McKenna and Xavier Amblard

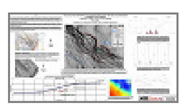
5.10. Landslides mapped using LIDAR imagery, Kitsap County, Washington Jonathan P. McKenna, David J. Lidke, and Jeffrey A. Coe



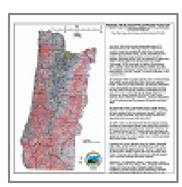
5.11. Concept plan process facilitates the update of municipal code for landslide susceptibility Tova Peltz and Christina Robertson-Gardiner



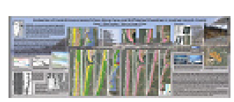
5.12. Producing the Oregon City LIDAR map Ian P. Madin and William J. Burns



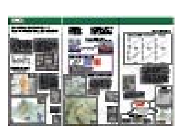
5.13. Evaluation and monitoring of landslide hazards along the Oak Lodge water main, Clackamas County, Oregon: Threading a needle with a 24-inch pipeline Erick J. Staley



5.14. Improving the 2002 geographic information system (GIS) overview map of potential rapidly moving landslides in western Oregon Yumei Wang



5.15. Evaluation of coastal erosion hazard zones along dune and bluff-backed shorelines in southern Lincoln County: Seal Rock to Cape Perpetua Robert C. Witter, Jonathan C. Allan, and George R. Priest



5.16. Hazard maps for debris flows and avalanches using GIS and LIDAR Julie Griswold and Richard Iverson

5.1. A new working group in Oregon: The Oregon Landslide Workgroup (OLW)

William J. Burns and Yumei Wang, Oregon Department of Geology and Mineral Industries

Many areas of Oregon are highly susceptible to landsliding. As population grows, development will expand into steeper terrain, increasing the frequency and extent of damages from landsliding.

In order to reduce future landslide damages in Oregon, a diverse group of people is needed to collaboratively determine possible risk-reduction steps. To address this need, the Oregon Department of Geology and Mineral Industries (DOGAMI) has begun forming a preliminary landslide working group, titled the Oregon Landslide Workgroup (OLW).

OLW will be a partnership of representatives from the public and private sectors including: federal, state, regional, county, and city elected officials; academic researchers; not-for-profit organizations; and consultants, corporations and the insurance industry.

OLW's principal goals will be to:

- Promote efforts to reduce landslide damages and losses
- Conduct education efforts to motivate key decision makers to reduce risks associated with landslides through land-use planning and design permitting
- Foster productive linkages between scientists, engineers, planners, developers, property owners, critical infrastructure providers, businesses and governmental agencies to improve our communities' ability to recover after a major landslide event

5.2. Relative earthquake induced hazard maps and identified landslide hazard map for six counties in the mid-Willamette Valley, including Yamhill, Marion, Polk, Benton, Linn, and Lane counties, Oregon

William J. Burns, Oregon Department of Geology and Mineral Industries, R. Jon Hofmeister, formerly at Oregon Department of Geology and Mineral Industries, Yumei Wang, Oregon Department of Geology and Mineral Industries, cartography by Rudie Watzig, Oregon Department of Geology and Mineral Industries

In order to become resilient to geologic hazards, communities in Oregon have begun a large-scale endeavor to perform pre-disaster mitigation. A first step in this process is the development of natural hazards mitigation plans. For this project, six counties and one city merged together resources to begin:

- Identifying potential natural hazards,
- Identifying vulnerability to these hazards,
- Assessing the level of risk, and thus
- Increasing the level of resilience through pre-disaster mitigation.

To assist these six counties in the development of their natural hazards mitigation plans, the Department of Geology and Mineral Industries (DOGAMI) performed the following tasks related to geologic hazards:

- Identified the primary geologic hazards of six counties in the Mid-Willamette Valley including Yamhill, Marion, Polk, Benton, Linn, and Lane Counties and the City of Albany (herein know as the study area or individual communities).
- Developed countywide earthquake and landslide hazard maps for each county.
- Developed future earthquake damage estimates for each community.

The purpose of this study is to help communities prepare pre-disaster mitigation plans, identify potential geologic hazards, help communities' perform earthquake damage and loss estimation, and to recommend future action items. Several products have been generated as part of this project. They include digital GIS layers for each community, depicting:

- Relative earthquake ground shaking amplification hazards
- Relative earthquake liquefaction hazards
- Relative earthquake-induced landslide hazards
- Identified landslide areas

Damage and loss estimates for each community were analyzed for two earthquake scenarios:

- A magnitude ~6.5 Crustal Fault earthquake
- A magnitude 9.0 Cascadia Subduction Zone earthquake

To improve the existing hazard maps and data, action items are provided. These action items range from site-specific items such as identification of individual school buildings that have a high risk of collapse in an earthquake to identification of landslide hazard areas over large regions of the state.

The identified earthquake-induced hazards include ground shaking amplification, liquefaction, earthquake induced landslides, and tsunamis. In order to evaluate non-earthquake related landslide hazards, we used identified landslide areas, potential "rapidly moving landslide" (debris flow) hazards maps, and an inventory of slope failures in Oregon from three storm events (1996-97). Dam failures are frequently caused by geologic hazard events, and we evaluate these. Finally, we discuss volcanic hazards from Mt. Jefferson and the Three Sisters Region.

The relative earthquake hazard maps developed in this study identify areas of higher or lower potential hazard and can help guide planners who have to determine which areas should require future site-specific seismic evaluations. The identified landslide areas map is a digitized compilation of previously identified landslides. All of these maps should only serve as a guide for future site-specific evaluations.

Ground shaking amplification and liquefaction hazards are usually highest in the young, soft alluvial sediments of the Willamette Valley and along other major stream channels. Landslide hazards are highest in steep, mountainous terrain and at the base of steep canyons. Landslide areas identified in the accompanying GIS files also pose significant hazards for development.

We used regional earthquake hazard information developed in this study to assess potential damage and loss for various earthquake scenarios. We consolidated information into a computer program called HAZUS-MH, which is a federally developed program used to model various earthquake scenarios and estimate associated damage and loss. With the improved HAZUS-MH study region (included with this report), we modeled damage and loss estimates for two earthquake scenarios—resulting in expected total building damage on the order of $11.7 billion for a Cascadia Subduction Zone event.

The products from this study can be used to help the Mid-Willamette Valley communities become more resilient from the impacts of geologic hazards through pre-disaster mitigation.

5.3. Modeling the landslide risk for the BPA transmission system

John Eidinger, G&E Engineering Systems Inc., Donald Wells, Geomatrix Consultants Inc., and Leon Kempner and Jared Perez, Bonneville Power Administration

The Bonneville Power Administration operates the high-voltage transmission network in the Pacific Northwest that includes more than 500 substations and 80,000 transmission towers. BPA is examining the vulnerability of this network to earthquake-induced ground shaking, landsliding, and liquefaction hazards.

To assess the major seismic risk, BPA has studied its all of its substations along coastal Washington and Oregon states, and a sample of its transmission lines through the Cascade and the Coastal ranges. The substations are primarily vulnerable to ground shaking hazard, and locally, at a few substations, the liquefaction hazard. The transmission towers are most vulnerable to the landslide hazards in the Coastal and Cascade ranges, and liquefaction near rivers.

To process the large inventory of facilities, a GIS-based risk model called SERA (System Earthquake Risk Assessment) is used. SERA factors in high resolution details of each piece of equipment at substations, and every transmission tower. Overlaid on this inventory are the seismic hazards, computed on a scenario basis. Scenario earthquakes considered include a Cascadia Subduction Zone M 9, Intraplate M 7.5 events centered near Portland or Tacoma, and a variety of crustal events (Seattle fault, Portland fault and several others).

The landslide model factors in the following attributes: season (saturated / dry); morphology (GIS/DEM based); aerial reconnaissance (visual examination for landslide-prone features); tower style of construction; and the initiating scenario ground motions.

We describe the BPA system's overall performance considering damage (inertial or landslide/liquefaction induced) to each component, the redundancies in the network, and BPA's ability to restore service post-earthquake. Specifics of the landslide models used, and the difficulties encountered in trying to develop site-specific landslide forecasts by combining regional GIS-based landslide predictors such as slope and geology, site-specific issues, to more than 20,000 transmission locations at widely varying locations are examined. We address the desire to use generic landslide screening tools (High, Medium, Low) that might be suitable for a planning study versus the practicality of needing high confidence that the landslide risk is sufficiently "real" so as to merit spending real mitigation dollars.

5.4. US Highway 26 emergency landslide repair, milepost 24, Clatsop County, Oregon

George Freitag and Stanley Kelsay, GRI Geotechnical & Environmental Consultants, and Thomas Braibish, Oregon Department of Transportation

Following a period of prolonged, intense precipitation, a landslide occurred on November 7, 2006, that closed the eastbound travel lane of US Highway 26 near milepost 24 in Clatsop County, Oregon. US Highway 26 is a State Highway Freight Route with average daily traffic of about 6,800 vehicles and is the direct connector between metropolitan Portland and communities on the northern Oregon Coast.

The landslide measured about 70 ft wide at the road and extended below the roadway about 1,500 ft (horizontally) and 200 ft (vertically) to Quartz Creek. The landslide locally undermined the outside 1 to 3 ft of pavement, and about 50 ft of guardrail was hanging in mid-air.

The Oregon Department of Transportation (ODOT) contracted GRI to investigate the landslide and develop a plan for repair. Field investigation revealed the landslide area to be generally underlain by soft to medium-hard Tertiary marine sandstone mapped as Cowlitz Formation. Rock Quality Designation (RQD) ranged from 8 to 100%; RQD values were in excess of 90% below a depth of 20 ft. The cored sandstone typically exhibited close to wide joints with local secondary calcite mineralization along discontinuities. Laboratory unconfined compressive strength measurements ranged from 130 to 8,410 psi (n = 16), with values generally increasing with depth.

After consideration of geologic, topographic, right-of-way, and mobility constraints, an anchored soldier-pile/micropile wall system was selected for the repair. Berger/ABAM Engineers, Inc. assisted GRI with structural engineering and preparation of construction documents. By December 12, 2006, Moore Excavation, Inc. and their specialty micropile contractor, Scheffler Northwest Inc., were on-site installing the wall system. ODOT reopened the eastbound travel lane to the public on December 31, 2006, meeting the contract requirements of this emergency repair.

5.5. Schooner Landing Resort landslide Newport, Oregon field examination and mitigation design

John Jenkins, PBS Engineering and Environmental, Inc.

The Schooner Landing Resort, located on the coast in Newport, Oregon has an active landslide within its boundaries. The landslide failure is in seaward dipping sedimentary rocks. Past problems from various ground movements within this slide required re-leveling building #5 several times a year and relocating all of its underground utilities. Although previous engineering companies had conducted subsurface investigations, no credible mitigation designs were ever developed. The Resort finally engaged PBS to develop corrective actions.

Our work was carried out in a series of sequential phases, starting with detailed landslide/geologic mapping and examining existing engineering reports. The engineering information in these reports and field observations were used to develop a plan to fill in gaps in the data. A subsurface investigation was performed consisting of installing a pumping well to investigate the potential for dewatering, and drilling three borings in critical areas. Multi-level piezometers and slope indicators were installed and monitored and a pump test was completed. The additional borings were used to evaluate the response to pumping and the potential effectiveness of drainage by vertical wells or horizontal drains and provide additional landslide movement data. The dewatering well is currently pumping.

Based on this fieldwork, we developed an understanding of the landslide's geometry and developed a conceptual model of the failure mechanics. From this, we developed a series of remedial treatments consisting of an array of surface drains, vertical wells, and horizontal drains. We are presently in the process of developing construction-related documents, including cost estimates, for stabilizing the slope.

5.6. Giant landslides in the Coburg Hills: Implications to urban rural development

Ian P. Madin and Robert B. Murray, Oregon Department of Geology and Mineral Industries

Recent geologic mapping of the Coburg Quadrangle in the southern Willamette Valley has identified a series of major landslides originating from the nearly 800-m high escarpment of the Coburg Hills. Although much of the hills are currently timberland, they are close to the rapidly growing Eugene urban area, and will soon be a site for rural residential development. Understanding the landslide hazards of the area will be crucial to managing this development.

The Coburg Hills consists of a thick sequence of Oligocene basalt flows overlying Eocene and Oligocene volcaniclastic and marine sedimentary rocks. A silicic ash flow interbedded with the basalt flows appears to be the main failure plane for major landslides, probably because it has relatively low permeability. Horizons of severely weathered and altered basalt are also failure planes.

Landslides typically cover 0.5-1.5 km3, and extend over an elevation range of 300-500 m. The slides commonly coalesce into large complexes. From head to toe, the slides consist of steep, arcuate scarps, zones of bench-and-scarp topography, and toes that consist of debris fans resembling large alluvial fans.

We interpret the history of these slides to begin with a catastrophic failure that produced a major debris avalanche which formed the fan-like toes, followed by continued slow failure by block gliding and slumping in the headwall, scarp and bench regions. This sequence has significant implications for future development. It is probably unreasonable to restrict development of the debris avalanche deposits at the base of the slides, because these areas are neither likely to slide further, nor are they likely to experiences future debris avalanches. On the other hand, the steep slopes on the upper reaches of the slides are clearly hazardous for development because of their abundant small block slides and slumps. However, the greatest risk to life safety is on steep slopes between slides, because future catastrophic failures and debris avalanches are most likely there.

5.7. A new landslide database for Oregon

Ian P. Madin and William J. Burns, Oregon Department of Geology and Mineral Industries

In 2007, DOGAMI is preparing a new digital map and database of Oregon landslides as part of a multiyear partnership with the U.S. Geological Survey's landslide program. Over the years, geologists have mapped hundreds of landslides around the state, typically in the course of geologic mapping. Since the landslide information in these maps is not easily available to the general public and local government officials, we are compiling all of the mapped landslides from these sources into a single, uniform, statewide database. This new database will provide a base layer for future efforts to systematically map all landslides in the state using new LiDAR topographic images.

About half of the state is already covered by DOGAMI's OGDC v. 3 digital database which is compiled from the best available mapping. OGDC v. 3 contains 1,898 discrete landslide polygons, covering 2000 km^2, which is about 1.4% of the entire map area. The landslide database will start with the landslides extracted from OGDC v. 3, and then will cover the rest of the state by digitizing and attributing slides from digital and paper maps.

The database will include information about the age and style of sliding, and will document the map source from which it came. When completed, the new database will be made available as a theme on DOGAMI's interactive geologic map website (http://www.oregongeology.com/sub/ogdc/index.htm) so that the information is readily available to geologists, engineers, planners and the general public.

5.8. Asset management – based unstable slope rating system for Oregon highways

Curran Mohney and Jamie Schick, Oregon Department of Transportation

The Oregon Unstable Slope Rating System is a new method for rating landslide and rockfall hazards along the Oregon State highway system that follows the Asset Management principles brought forth by the Federal Highway Administration. Previous rating systems used by the agency focused on rockfall problems while ignoring landslides. These systems also focused on the risk of failure but disregarded the consequence of failure at the site as well as the large-scale function of the system. Oregon highways span numerous physiographic and geographic boundaries, each having its own particular stability issue such as high rock cuts in mountainous areas, or large embankments on steep slopes in areas of high annual precipitation. This variability necessitates a rating system that can normalize the differences between physiographic provinces.

In the new Unstable Slope Rating System, risk and consequence are measured equally, but are separable for various analyses conducted under the Asset Management framework. Three main parameters are used to assess unstable slopes:

1) hazard score,
2) route hierarchy, and
3) maintenance and repair cost-to-benefit.

These parameters are combined to make effective decisions concerning landslide and rockfall project prioritization, and to evaluate a program's overall financial needs so that long-term funding strategies can be developed.

Information used to develop an individual score is obtained through field and office analyses. Field reconnaissance assessments are conducted for each unstable slope identified to collect information such as site distance, beginning and end points, and cross section. This information is collected and stored in the field along with a GPS point using a Trimble GeoXT. Roadway maintenance managers are interviewed for information such as frequency of events, road closure, accidents, and maintenance costs, the latter being used as part of the cost-benefit analysis. Additional information considered includes detour lengths and average daily traffic (ADT). This information is used to develop a hazard score which is then used to produce an overall score that includes conceptual design costs and maintenance costs. Once the rating is complete, the information is exported to ODOT's GIS platform.

The schedule for State highway surveys generally follows the OTIA prioritization, starting with the interstates and working progressively through secondary highways. The current program effort targets critical slopes for each of ODOT's five Regions. This will allow the more problematic unstable slopes to be incorporated early into the database and potentially targeted for mitigation funding. Currently, approximately 10 percent of the State highways have been surveyed. Up-to-date landslide and rockfall information will soon be available on the agency's website.

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5.9. Soil engineering properties of landslide and debris flow initiation sites, Coast Range, Oregon

Jonathan P. McKenna, U.S. Geological Survey, and Xavier Amblard, Ecole Polytechnique Universitaire Pierre et Marie Curie

Hundreds of debris flows and landslides occurred in the Oregon Coast Range as a result of heavy rainfall during the months of December 2005, and January 2006. Shallow translational slides and partially liquefied debris flows occurred adjacent to one another. Our field-and lab-based study attempts to explain this relationship by identifying physical differences between soils from the initiation locations of landslides and debris flows in a geologically homogenous terrain. Specific soil properties analyzed in this study are grain-size distribution, porosity, and saturated hydraulic conductivity.

Seven field sites in the Tyee Basin, Oregon, including 14 landslides and 21 debris flows were investigated during the spring and summer of 2006. Soils at all the sites are derived from the underlying Tyee Sandstone. Soils were sampled and measurements made within 2 m upslope of the head scarp of each failure. We collected bulk samples to determine the soils' grain-size distribution, used a modified California sampler on the moist ground to collect undisturbed samples for porosity analyses, and used a field permeameter to measure in-situ saturated hydraulic conductivity.

All soils weathering from the Tyee Sandstone are predominately sand with minor silt and clay, but soils from debris-flow sites contain more fine-grained sand than do those from the landslide sites; however detailed grain-size distribution tests are still ongoing.

Preliminary results indicate that initial porosity affects style of failure. Soils that mobilized as debris flows had an average porosity of 0.55 ± 0.04 while soils that failed as landslides had an average porosity of 0.48 ±0.02. This is significant because soils initially less porous than "critical" dilate as they begin to shear, while soils initially more porous tend to contract.

Saturated hydraulic conductivity measured at most debris-flow initiation sites clustered between 1.0 x 103 to 1.0 x 10-4 cm/s, while at landslide initiation sites, conductivity ranged from 1.5 x 10-2 cm/s to 1.5 x 104 cm/s. The optimum saturated hydraulic conductivity for debris-flow initiation is approximately 5.0 x 10-4cm/s which allows water to enter the soil column rapidly yet be retained in sufficient quantity to partially liquefy the soils upon shearing.

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5.10. Landslides mapped using LIDAR imagery, Kitsap County, Washington

Jonathan P. McKenna, David J. Lidke, and Jeffrey A. Coe, U.S. Geological Survey

Landslides are a recurring problem on hillslopes throughout the Puget Lowland, Washington but can be difficult to identify in this densely forested terrain. However, digital terrain models of the bare-earth surface derived from LiDAR data express topographic details sufficiently well to identify landslides. Landslides and escarpments were mapped using LiDAR imagery and field checked (when permissible and accessible)throughout Kitsap County, WA. We relied almost entirely on derivatives of LiDAR data for our mapping including topographic contour, slope, and hill-shaded relief maps. Each mapped landslide was assigned a level of "high" or "moderate" confidence based on the LiDAR characteristics and on field observations.

A total of 232 landslides were identified representing 0.8% of the land area mapped. Earth topples, shallow falls, and deep-seated landslide complexes are the most common types of landslides. The smallest feature covers an area of 252 m^2, while the largest covers nearly 9 km^2. Previous mapping efforts relying solely on field and photo-grammetric methods identified only 53 % of the landslides (32% high confidence and 21% moderate confidence). The remaining 47% we identified using LiDAR have 8% high confidence and 39% moderate confidence. Coastal areas are especially susceptible to landsliding; 53% of the landslides mapped lie within 250 m of the present coastline. The remaining 47% occur along drainages farther inland.

The LiDAR data we used for mapping have some limitations including:

1. rounding of corners between low slope surfaces and vertical faces (i.e. along the edges of steep escarpments) which results in scarps being mapped too far headward),
2. incorrect distance measurements,
3. removal of valid ground elevations,
4. false ground roughness, and
5. faceted surface texture.

Several of these limitations are introduced by algorithms in the processing software that are designed to remove non-ground elevations from LiDAR data. Despite these limitations, the algorithm-enhanced LiDAR imagery does effectively "remove" vegetation that obscures many landslides, and is therefore a valuable tool for landslide inventories and investigations in heavily vegetated regions such as the Puget Lowland.

5.11. Concept plan process facilitates the update of municipal code for landslide susceptibility

Tova Peltz, Geotechnical Resources, Inc., and Christina Robertson-Gardiner, City of Oregon City

In 2002, nearly 300 acres of rural land located just east of Oregon City were brought into the Portland Metropolitan Urban Growth Boundary (UGB) to accommodate future growth. The Park Place Concept Plan was developed to help the City of Oregon City (City) prepare for this growth by working with local citizens, area stakeholders, and local and regional jurisdictions to develop a common vision for the area. Development of the Concept Plan has been a community-based process, led by the Design Team, which includes land use planners, engineers and City planners, and the Project Advisory Committee (PAC).

Early in the Concept Plan process, the local community identified their concern regarding landslide hazards and the future development. Several local property owners described their own experiences with landslide-related property damage that occurred during the 1996 storms. These experiences reflect an extensive history of landslides in Oregon City and its surroundings, typically associated with landslide-prone, fine-grained soils, steep topography, and groundwater conditions. This history has been well documented in many publications.

These Landslides have caused millions of dollars of property damage for the City and local property owners and continue to occur. The City recognizes the ongoing risk associated with development in landslide-susceptible areas and, with the Design Team, the City hired GRI to conduct a preliminary geotechnical and geological evaluation of the concept plan area, specifically to 1) identify, on a preliminary basis, the potential geologic hazards associated within the study area, and 2) provide geotechnical considerations for future development.

GRI's evaluation consisted of a limited field reconnaissance and extensive review of geologic reports, maps, available geotechnical reports, subsurface information, and aerial photographs. GRI developed a practical guide provided a document for the Concept Plan to serve as a practical guide to assist the City in their understanding and management of the short- and long-term geologic risks associated with future development in the Park Place Concept Plan area. The City is using this document as a transitional document to update the municipal code to better identify and mitigate landslide hazards for future development within the City. In the longer term, the City is working with DOGAMI to incorporate a future landslide susceptibility map (expected publication date in late 2008) into its municipal code as a specific reference document to identify the level of geotechnical and geologic investigation required for future development within the City.

5.12. Producing the Oregon City LIDAR map

Ian P. Madin and William J. Burns, cartography by Mark Sanchez, Oregon Department of Geology and Mineral Industries

During 1996 and 1997, heavier than normal rains in Oregon caused thousands of landslides. Over 700 of these landslides were mapped in the Portland metropolitan area (Burns et al., 1998). Some of these slides were the reactivation of ancient and historically active landslides, and some were new failures. Many of these slides occurred within the Oregon City area; an inventory of these landslides is available through Oregon Department of Geology and Mineral Industries (DOGAMI) Special Paper 34 (Hoffmeister, 2000).

During the 2005-06 winter season, Portland and most of western Oregon again experienced heavier than normal rainfall, which resulted in hundreds of landslides. Again, many of the landslides were also reactivation older landslides, several occurred in the Oregon City area, impacting infrastructure as well as several residential homes and an apartment complex. Identifying these existing ancient and historic landslides is thus an obvious priority in the attempt to begin the reduction of the risk from landslide damages.

The accompanying map is designed to provide timely access to new information about potential landslide hazards in the Oregon City area. The new information comes from two sources, a recently completed geologic map of the Oregon City 7.5 minute quadrangle (Madin, in preparation) and high-resolution topographic data in the form of a digital elevation model (DEM) derived from light detection and ranging(LIDAR) surveys conducted by the City of Oregon City. This landslide information will eventually be published both as part of the geologic map and as part of a regional landslide geomorphology map. Oregon City is the first Oregon community for which this kind of high resolution landslide geomorphologic mapping is available.

METHODS: The two primary data sources were used to make this map: were serial stereo aerial IR photos of a variety of scales, and a LIDAR-based DEM provided by the City of Oregon City. Landslide geomorphology from both sets of imagery was compiled and then combined using geographic information system (GIS) software (Map-Info™).

The majority of the landslide topography occurs in canyons that cut the Oregon City plateau where slopes are typically forested, and topography is obscured when forest cover is intact. In an attempt to get around this problem, a time series of aerial IR photos was examined (1939, 1948, 1956, 1964, 1973, 1980,1990, and 2000). For all of these photo series, stereographically photo pairs were examined to look for topography characteristic of landslides such as steep arcuate scarps (cliffs), hummocky topography, and cracks and grabens (troughs or depressions) on the surfaces of slopes, and irregular lobate toes. The outlines of areas of landslide topography were transferred from the stereo photos to the GIS by heads-up digitization on a geo-referenced (UTM Zone 10, NAD 27) image of the USGS 1:24,000 scale topographic map (digital raster graphic: DRG). The transfer was accomplished with the DRG zoomed to scales between1:12,000 and 1: 6,000.

After the completion of the aerial photography analysis, high-resolution, bare- earth LIDAR data became available from the City of Oregon City. LIDAR data are collected by scanning the ground with a laser range finder flown in a precision-navigated aircraft. The resultant cloud of elevation data is processed to remove laser returns from vegetation and structures, producing an accurate and detailed model of the shape of the ground surface.

We processed the Oregon City LIDAR data-points to produce a DEM grid (Oregon State Plane N, 1983) with 5 ft by 5 ft cells, and then enhanced that DEM with both relief shading and slope maps to highlight subtle topography. We also produced elevation contours at 2-ft intervals to help visualize the data. We then digitized the areas of landslide topography directly from LIDAR imagery at a scale of 1:2400, again using topographic evidence such as scarps, hummocky terrain, and lobate toes. An additional advantage of the LIDAR data was that we could instantly produce topographic cross sections along a suspect slope. With the LIDAR data it was also possible to see subtle fan deposits at the mouths of small canyons that we interpret as debris flow or earth flow deposits.

We compared the areas of landslide topography mapped in this study with those mapped in previous studies (Hammond and others, 1974; Schlicker and Finlayson, 1979; Burns, 1999). We found that previous maps identified most of the larger (greater than 5 acres) slide areas, but LIDAR data provided much more accurate delineation of the boundaries of the areas. Previous studies identified only a few of the smaller slide areas and, in several cases, identified areas which did not show any visible landslide features on the LIDAR DEM. Only the LIDAR DEM showed deposits of debris flows and earth flows. Our confidence in the existence, types, and boundaries of the larger slide areas identified on the LIDAR DEM is very high; we are less confident regarding the more numerous smaller slide areas.

5.13. Evaluation and monitoring of landslide hazards along the Oak Lodge water main, Clackamas County, Oregon: Threading a needle with a 24-inch pipeline

Erick J. Staley, GeoDesign, Inc.

The Oak Lodge Water District manages a 24-inch-diameter water main located west of Gladstone, Oregon that serves as a primary link between two 5-million-gallon reservoirs and thousands of residential and commercial properties served by the district. The water main is located between two ancient landslides, parts of which may be active. Although the water main was installed in 1964 and apparently has not experienced damage related to landsliding, repeated cracking in roadways and damage to residences from possible ground movement in the site vicinity caused concern for the water main's stability.

A study of the landslide hazards potentially impacting the water main has been conducted since early 2004including review of LiDAR ground surface data, reconnaissance landslide mapping, monitoring inclinometers and vibrating-wire piezometers from two borings advanced along the pipeline alignment, and monitoring strain gauges installed on the pipeline.

The limits of the ancient landslide scarps and their respective slide masses are evident on digital elevation models from the LiDAR data. LiDAR data were also used to create an accurate ground surface profile through dense residential development where surveying would have been extremely difficult considering the number of parties involved. Boring logs indicate colluvial soils overlying silts and clays of the Sandy River Mudstone, which in turn overlie weathered basalt of the Columbia River Basalt Group. The interpreted primary slide plane lies along the basalt-mudstone contact; several secondary scarps have developed within each slide mass.

While landslide movements may have damaged residences and roads in the vicinity, the water main appears to be favorably aligned between the two landslides. Recent inclinometer data do not indicate any significant displacement has occurred, while piezometer data show a seasonal variation in water levels of approximately 5 feet. Strain gauges could not be used to evaluate pipe stress because the seasonal change in water temperature within the pipeline causes thermal expansion exceeding the thresholds of the strain gauges.

Future work will include continued monitoring of the pipeline instrumentation to check for subsurface displacement and to establish a range of expected water levels during average to wet winters.

5.14. Improving the 2002 geographic information system (GIS) overview map of potential rapidly moving landslides in western Oregon

Yumei Wang, Oregon Department of Geology and Mineral Industries

Since 2005, DOGAMI has been collaborating with the U.S. Geological Survey and conducting research to improve the accuracy of predictive modeling for debris flows using newly available high-resolution LiDAR. To date, DOGAMI has used LiDAR to identify existing landslides but not for predictive modeling. DOGAMI and the USGS are beginning to conduct pilot studies to develop debris flow hazard maps using LiDAR. Forthcoming LiDAR-based maps will replace the preliminary IMS-22 product, which has been publicly available since 2002. The Geographic Information System (GIS) data from IMS 22 have been plotted at a scale of 1:500,000. A synopsis of the IMS 22 text is provided below.

The preliminary IMS-22 product indicates areas in western Oregon where rapidly moving landslides (debris flows) pose potential hazards. These data provide preliminary but important information to local governments and other property owners about locations that may require site-specific evaluation to determine the actual risks. IMS-22 was co-developed by the Oregon Department of Geology and Mineral Industries (DOGAMI), Earth Systems Institute; Oregon Department of Forestry; and Oregon Department of Land Conservation and Development (Hofmeister and others, 2002).

The extent and severity of the hazard posed by rapidly moving landslides varies considerably across western Oregon. In general, the most hazardous areas are in mountainous terrains—which fortunately are usually sparsely populated—especially drainage channels and depositional fans associated with debris flows.

The IMS 22 data was developed with GIS-based digital modeling, checking and calibrating the models with limited field evaluations, and comparing the models with historic landslide inventories. The GIS data provided in the IMS 22 publication were developed with data at a scale of 1:24,000 (1 in. = 2,000 ft). Therefore, the data are appropriate only at that scale or smaller (e.g., 1:48,000) and cannot show greater detail if enlarged.

Landslides are a serious geologic hazard in Oregon, threatening public safety, natural resources, and infrastructure; and costing millions of dollars for repairs each year. The IMS 22 product is part of the State's attempt to protect the lives and property of its citizens. It does not aim to address all possible landslide hazards, such as rotational landslides and lateral spreading.

Reference: R. Jon Hofmeister, Daniel J. Miller, Keith A. Mills, Jason C. Hinkle, and Ann E. Beier, 2002, "Geographic Information System (GIS) Overview Map of Potential Rapidly Moving Landslides in Western Oregon, Oregon Department of Geology and Mineral Industries Interpretative Map Series IMS 22, 52p.

5.15. Evaluation of coastal erosion hazard zones along dune and bluff-backed shorelines in southern Lincoln County: Seal Rock to Cape Perpetua

Robert C. Witter, Jonathan C. Allan, and George R. Priest, Oregon Department of Geology and Mineral Industries

Four coastal erosion hazard zones for both dune- and bluff-backed shorelines in southern Lincoln County are defined by a digital geographic information system (GIS) database. Our approach follows methods used by Allan and Priest (2001) and Priest and Allan (2004) to evaluate coastal erosion hazards for Tillamook and northern Lincoln Counties, respectively. The database presented here, when combined with erosion hazards data from northern Lincoln County, will provide seamless digital maps that can be used by County and local land use planners to revise ordinances that promote safer and more sustainable development in shore-land, beach and dune environments.

The database includes a map that depicts four erosion hazard zones: the active-hazard zone and the high- ,moderate- and low-hazard zones. The active hazard zone is considered the area of beach and bluff subject to historical erosion processes. The high-, moderate-, and low-hazard zones may be viewed as potential areas of future expansion of the active-hazard zone. The erosion hazard zones are derived in part from a 1:4,800 scale shore land geologic map that extends 1,500- to 3,500-ft (460- to 1070-m) landward of the shoreline. Polygons on the map include geologic units that identify landslides, slide block, and earth flow deposits and classify these features as active, potentially active, or prehistoric. Historical bluff-top erosion rate data, also used to define erosion hazard zones, were estimated from analysis of historical aerial photography, LiDAR and precise surveys using a Trimble 5700/5800 Real-Time Kinematic Differential Global Positioning System (GPS). Estimated bluff-top erosion rates between 1939 and 2007 range from 0 ± 0.21 to -0.49 ± 0.09. Finally, the database also includes a compilation of previously mapped landslides and landslide terrain within 9.5 mi (15.3 km) of the coast.

The active-hazard zone for southern Lincoln County encompasses areas of coastal bluffs and dunes undergoing active erosion, whether by extreme wave erosion, near-shore sediment transport, gradual erosion or mass wasting processes. On dune-backed shorelines, the active-hazard zone reflects the zone of historical beach variability. On bluff-backed shorelines the active hazard zone includes the beach, bluff toe and escarpment, all seaward of the top edge of the bluff.

Three additional scenario-based hazard zones were mapped for dune-backed beaches using a geometric model that predicts the landward extent of erosion when the total water level, produced by storm wave run up superimposed on the tide, exceeds the elevation of the junction between the beach and the dune.

High-, moderate- and low-hazard zones for bluff-backed shorelines predict areas of future erosion derived from calculations that consider coastal geologic mapping, the slope of repose for talus of bluff materials, historical bluff erosion rates, and empirical estimates of maximum landslide block widths. Bluff hazard zones are defined by three scenarios that have decreasing relative likelihood over the next 60 to 100 years.

5.16. Hazard maps for debris flows and avalanches using GIS and LIDAR

Julie Griswold and Richard Iverson, U.S. Geological Survey

Hazard maps for lahars, non-volcanic debris flows, or rock avalanches can be prepared using a GIS method employing statistically calibrated predictive equations, LAHARZ software (Schilling, 1998), and digital elevation models (DEMs) to compute and depict patterns of inundation downstream from potential source areas. Although coarse, low-resolution DEMs derived from USGS topographic maps are adequate for assessing hazards from large volcanic lahars, high-accuracy, high- resolution DEMs are necessary to compute and depict hazards from non-volcanic debris flows that are typically smaller than 100,000 cubic meters.

This poster shows examples of computed hazard zones for such prospective rock avalanches along Highway 20 above Newhalem, Washington, and for debris flows along the Umpqua River in southern Oregon. The Newhalem DEM has a minimum resolution of 10 meters. The Umpqua River DEM generated from LIDAR (light detection and ranging technology) data obtained from the Oregon Department of Forestry, has a resolution of 1 meter.

Uncertainty and error in the hazard maps are addressed in two ways: 1) Standard statistical techniques are used to assess the error in the semi-empirical equations that predict the maximum valley cross-sectional areas and total downstream planimetric areas likely to be inundated by landslides of various volumes; and 2) Nested hazard zones showing inundation limits for prospective landslides with a range of volumes depict the uncertainty in predicting the volumes of future landslides descending any particular drainage.

Hazard zones generated using these methods appear to be comparable to those generated by traditional field mapping techniques but are objective and reproducible.

6.0 FIELD TRIPS AND FIELD TRIP GUIDE

On Friday April 27 and Saturday April 28, 2007 we led field trips. The first day consisted of eight stops in the Oregon City area (Figure 6.0-1). The second day consisted of four stops in Lincoln County (Figure 6.0-2). Day 2 field trip participants are shown in Figure 6.0-3.

The field trip guide is provided on the following pages.

Figure 6.0-1. Landslide symposium field trip day 1. (top left) Scott Burns talks about the Moxley Residence landslide. (top right) Lina Ma straddles a large crack at the Newell Creek Apartments landslide. (bottom left) Discussion of the Spady landslide. (bottom right) John Jenkins shows a map at the Beaver Lake landslide.

Figure 6.0-2. Landslide symposium field trip day 2. (top left) Al Niem and Scott Burns show a map of the geology of Lincoln County. (top right) Jon Allen and Rob Witter display a poster and talk about the landslide/beach erosion at the Stevens Street landslide. (bottom left) David Scofield talks about the Depoe Bay landslide. (bottom right) George Priest discusses the Johnson Creek landslide.

Figure 6.0-3. Group photo. Landslide symposium field trip day 1 stop at Sha Spady's.

Landslides in Oregon City and Coastal Lincoln County, Oregon

2007 Landslide Symposium Field Trip Guide, April 27-28

by Scott Burns[1], William Burns[2], and Jason Hinkle[3]

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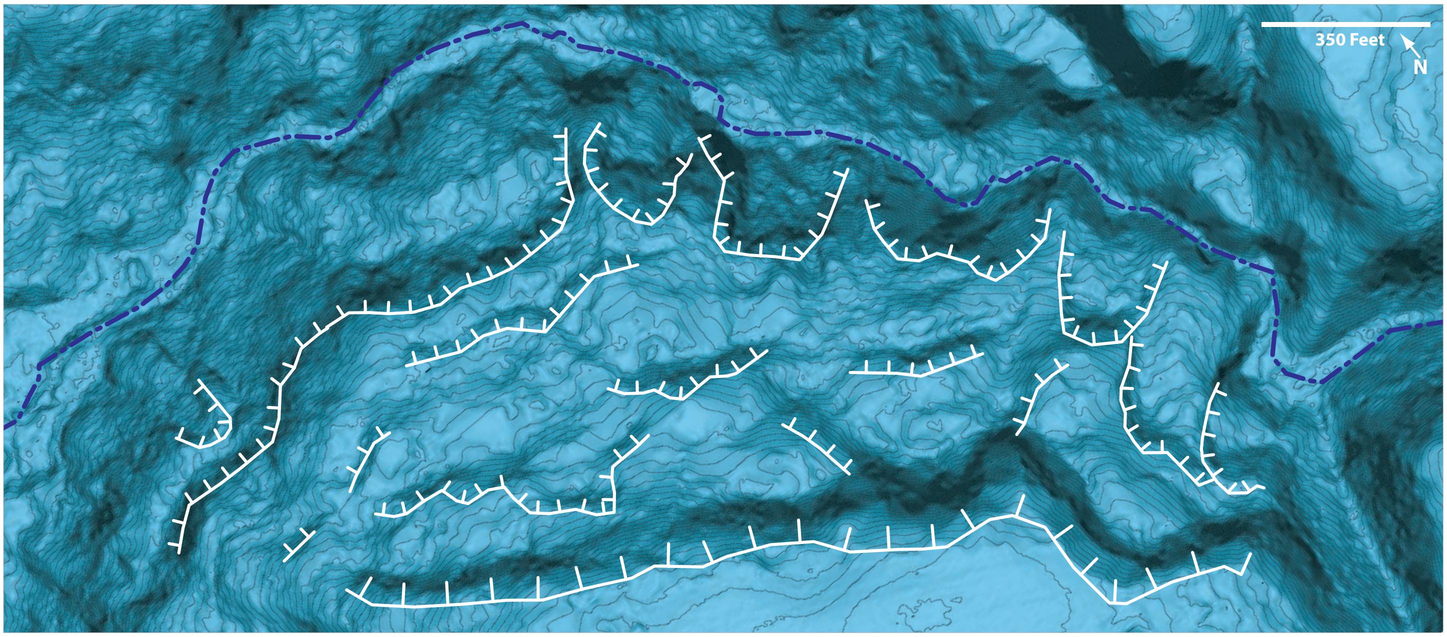

LIDAR-derived digital elevation model draped over a slope map showing a large landslide in the Oregon City area. Contour interval is 3 ft. White hashed lines indicate the headscarp and internal scarps; dot-dash blue line is an intermittent stream.

CONTENTS

Overview. Many parts of Oregon are highly susceptible to landslides. Landslides pose significant threats to people and infrastructure particularly in the portions of the state with moderate to steep slopes. As population growth continues to expand and development into steeper terrain occurs, greater losses are likely to result. Most of Oregon's landslide damage has been associated with severe winter storms where landslide losses exceed $100 million in direct damage (such as the February 1996 event).

Annual average maintenance and repair costs for landslides in Oregon are over $10 million (Wang and others, 2002). Landslides induced by earthquake shaking are likely in many parts of Oregon, and losses associated with sliding in moderate-to-large earthquakes are likely to be significant. The purpose of this field trip guide is to help educate professionals and the public about the different types of landslides in the Oregon City area and along the coast in Lincoln County.

State of Oregon
Department of Geology and Mineral Industries
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DAY 1 —
LANDSLIDES IN AND AROUND OREGON CITY, OREGON

Landslides are a prominent hazard in the Oregon City, Oregon, area. Several landslide studies and maps exist for the area, including those by Hammond and others (1974), Schlicker and Finlayson (1979), and recently Madin and Burns (2006).

During 1996 and 1997, heavier than normal rains in Oregon caused thousands of landslides. Over 700 of these landslides were mapped in the Portland metropolitan area (Burns and others, 1998). Some of these slides were the reactivation of ancient and historically active landslides, and some were new failures. Many of these slides occurred within the Oregon City area; an inventory of these landslides was prepared by Burns and others (1998) for the Portland METRO (Madin and Burns, 2006)

During the 2005-06 winter season, Portland and most of western Oregon again experienced heavier than normal rainfall, which resulted in hundreds of landslides. Again, many of the landslides were reactivations of older landslides, making the identification of these existing ancient and historic landslides an obvious priority in the attempt to begin the reduction of the risk from landslides. Several of these reactivated landslides occurred in the Oregon City area, impacting infrastructure as well as several residential homes and an apartment complex (Madin and Burns, 2006).

The Day 1 field trip comprises eight stops in the Oregon City area (Figure 1).

The stratigraphy of the Oregon City area consists of generally flat-lying Miocene to Pleistocene basalts and fluvial sediments. Bedrock in the area for engineering purposes includes the Columbia River Basalt Group, which is overlain by the Troutdale Formation. The Troutdale Formation is topped in some places by the Boring Lavas and/or the Willamette Silts (Figure 2 and Figure 3).

The oldest rocks exposed in the area are the middle Miocene Columbia River Basalt Group (CRBG). This basalt is a series of lava flows or flood basalts 5–45 m thick, with a total thickness of about 300 m (Schlicker and Finlayson, 1979; Tolan and Beeson, 1984). Thin, baked soil zones often separate individual flows. The Miocene-Pleistocene fluvial sedimentary rocks, consisting mainly of the Springwater Formation and the Troutdale Forma-

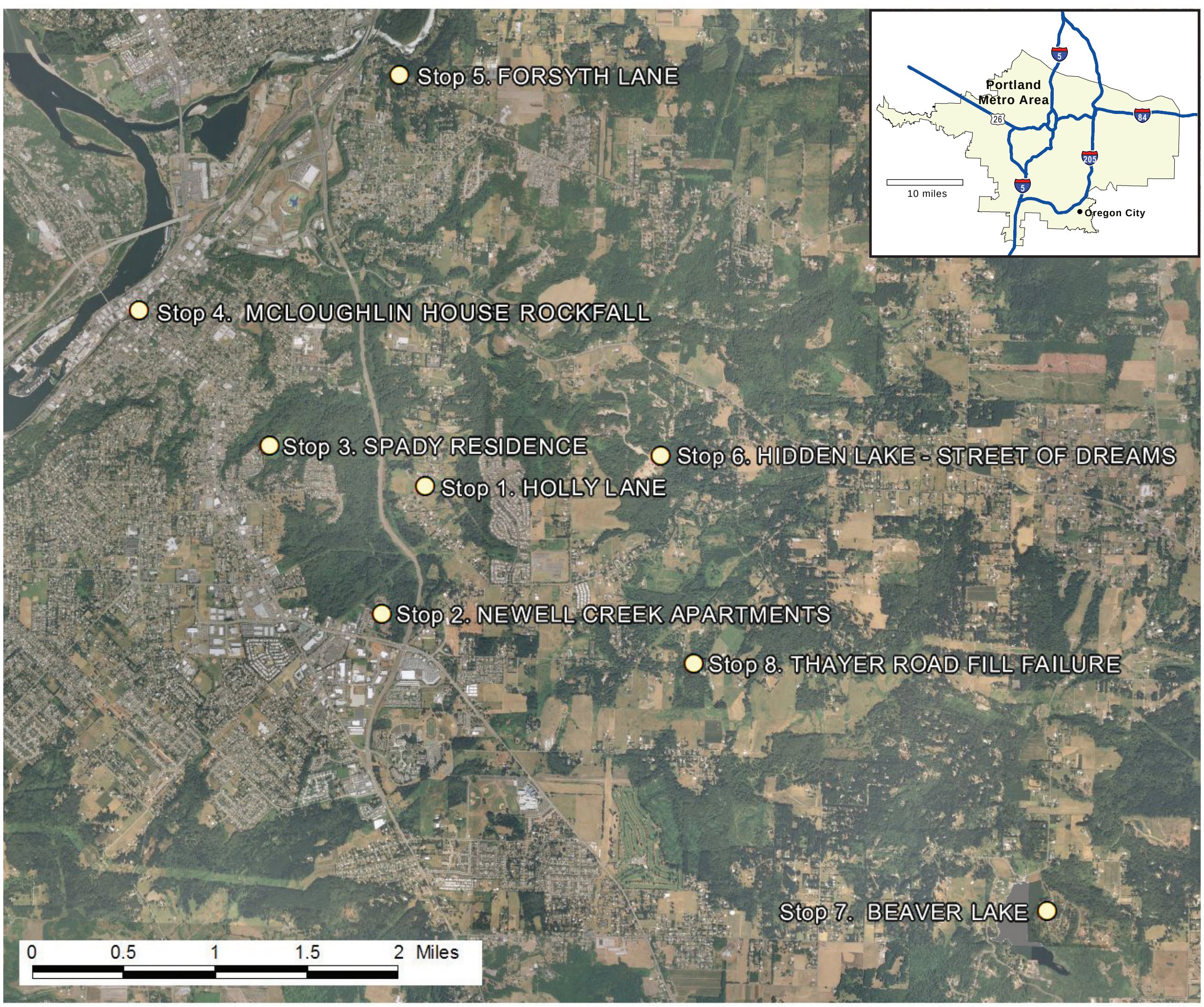


Figure 1. Locations (yellow dots) of Day 1 field trip stops. Inset map shows location of Oregon City relative to Portland metro area.

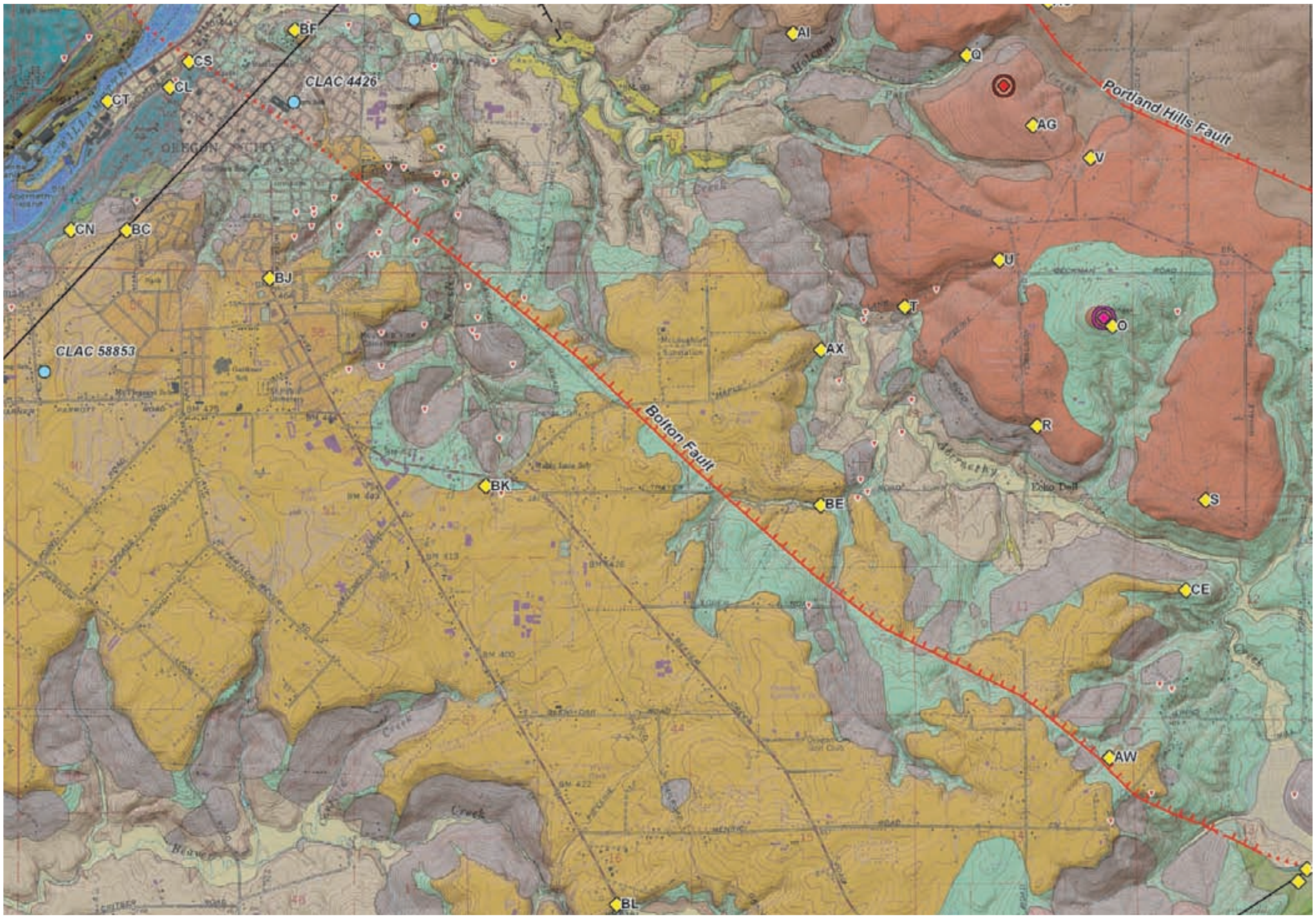
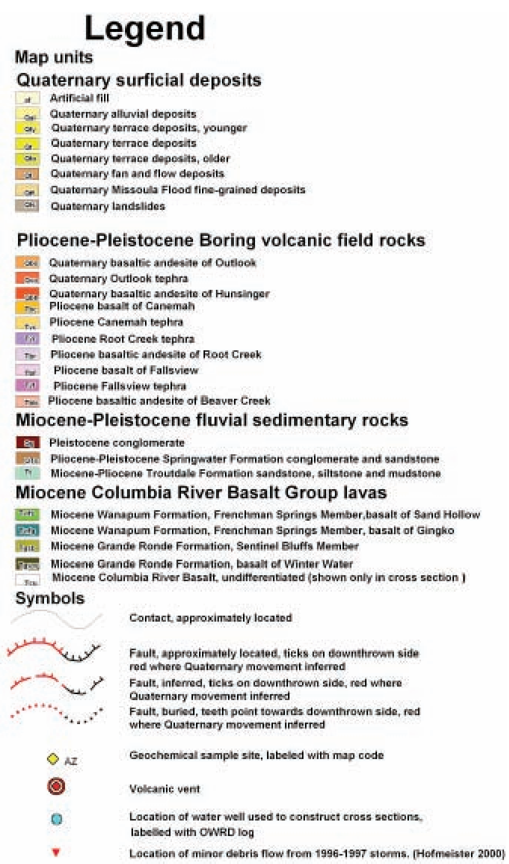


Figure 2. Portion of the geologic map of the Oregon City quadrangle, Clackamas county, Oregon (Madin, in preparation).



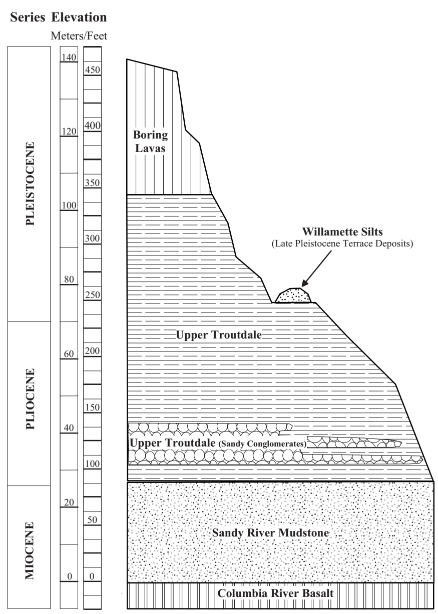


Figure 3. Generalized stratigraphy of Newell Creek Canyon, Oregon City, Oregon (Burns, 1999).

tion (Sandy River Mudstone), unconformably overlie the CRBG. The Springwater Formation consists mostly of pebble, cobble, and boulder conglomerate; the Troutdale Formation is largely mudstone, claystone, sandstone, and minor conglomerate and tuff. These sedimentary rocks are overlain by Pliocene-Pleistocene Boring volcanic field rocks. The Boring lavas are typically massive, with jointing restricted to well developed to crude columns. Weathering along the joint faces typically leads to the development of spheroidal weathering into large, rounded corestones in a matrix of red clay. Intact weathered basalt is typically soft and grey, white or pink, with abundant red clay coatings on joint faces. Quaternary surficial deposits, ranging from active channels and flood plains of rivers and streams to Missoula (Bretz) Flood Deposits (latest Pleistocene) consisting of silt, sand, and minor gravel, blanket the lower lying areas (Madin, in preparation; Burns, 1999).

STOP 1-1
MOXLEY RESIDENCE, HOLLY LANE

PRIVATE PROPERTY - DO NOT ENTER
WITHOUT OWNER'S PERMISSION

In February 1996 over 25 cm of rain fell in four days, reactivating an ancient landslide (Figure 4) in the fine-grained Troutdale Formation (Burns, 1998; Burns and others, 1998). Four homes had been built along the headscarp — three across the headscarp with daylight basements and one just below the scarp at the north end. After reactivation, the foundations of the homes on the scarp developed cracks over 10 cm wide (Figure 5). The scarp dropped 60 cm the first winter. Movement was also noted at the bottom of the slide. In summer 1996 the owner of the southernmost home on the scarp patched up the house, sold it to Rod Moxley (without any disclosure of the landslide problems), and moved to Utah.

A second large rainfall event in December 1996 caused another drop of 60 cm in the scarp and a widening of the cracks in the foundations to over 40 cm. The three homes were destroyed. Over $1 million in damage had occurred.

The home at the north end was below the scarp. The owner put in many wells surrounding the home to help stabilization after he rebuilt the foundation. The two middle homes were moved back on the property to the west, away from the scarp, and were rebuilt. The original Moxley home was abandoned and a new home was built on the western edge of the property. A large drainage system was installed below the Moxley home.

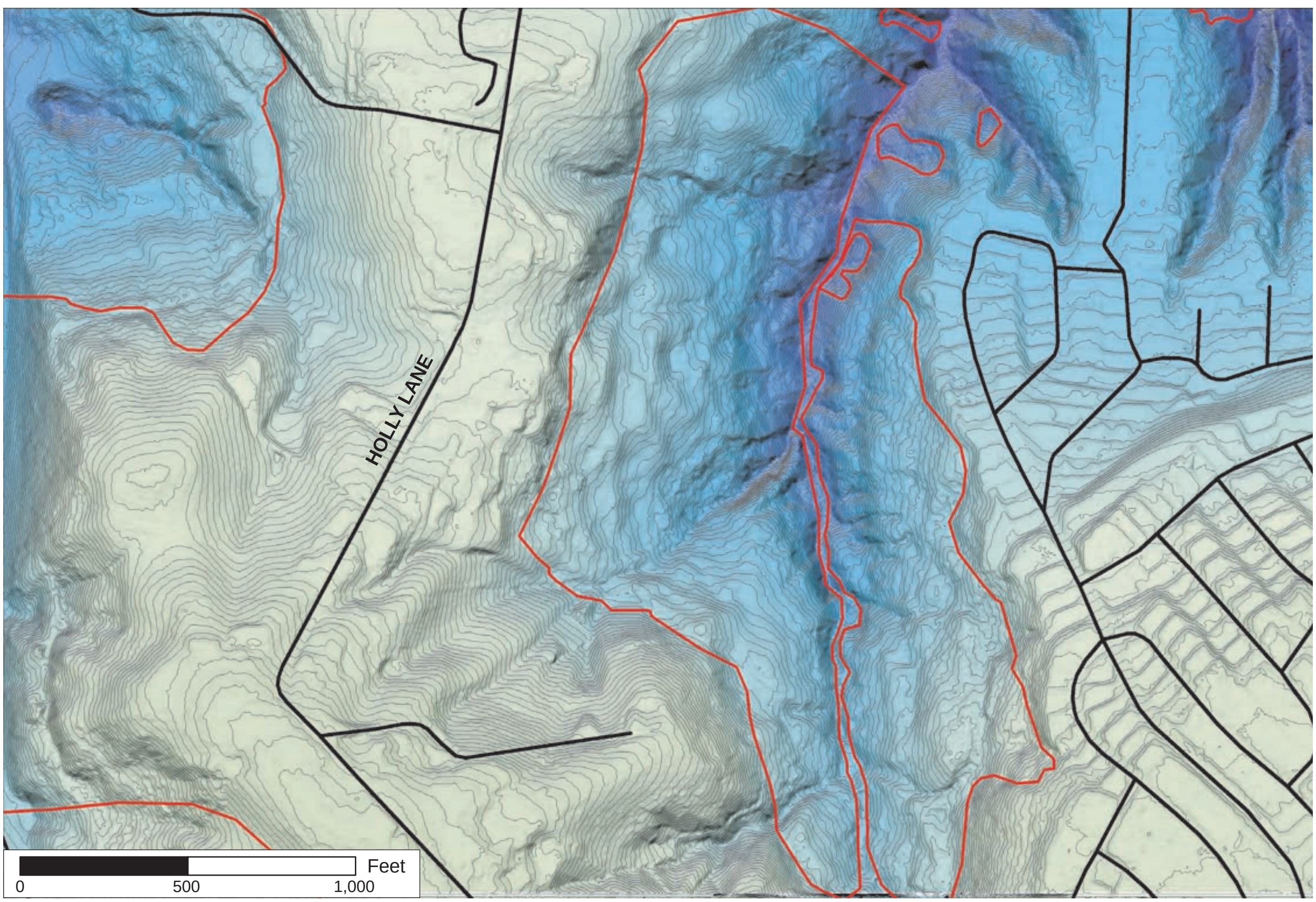


Figure 4. Holly Lane landslide. The image consists of a LIDAR-derived digital elevation model draped over a slope map. Tan color indicates higher elevation; blue color indicates lower elevation. Contour interval is 3 ft. Slide extent is shown by the red outline. Black lines are streets.

Figure 5. Photographs of the Moxley House in 1996: (top) cracks in foundation,
(middle) movement along the toe of the landslide,
(bottom) head scarp across driveway.

STOP 1-2
NEWELL CREEK APARTMENTS, HIGHWAY 213 AND BEAVER CREEK ROAD

The 25 cm of rainfall in December 2005 reactivated an ancient landslide complex at the head of Newell Canyon (south end) at the site of the Newell Creek Apartments. A 1993 study (Burns, 1993) recommended that the site not be developed because the site was on an ancient landslide that could reactivate (Figure 6). Nevertheless, the proposed apartment complex was built in 1996. The northern slump, in the fine-grained Troutdale Formation, began moving in December 2005. Broken water and sewer lines in December 2005 between the two ancient slides alerted owners to the initial movement. Significant movement was noted by mid January 2006 (Figure 7). By winter 2006 the scarp at the north end of the property was about 4 m high. Inclinometers were installed. The slide stopped moving in summer but started again in November 2006, when the area received over 25 cm of rainfall. Scarp height is now 8 m (Figure 8). It is very expensive to mitigate these slides once they start to move.

The eight apartments in the structure just above the scarp at the north end remain empty, while the building owner decides what to do. The structures on the northern slide were evacuated in winter 2006 but are occupied today.

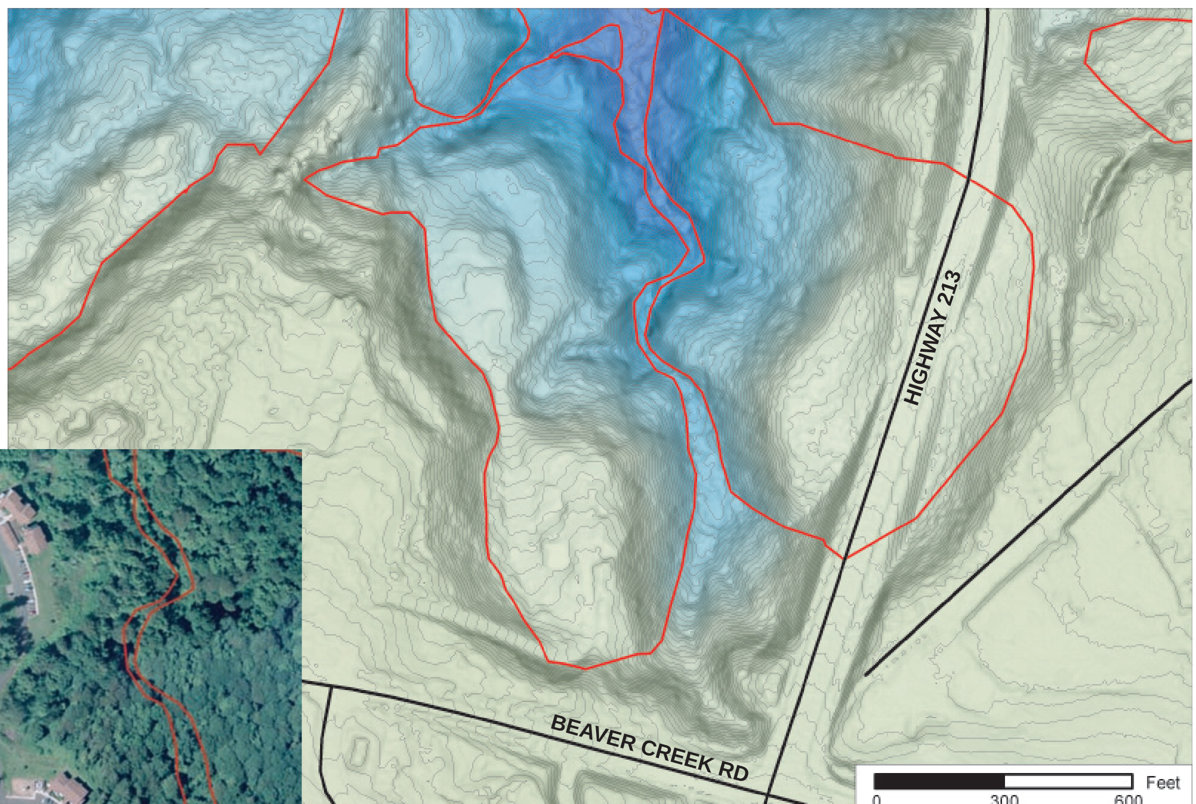


Figure 6. (top) Newell Creek Canyon Apartments landslide. The image consists of a LIDAR-derived digital elevation model draped over a slope map. Tan color indicates higher elevation; blue color indicates lower elevation. Contour interval is 3 ft. Slide extent is shown by the red outline. Black lines are streets. (middle left) Aerial photograph of apartment complex. (middle bottom) Close-up of north end of complex.

Figure 7. Photographs of Newell Creek Canyon Apartments in winter 2005, just after the landslide reactivated. (top left) Right flank of slide between the two apartment complexes. (top right) Central portion of the slide. (left) The beginning of a graben along the backside of the slide just below the ancient head scarp.

Figure 8. Photographs showing scarps along the crest of the toe of the large Newell Creek Apartment landslide from (left) 2006 and (right) 2007.

STOP 1-3
SPADY RESIDENCE, CASCADE AVENUE AND MAGNOLIA STREET

PRIVATE PROPERTY - DO NOT ENTER WITHOUT OWNER'S PERMISSION

This landslide occurred in many phases on a slope in the fine-grained Troutdale Formation. In February 2006 the earthflow began (Figure 9). It stabilized over the summer, but the following winter it increased in size (Figure 10). It increased in area almost 5 times (Figure 9 and Figure 10). It also developed into a debris flow downstream (Figure 10 and Figure 11) and ponded the adjacent channel. At this site we will also visit a landslide that occurred in an abandoned garbage dump. It is a classic earthflow with levees on the edges. It has been stabilized by a cutoff trench at the top of the slide. It showed movement at the toe in 1996 (Figure 11).

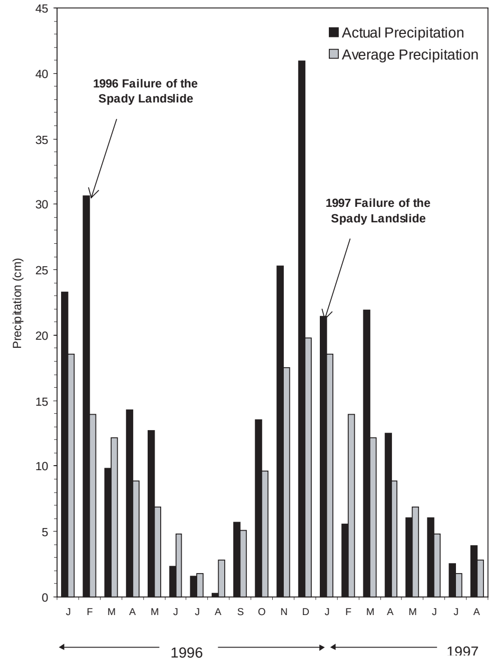


Figure 9. Histogram of monthly precipitation for Oregon City from 1996 to 1997 (August) (Burns, 1998).

Figure 10. (top) Photograph of the head scarp Spady residence landslide after the 1996 activity Plane table survey rod is 4.572 m (15 ft) high. (bottom) Photograph of the scarp after enlargement during 1997.

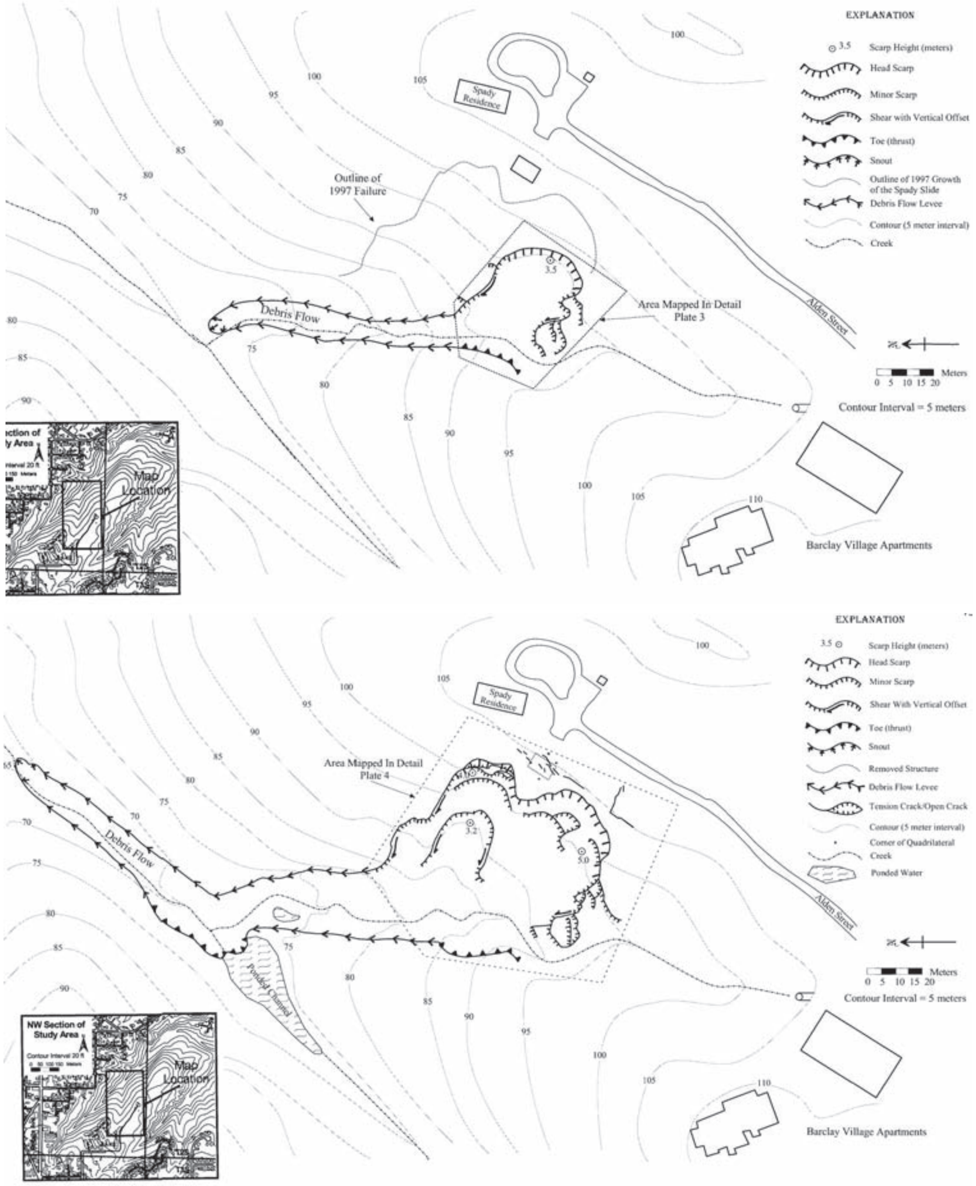


Figure 10. Detailed maps of the (top) 1996 Spady landslide and (bottom) 1997 Spady landslide (Burns, 1998). Diagrams include the debris flow section of the landslide and the ponded adjacent channel.

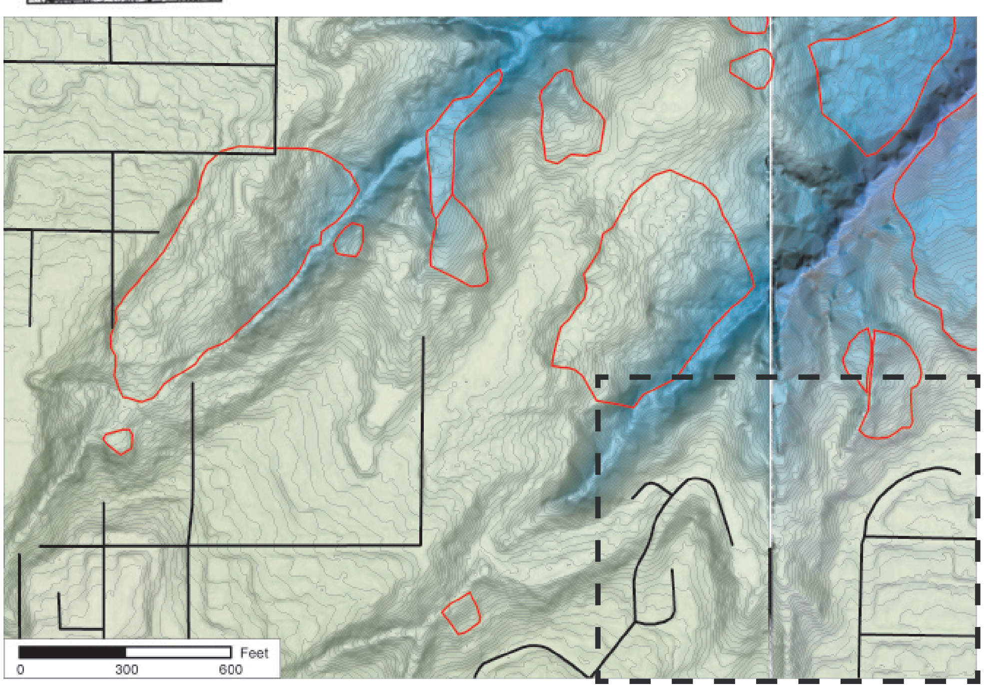


Figure 11. Spady property landslide. The image consists of a LIDAR-derived digital elevation model draped over a slope map. Tan color indicates higher elevation; blue color indicates lower elevation. Contour interval is 3 ft. Dashed area indicates an area of overlap with Figure 12. Slide extent is shown by the red outline. Black lines are streets.

(*Stop 1-3, continued*)

Directly east of the Spady stop is a portion of a housing development in the Barclay Hills subdivision built on an ancient slide that reactivated in 1996. The toe of the slide moved 25 cm (10 in) and disconnected the sewage pumping station (Figure 12 and Figure 13). The upper part of the slide shows movement at the headscarp (Figure 12 and Figure 13). In December 2006 a break in the storm water drainage system saturated the steep slopes. This caused the backyards of three homes at the end of Barclay Hills Drive to slide (Figure 12 and Figure 13).

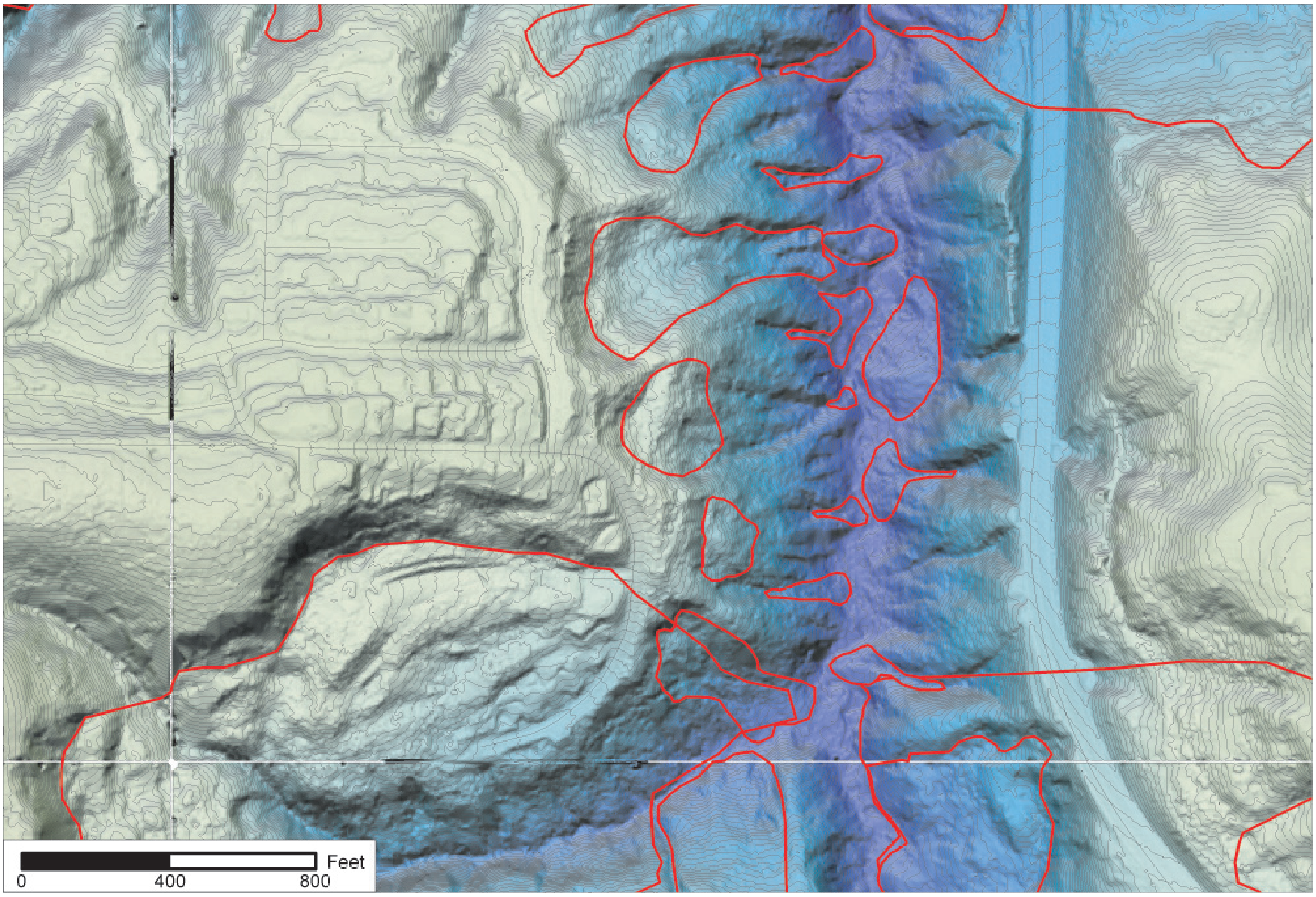
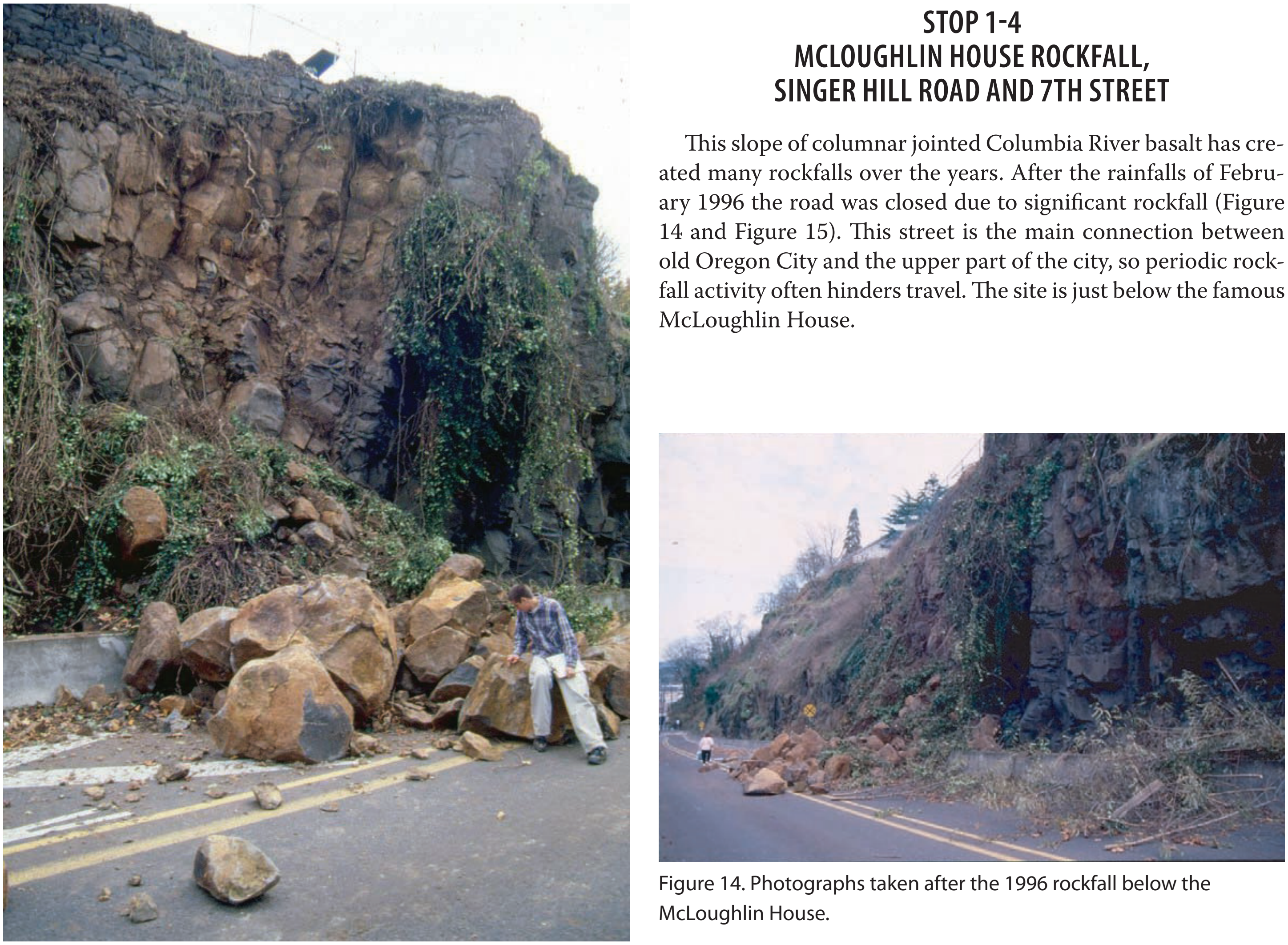


Figure 12. Barclay Hills subdivision. The image consists of a LIDAR-derived digital elevation model draped over a slope map. Tan color indicates higher elevation; blue color indicates lower elevation. Contour interval is 3 ft. Slide extent is shown by the red outline.

Figure 13. Barclay Hills subdivision. (left) In 1996 the toe of the slide moved 25 cm (10 in) and disconnected the sewage pumping station. (center) Upper part of the slide shows movement at the scarp. (right) In December 2006 the backyards of three homes at the end of Barclay Hills Drive slid away.



STOP 1-4
MCLOUGHLIN HOUSE ROCKFALL, SINGER HILL ROAD AND 7TH STREET

This slope of columnar jointed Columbia River basalt has created many rockfalls over the years. After the rainfalls of February 1996 the road was closed due to significant rockfall (Figure 14 and Figure 15). This street is the main connection between old Oregon City and the upper part of the city, so periodic rockfall activity often hinders travel. The site is just below the famous McLoughlin House.

Figure 14. Photographs taken after the 1996 rockfall below the McLoughlin House.

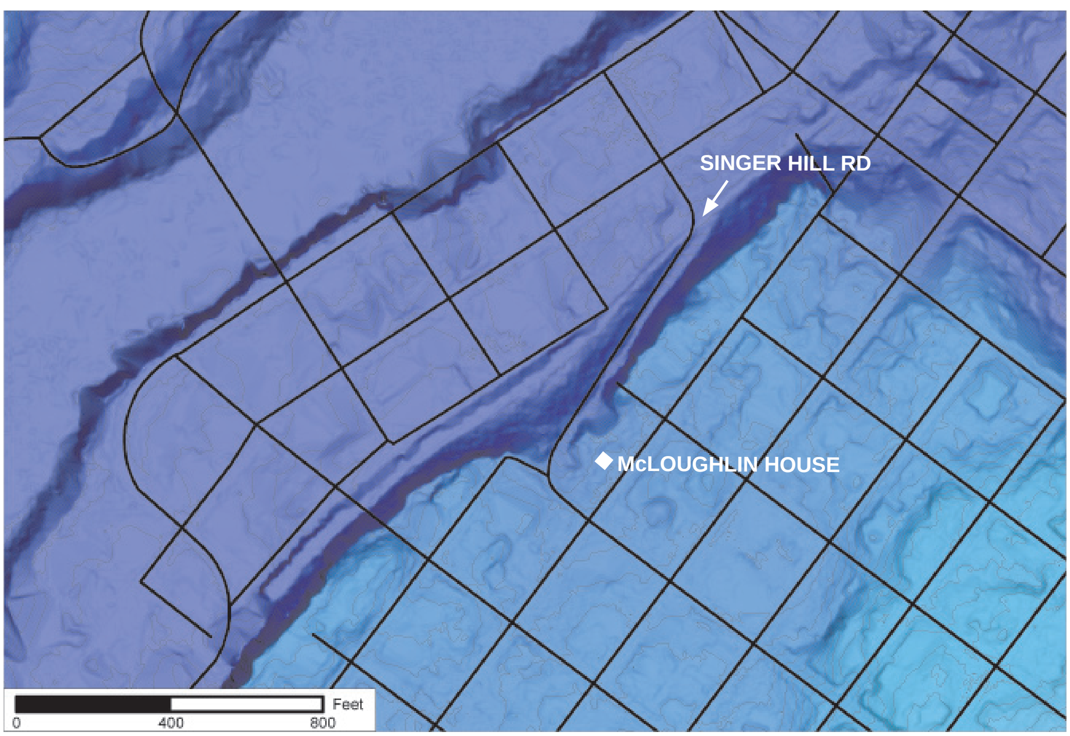


Figure 15. McLoughlin House rock fall area. The image consists of a LIDAR-derived digital elevation model draped over a slope map. Blue color indicates higher elevation; purple color indicates lower elevation. Contour interval is 3 ft. Black lines are streets.

STOP 1-5
FORSYTHE LANE LANDSLIDE, FORSYTHE LANE

This large landslide occurred on the bluffs above the Clackamas River in 1996 and lies above the water intake valve for the city of Oregon City on the river (Figure 16 and Figure 17). This was one of the largest landslides in Clackamas County that winter. It cost more than a million dollars to mitigate this site.

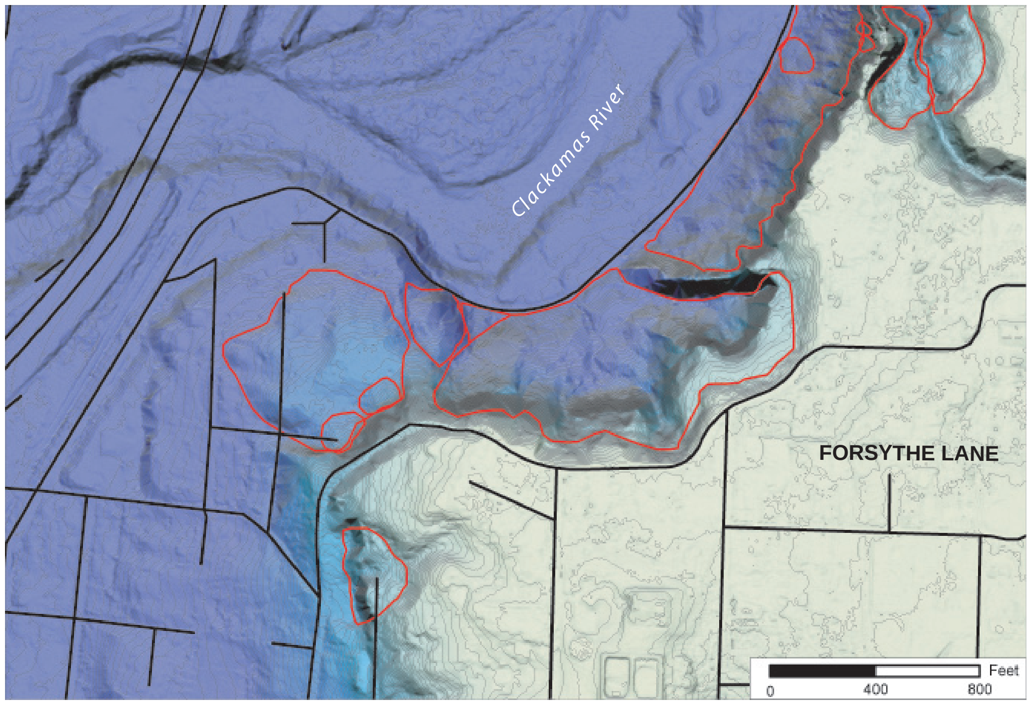


Figure 16. Forsythe Lane landslide area. The image consists of a LIDAR-derived digital elevation model draped over a slope map. Tan color indicates higher elevation; blue color indicates lower elevation. Contour interval is 3 ft. Slide extent is shown by the red outline. Black lines are streets.

Figure 17. Photograph of Forsythe Road landslide during repair in 1997.

STOP 1-6
HIDDEN LAKES (STREET OF DREAMS) LANDSLIDE

In the winter of 2007, two of the home sites in the 2004 and 2006 Street of Dreams had landslide problems. The whole development is located on an ancient landslide (Figure 18) described by Madin and Burns (2006). Fear was that the whole landslide had reactivated and these multimillion dollar homes were all moving. When these ancient landslides reactivate, they first show movement at the headscarp and the toe. The two homes with problems were at the toe.

The two homes experiencing landslide-related damage along the toe of the large, ancient landslide are both are on slope that end in Abernethy Creek in a meander bend. The creek had cut off the toes of both slopes. The Moxie House lost its backyard of fill (and a septic tank and leaching field) to a slide that had been undercut by the stream (Figure 19). The septic tank has been moved.

The neighboring Romeo and Juliet house had bigger problems. A large crack cut through the driveway and into the house (Figure 19).

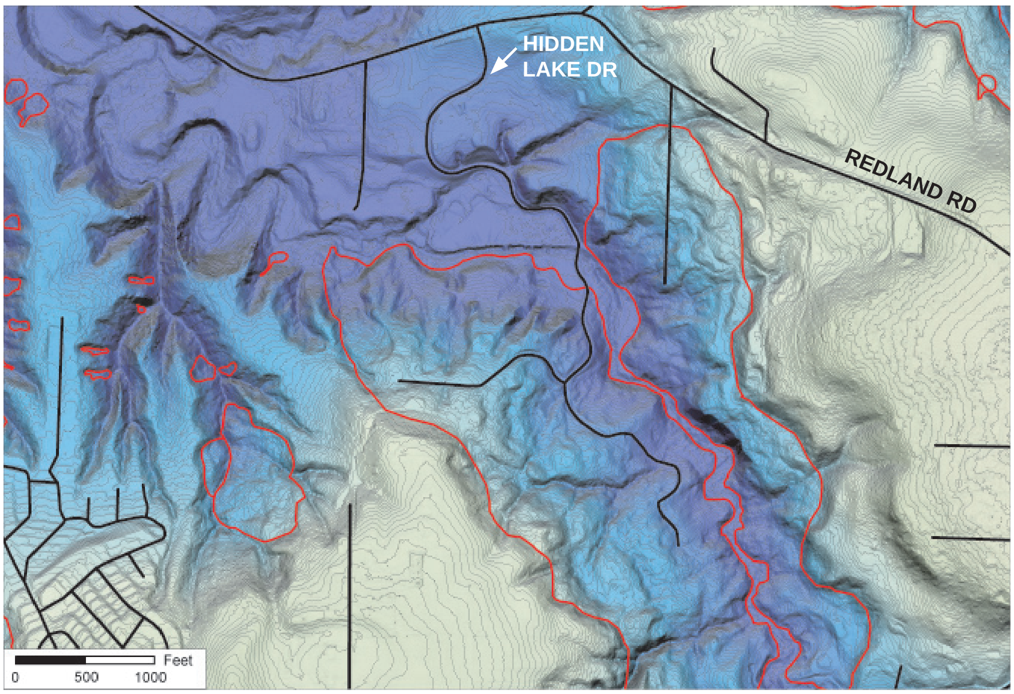


Figure 18. Hidden Lakes Estates area. The image consists of a LIDAR-derived digital elevation model draped over a slope map. Tan color indicates higher elevation; blue color indicates lower elevation. Contour interval is 3 ft. Slide extent is shown by the red outline. Black lines are streets.

Figure 19. Site photographs of two homes in the Hidden Lakes Estates in 2007. (left) Slopes below the two house leading down to the creek. (right) Cracks in the driveway of the Romeo and Juliet house.

STOP 1-7
BEAVER LAKE LANDSLIDE, SOUTH HENRICI ROAD

After many years of trying to get building permits for this development, the county granted permits for the Beaver Lake area in 1995. The roads were put in, and a dam was built to create Beaver Lake (Figure 20). Clay-rich soil was removed from the slope to make the dam. It was not noted that in removing the soil from the toe of the slope, the toe of an ancient landslide was also removed. When the heavy rains of February 1996 came, the slide reactivated and created a 1.5-m scarp across four lots (Figure 20). No homes had been built on the site. The home sites were selling for $200,000 per lot.

The county put a moratorium on building at the site. It finally allowed building on other parts of the development not on the ancient landslide. Now, with the use of a shear key, the ancient slide is said to be stabilized and homes are now planned for the site.

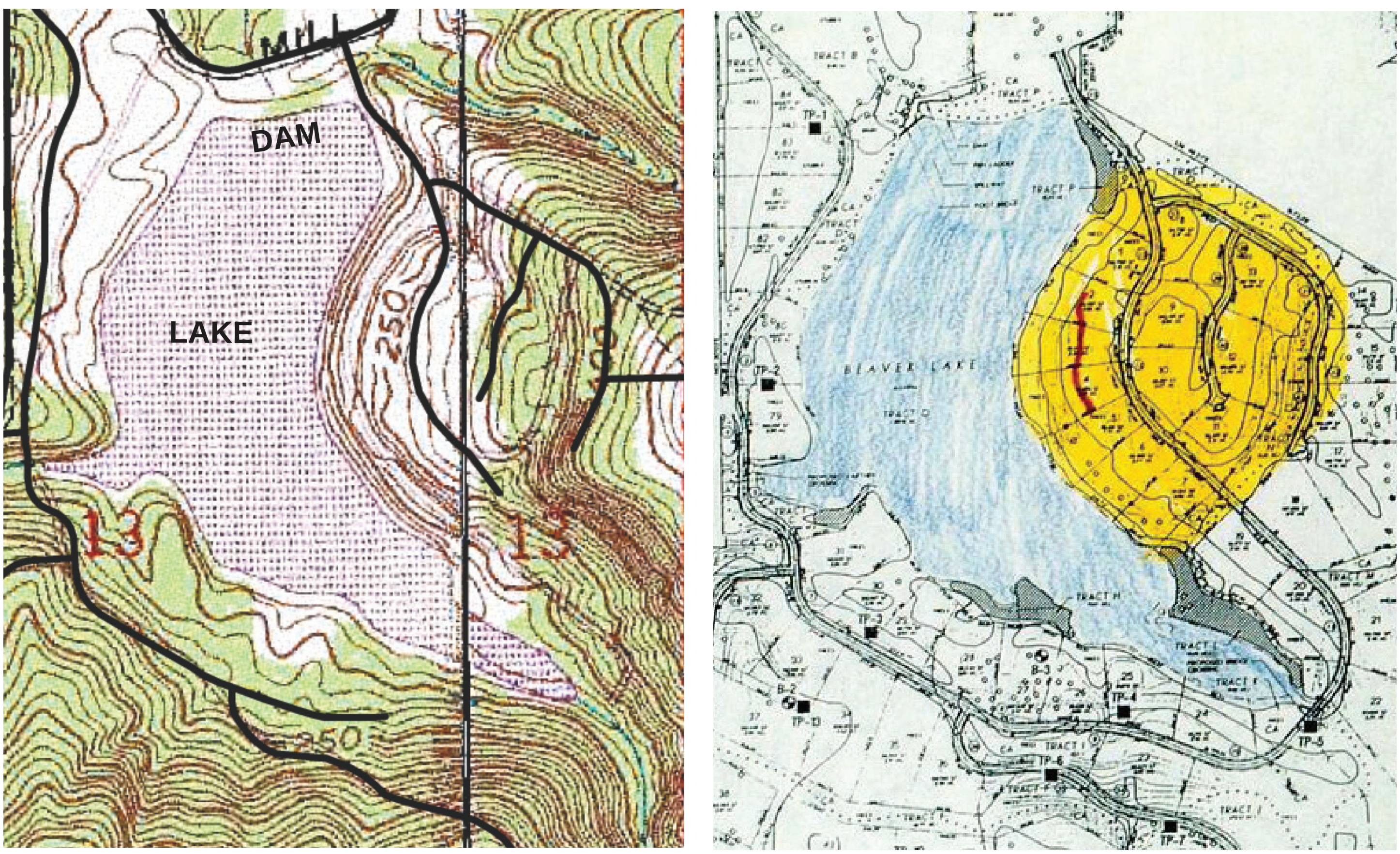


Figure 20. (left) Map of the Beaver Lake Estates area, showing man-made lake. (right) Landslide scarp (red line) crosses four lots.

STOP 1-8
THAYER ROAD FILL FAILURE

This road is closed. The fill on this road failed in the rains of February 1996. The road was rebuilt but failed again in winter 2006 after the rains of December 2005. The fill was rebuilt but is again showing signs of movement (Figure 21 and Figure 22). The county has remained closed.

What happened? The fill did fail, but it is because it is on an ancient slide that reactivated in 1996 and took the fill and the road on top with it. Again in the winter of 2005-2006 the ancient slide reactivated, and the road was destroyed.

Figure 21. Aerial photograph of Thayer Road area.

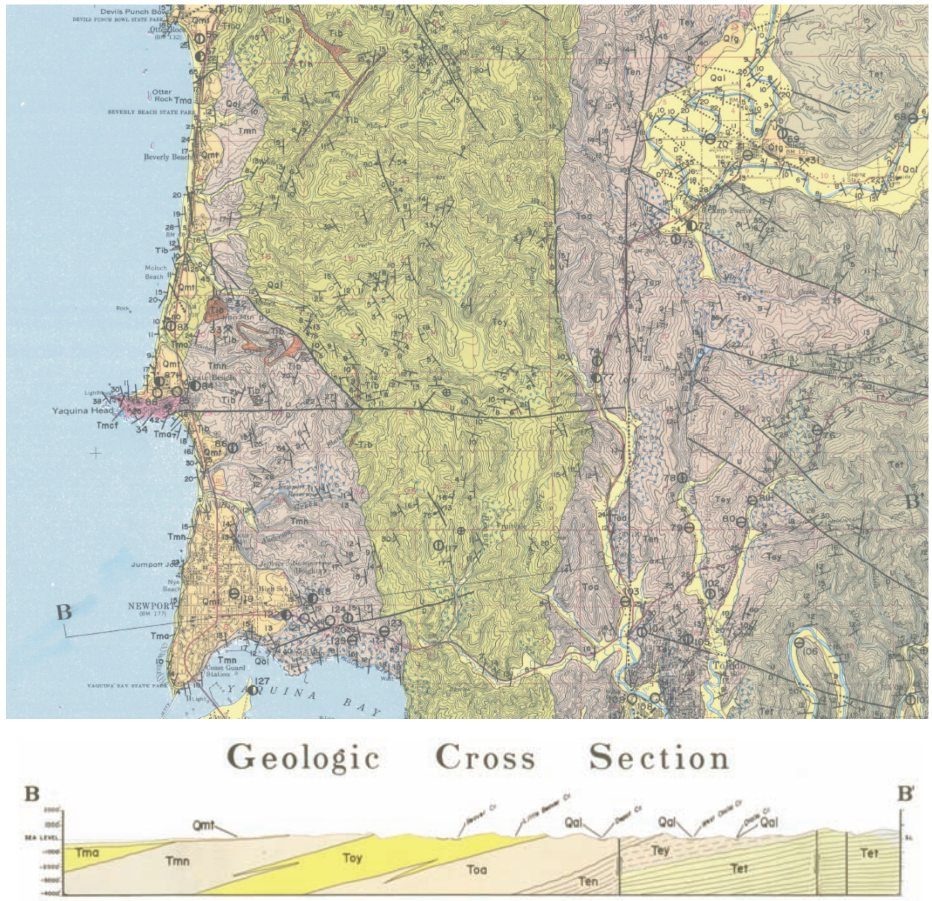
Figure 22. Site photographs in 2007 show fill failure just one month after the road was repaired for the third time.

DAY 2 —
COASTAL LANDSLIDES IN LINCOLN COUNTY, OREGON

Landslides are a prominent hazard along the Oregon Coast. This field trip focuses on four landslides (Figure 23).

The geology of the Oregon Coast in Lincoln county is generally made up of indurated rock ranging from Eocene to Middle Miocene overlain by unconsolidated Quaternary age deposits (Figure 24; Schlicker and others, 1973). The consolidated units include submarine and subaerial basalt flows, breccia, tuff, marine siltstone, clayey siltstone, sandstone, and intrusive rocks. The two most extensive units in Lincoln county are the Siletz River Volcanics and the Tyee Formation. As shown in cross-section B-B', most of the units dip toward the coast. As a result, many of the large translational landslides have failure planes related to this general structural trend.

Figure 23. Day 2 overview map.



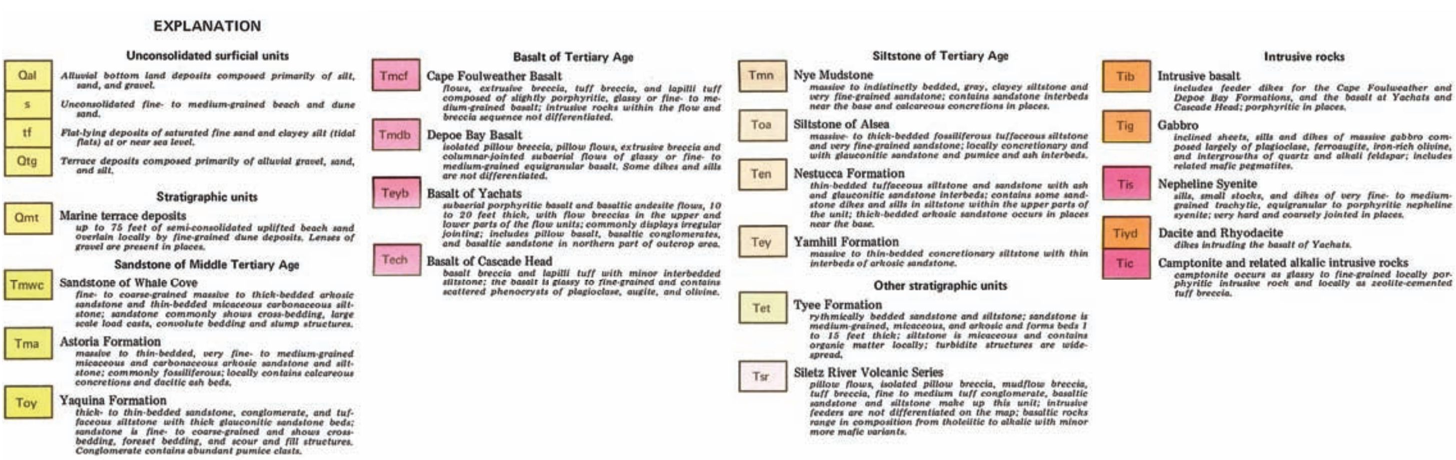


Figure 24. Portion of the geologic map of the Yaquina River section of Lincoln county, Oregon (Schlicker and others, 1973, plate 5).

STOP 2-1
STEVENS STREET LANDSLIDE, GLENEDEN BEACH

In November 2006 over 25 cm of rain fell at the coast. In addition, huge storms to the southwest unleashed massive waves on the coast. Sand on the beach at Gleneden Beach moved off shore because of the storms, and, at high tide, waves hit the sea cliff. Many homes had rip-rap at the base, but three homes at the end of Stevens Street did not (Figure 25). These properties lost 5 m of cliff in front of their homes in a week. We will visit these properties by walking along the beach from the state park.

Mitigation was twofold. First, rockfill was put in front of the three homes to give them back 5 m of cliff (Figure 26). Then, rip-rap was put at the base to protect the slopes.

Figure 26. Site photograph in 2007 of rockfill and rip-rap along the beach (western) side.

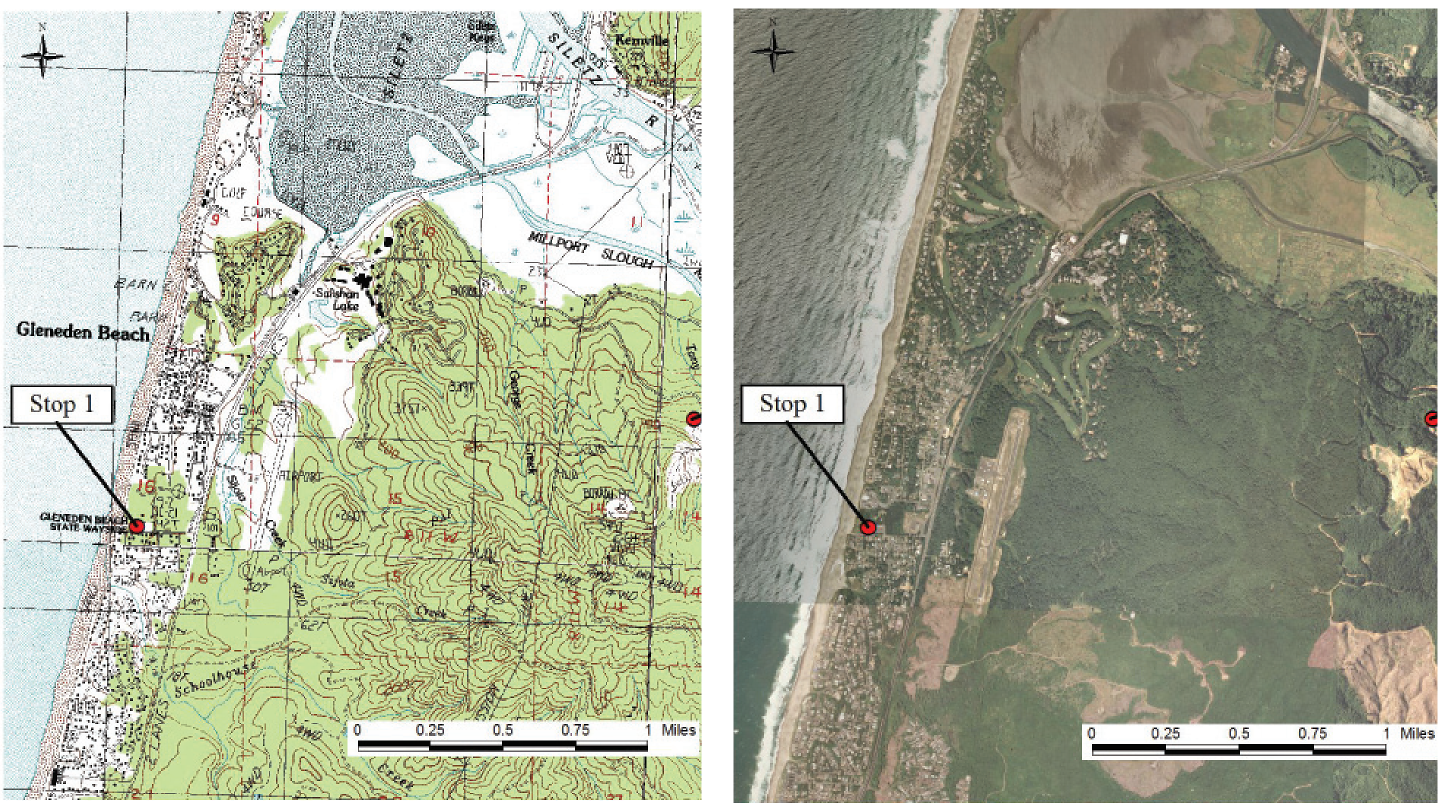


Figure 25. (left) Map of the Gleneden Beach location and (right) orthophoto of the site in Gleneden Beach.

STOP 2-2
DEPOE BAY RETAINING WALL LANDSLIDE

The following text is taken directly from the U.S. Army Corps of Engineers Decision Document, Depoe Bay Retaining Wall Landslide, Depoe Bay, OR (USACE, 2003). Figure references have been added.

The Depoe Bay harbor was improved in 1939 by the Corps of Engineers and then further enlarged to its current configuration in 1952, during which time the 750-foot long retaining wall was constructed [Figure 27]. Movement of the southern 300 feet of the retaining wall began shortly after construction. The wall continued to translate and rotate through the late 1980s and its movement appeared to accelerate in the early 1990s. By 1993, the southern end of the wall had moved about 3 feet horizontally and 0.5-foot vertically downward. In the early 1990s, geotechnical investigations were conducted on the wall and foundation. Repairs conducted on the wall in 1996, based on information obtained from the initial investigation, did not stop the wall from moving. Subsequent investigations revealed a landslide was the cause of the wall movement [Figure 28 and Figure 29].

Though an exact cause of the slide mass and movement cannot be precisely determined, any one of the following activities/events, individually or in combination, are likely candidates.

- Deepening of the harbor, which removed toe support of the marginally stable slopes.
- Construction activities surrounding the retaining wall and/or check dam.
- Excessive precipitation.

The landslide extends approximately 350 feet upslope of the retaining wall (east-west direction) and approximately 500 feet in the north-south direction. The check dam, approximately 300 feet southeast of the retaining wall, is exhibiting distress consistent with slide movement. A slope inclinometer located near the structure shows some fairly shallow displacement, indicating that it is probably close to the approximate southern boundary.

The slide mass movement is impacting the moorage basin as the wall continues its translation and rotation. The bay front parking lot and sidewalk show significant signs of distress due to the wall movement. City officials have expressed concerns regarding the impact of the slide on existing underground utilities such as sewer and water. Property owners in the area have expressed concern regarding impact to their property values as a result of the wall movement. Damage to buildings has likely occurred and will continue to occur if the movement is not stabilized.

Four conceptual remedial alternatives were considered to stabilize both the slide mass and retaining wall, as well as a no action alternative. The selected plan, installing a shear pile wall, thoroughly satisfied all the criteria considered. The criteria included stabilizing the movement of the slide mass impacting the retaining wall; adaptability of design to extend beyond the south end of the wall, if necessary; minimizing environmental impacts to coastal resources; ease of construction; and minimizing long-term maintenance costs. The total construction cost for the selected plan is estimated at $2.4 million.

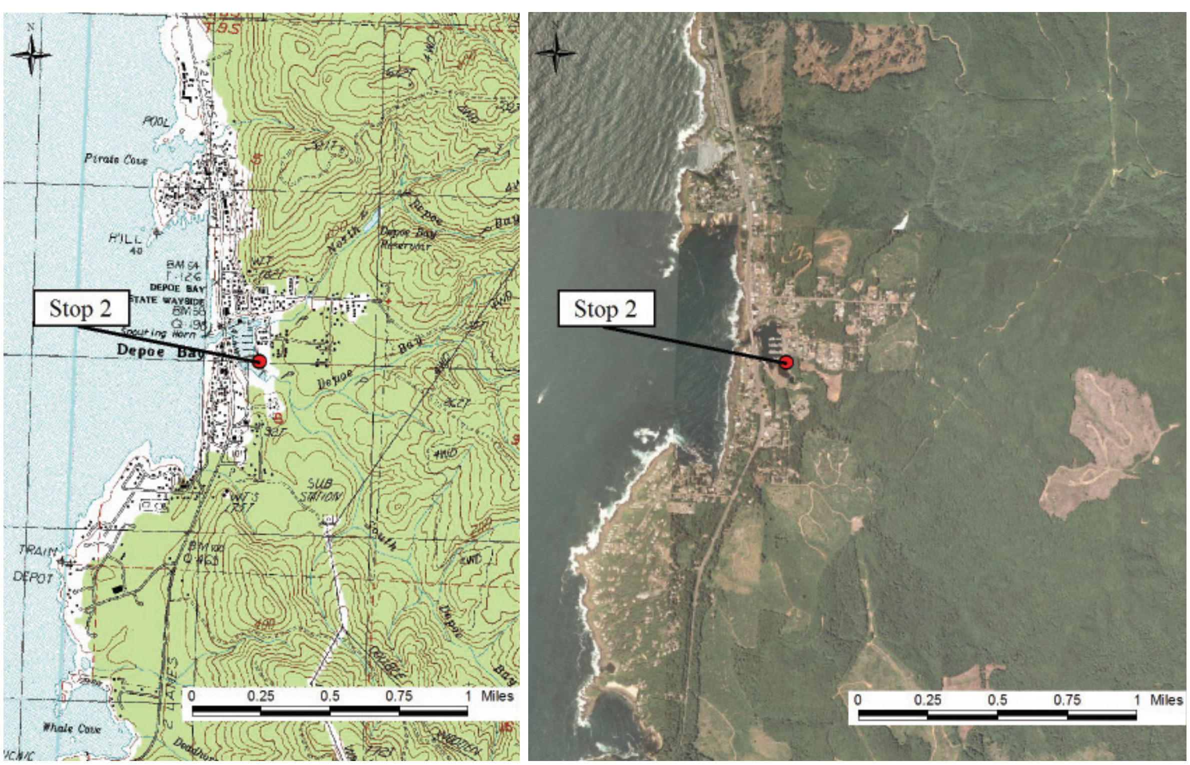
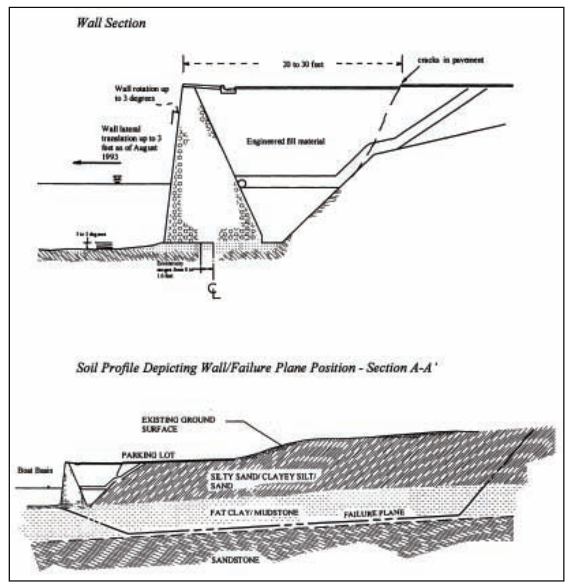


Figure 27. (left) Map of the location and (right) orthophoto of the site in Depoe Bay.

Figure 28. 1990s era site photograph of the Retaining Wall landslide at Depoe Bay.



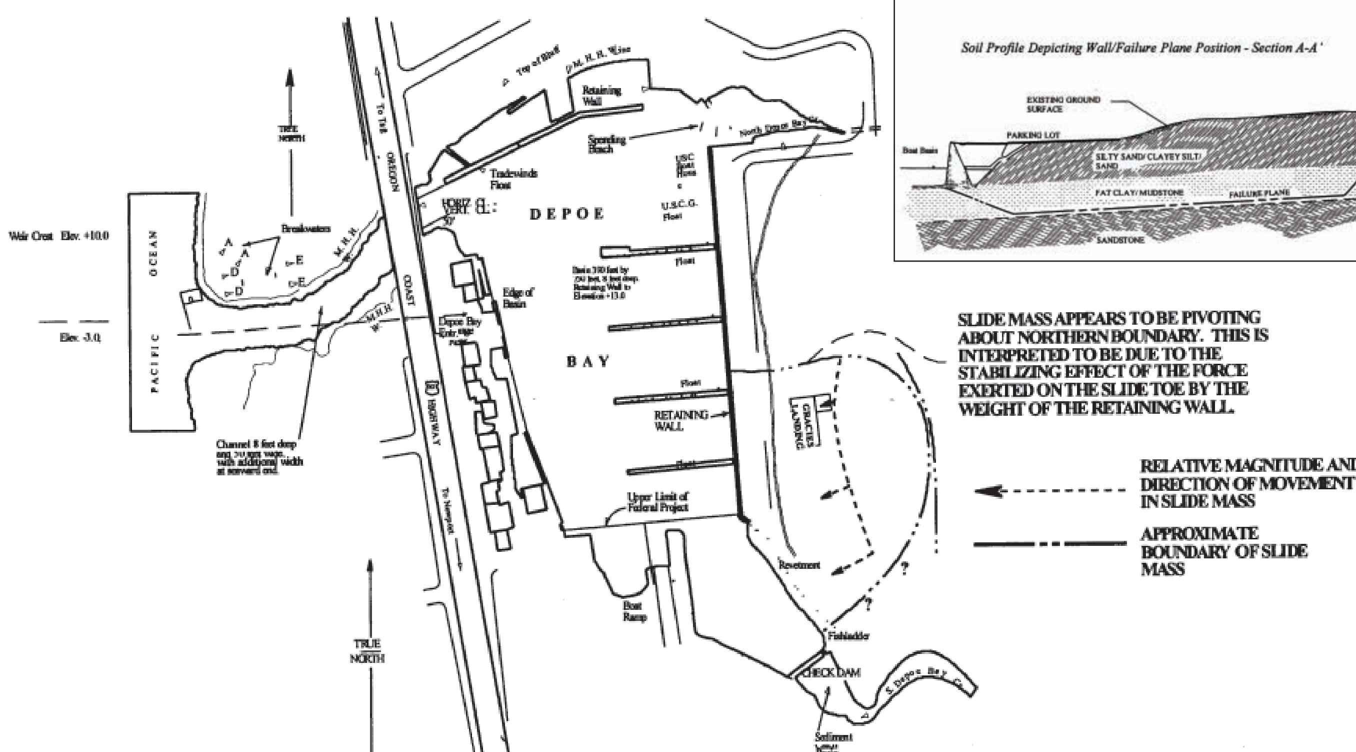
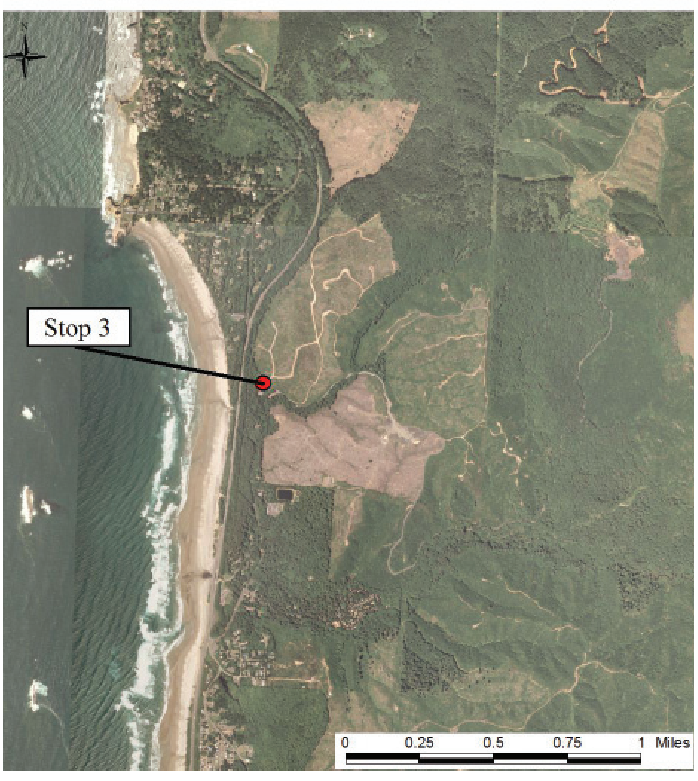


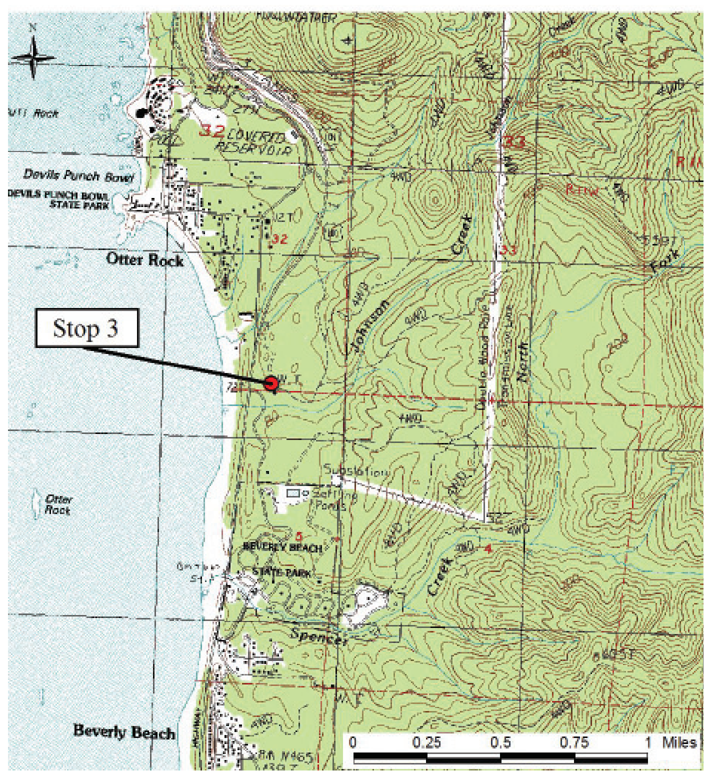
Figure 29. Site-specific map and cross-section of the Depoe Bay retaining wall landslide (USACE, 2003).

STOP 2-3
JOHNSON CREEK LANDSLIDE

The Johnson Creek landslide is a large translational slide in seaward-dipping siltstone and sandstone of the Tertiary Astoria Formation located just north of Newport, Oregon (Figure 30). The slide is representative of many large translational slides along the U.S. west coast. A 5-year research project started in the fall of 2002 is aimed at determining what makes the slide move and what are the most cost effective means of slowing or stopping it. The project is funded by the Oregon Department of Transportation (ODOT) Research Program, using Federal Highway Administration (FHWA) support (Priest and others, 2006). New research is also being led by members of the U.S. Geological Survey Landslide Group. Since the beginning of this project, the landslide has been heavily instrumented and monitored (Figure 31 and Figure 32).

Figure 30. (right) Oblique air photograph, (bottom left) orthophoto, and (bottom right) topographic map showing location of the Johnson Creek landslide site.





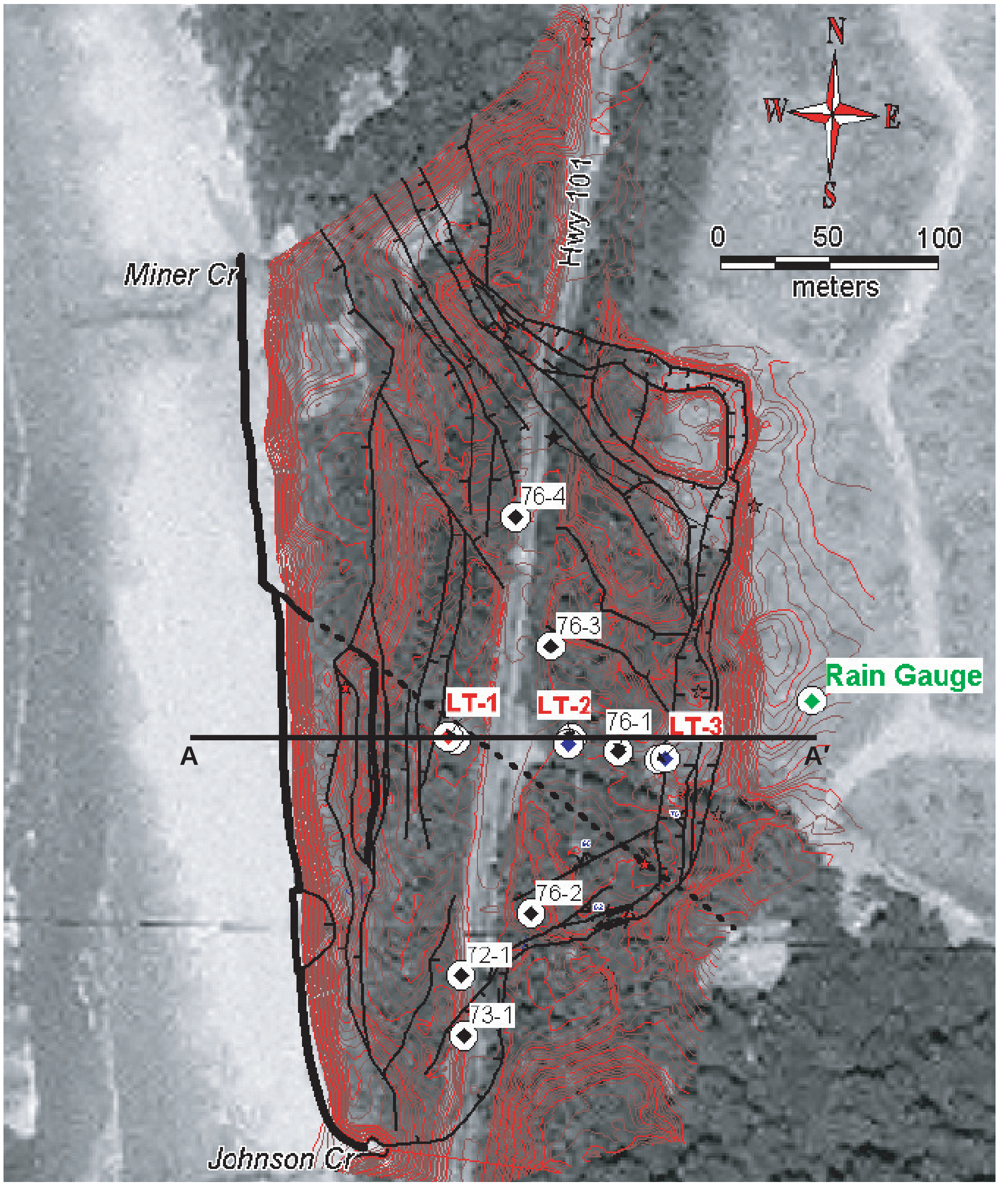


Figure 31. Site map of the Johnson Creek landslide showing drill sites LT-1, LT-2, and LT-3 (red labels) plus location of 1970s boreholes (black diamonds with circles), and the rain gauge. Base map is a 2002 U.S. Geological Survey digital orthophoto quadrangle. Red lines are topographic contours at 2-m intervals; muted brown lines are contours at 0.5-m intervals; black lines are major slide block boundaries. Black teeth on slide boundaries point toward the downthrown side (Priest and others, 2006).

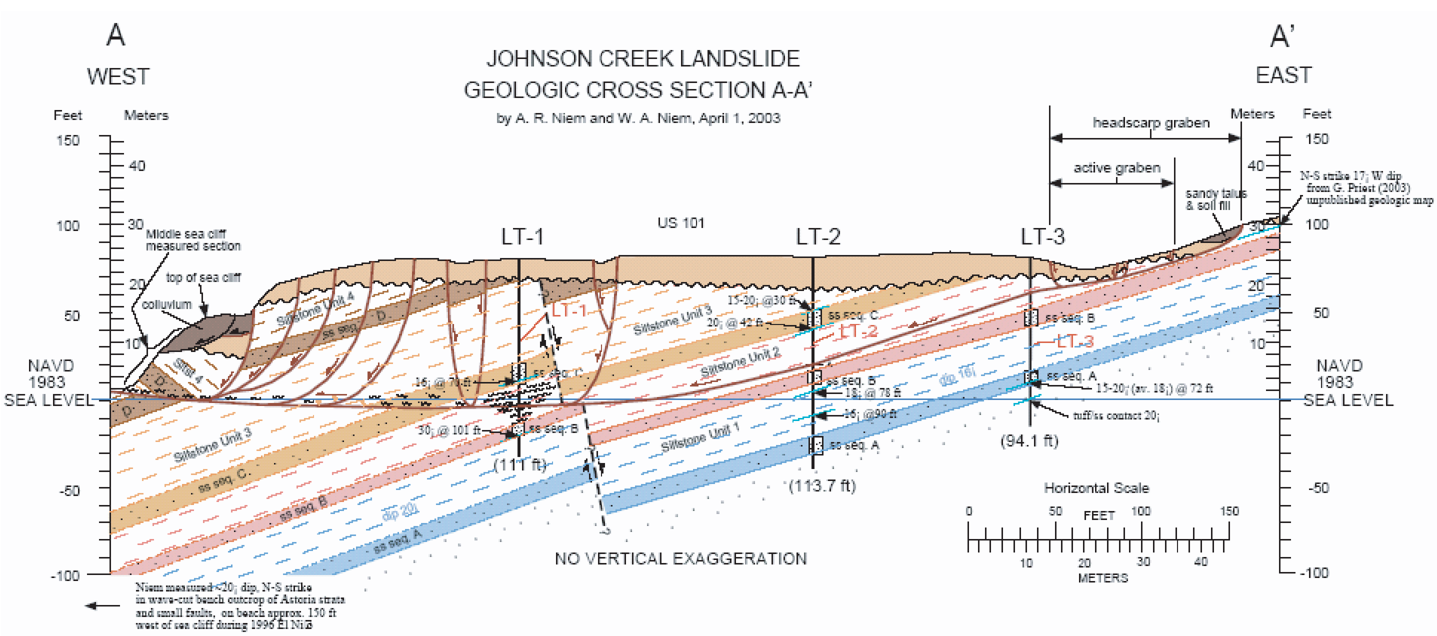


Figure 32. Johnson Creek landslide site cross-section (Niem, 2004).

STOP 2-4
TONY CREEK LANDSLIDE, SILETZ BAY
(NW NATURAL GAS LINE LANDSLIDE)

The Tony Creek landslide is a recent reactivation of a landslide mass within a pre-existing larger landslide landform. The landslide is roughly 0.07 km^2 (17 acres). Cracking is visible throughout from the headscarp at the edge of the quarry, through the stockpile, county road, and logging road, down to the toe at Tony Creek (Figure 33 and Figure 34).

Figure 33. Site photographs of the Tony Creek landslide in 2007.

Figure 34. Location map (left) and orthophoto (right) of the Tony Creek landslide site.

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Disclaimer. The Oregon Department of Geology and Mineral Industries is publishing this guide because the subject matter is consistent with the mission of the Department. Maps in this publication depict relative hazard zones on the basis of limited data as described further in the text. The maps cannot serve as a substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from those shown on the maps. **The map figures are not intended to be used for site specific planning.** It may be used as a general guide.

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State of Oregon
Department of Geology and Mineral Industries
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7.0 EVALUATION FORM AND SELECTED FEEDBACK

An evaluation form was distributed to all individuals who attended the main program portion of the symposium (Figure 6.0-1). Out of the 135 attendees, 78 filled out the evaluation form.

From the evaluation responses from these participants in the geologic hazard community, the symposium was very well received and provided a high-quality learning experience. In order for DOGAMI to better understand this audience's interest in geologic hazards, the participants were asked, "*What other topics would you like to see covered by DOGAMI in future workshops?*" (Figure 6.0-1, question 8).

Out of the 78 completed forms, 31 responded to question 8. The responses to this question are listed below:

- long term success of the use of anchors & micro piles in landslide repair
- landslide repair workshop
- more debris flow specific info
- slope stabilization measures
- landslide hazard mapping
- coastal bluff processes new remediation & case studies techniques; government & legal regulations on reporting slides
- production of susceptibility maps
- landslide mapping
- how to get the most out of landslide risk maps & geologic hazard maps for the engineering community
- policy / geohazard
- coastal landslides
- risk assessment
- coastal hazards & risk to civil infrastructure
- seismic
- seismic site hazard analysis code methodology
- tsunami hazard & evaluation strategies techniques
- updates on earthquake analysis as it changes
- earthquake preparedness
- earthquake hazard update
- seismic hazards in coastal settings
- discussion of DOGAMI map source data
- limitations of Oregon Water Resources Department monitoring database
- specific to field mapping & prefield photos of lidar mapping. Uses, techniques, methods…
- infiltration issues by private development
- mapping efforts, instrumentation advancements
- soil mechanics
- update on progress of statewide mapping program
- new info available for consultants
- good general cross section
- legal case histories & solutions significance & how resolved. What is teeth in risk prevention
- interaction with permitting agencies: eg clackamas county, skamania county

The large number of responses and wide variety of answers indicate a strong need for future symposia and field trips for the geohazard community. The answers reveal a wide range of interest, which provide important information for DOGAMI to consider when planning future events.

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THE LANDSLIDE SYMPOSIUM EVALUATION FORM, APRIL 26, 2007

1. How did you hear about the Landslide Symposium? (circle one)

   Email website word of mouth other

2. What was your overall impression of the Symposium?

3. Was the facility adequate for the Symposium? Yes No

4. Were the topics presented at the Symposium relevant? Yes No

5. What was the most helpful part of the Symposium?

6. What could be improved?

7. Would you be interested in a landslide workshop specific to your area?

8. What other topics would you like to see covered by DOGAMI in future workshops?

The Oregon Progress Board requires that we survey our stakeholders on the general quality of our service. Please take a moment to answer these final questions on the other side by circling one answer for each question.

Over please

Figure 6.0-1. Sample Landslide Symposium Evaluation Form.

1. How familiar are you with the products and services provided by DOGAMI?

Very familiar   Somewhat familiar   Not very familiar

2. How do rate the timeliness of the services provided by DOGAMI?

Excellent   Good   Fair   Poor   Don't know

3. How do you rate the ability of DOGAMI to provide services correctly the first time?

Excellent   Good   Fair   Poor   Don't know

4. How do you rate the helpfulness of DOGAMI employees?

Excellent   Good   Fair   Poor   Don't know

5. How do you rate the knowledge and expertise of DOGAMI employees?

Excellent   Good   Fair   Poor   Don't know

6. How do you rate the availability of information at DOGAMI?

Excellent   Good   Fair   Poor   Don't know

7. How do rate the overall quality of service provided by DOGAMI?

Excellent   Good   Fair   Poor   Don't know

Please share any final thoughts on the Landslide Symposium or your impressions of DOGAMI...

Thanks!

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