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Landslide Risk Reduction in the United States—Signs of Progress

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ABSTRACT

Scientific literature is replete with papers describing advances in applying new technologies to the study of landslides and advances in our understanding of factors affecting landslide occurrence, distribution, and movement. Far fewer papers look at how this knowledge is implemented to achieve landslide risk reduction. State and local governments exercise the greatest control on how landslide risk reduction is accomplished. Data generated from a questionnaire to state geological surveys, review of their agency Web sites, and two case studies demonstrate that progress has been made during the last 20 years in implementing actionable policy changes and programs to achieve a reduction is landslide risk in the United States. Progress is evident from the pivotal role played by state and local government in the areas of: (1) developing guidelines and training, (2) increasing public awareness and education, (3) implementing loss reduction measures, and (4) conducting emergency preparedness, response, and recovery. The number of states requiring registration for practicing geologists has nearly doubled during the last 20 years. This increase was accompanied by a shift from individual state tests as part of determining competency to a uniform national test. During this period, state geological surveys established Web sites as a primary means for promoting public awareness and education about landslide hazards. Measures reducing the impact of landslides have included providing information specific to residents and landowners, as well as supporting land-use planning efforts by local governments. Many state geological surveys are involved with emergency management of landslide hazards.

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INTRODUCTION

On Wednesday, October 11, 1995, the organization then named the Association of Engineering Geologists (AEG; now Association of Environmental & Engineering Geologists) held free public forums across the United States to disseminate information on landslide hazards to practicing professionals and the general public (DeGraff, 1995). National Landslide Awareness Day, as it was called, coincided with the United Nations' International Decade for Natural Disaster Reduction (IDNDR) Day. It consciously followed the style of teach-ins popularized during the late 1960s and early 1970s, including the first Earth Day.

AEG regional sections organized local events ranging from outdoor exhibitions at the Washington Park landslide in Portland, OR, to a day-long forum featuring speakers in St. Louis, MO, addressing technical topics for specialists in the morning and general topics for the public in the afternoon. Public field trips to local landslides were conducted by local geologists in the San Francisco Bay area. These events generated informative landslide feature articles in local media including in the *Portland Oregonian* (Hill, 1995) and the *Salt Lake Tribune* (Siegel, 1995). Other articles in the print media were generated by press releases issued by the U.S. Geological Survey (USGS), AEG sections, and state geological surveys from Colorado to New

Hampshire. State geological surveys participated in a number of other ways. They disseminated landslide information in their monthly non-technical publications like New Mexico Bureau of Mines and Geology's *Lite Geology* (Haneberg, 1995) and issuance of new general publications such as one on landslides in Ohio by their Division of Geological Survey (Hansen, 1995). The Utah Geological Survey made a display in their Salt Lake City office where the public could peruse landslide publications they had produced. In Denver, CO, the USGS's National Landslide Information Center held a news conference and distributed selected publications about reducing landslide hazards. They also featured a lunch-time talk about long-term research at the Slumgullion Landslide, CO.

During the 20 years since National Landslide Awareness Day, there have been many examples of an improved scientific understanding of landslide processes and a greater array of technology available for investigating landslide problems and mitigating their impact. While the relevant published literature is too numerous for a comprehensive listing, it is possible to highlight some significant advances. Scientific advances in understanding factors important to landslide occurrence include refining our knowledge of how precipitation initiates and promotes landslide occurrence and movement (Iverson and Major, 1987; Guzzetti et al., 2008; Priest et al., 2011; and McKenna et al., 2012). Other insights dealt with factors initiating particular types of landslides (Cannon, 2001; Stock et al., 2012). Still others have refined our knowledge of landslide movement and deposition (Major and Iverson, 1999; Petley et al., 2002; and Santi et al., 2008). Global positioning system (GPS), light detection and ranging (LiDAR), differential interferometric synthetic aperture radar (DinSAR and SAR), and other remote-sensing techniques and platforms have advanced the ability of researchers to measure and record aspects of movement, sediment transport, and other landslide process factors that had previously either eluded detection or were ineffectively measured (Tarchi et al., 2003; Schulz, 2007; Roering et al., 2009; Jomard et al., 2010; Stock et al., 2011; and Jaboyedoff et al., 2012). Some of these technological methods have improved the ability to monitor landslides in order to provide warnings useful in emergency response (Baum and Godt, 2010; Reid et al., 2012). In addition to monitoring to warn of possible landslide occurrence, modeling has improved prediction of the likelihood or characteristics of future landslides (Guzzetti et al., 2003; Gartner et al., 2008; Cannon et al., 2010; and De Graff et al., 2015b).

Less clear is the extent to which public policy and awareness have changed during this same period. Put another way: Has our ability to achieve landslide hazard reduction kept pace with our increased knowledge of this natural phenomenon? Just as major disastrous landslides like the 1983 Thistle landslide in Utah and the 1985 Mameyes landslide in Puerto Rico called attention to issues of landslide risk at the time of their occurrence, the 2014 Oso landslide in Washington gives renewed urgency to the question of whether the past 20 years of refining our knowledge and improving related technology have contributed to additional risk reduction. While we may not be able to highlight direct linkage, we can examine efforts to incorporate current scientific information into policy to counter landslide risk through land-use planning, decision making, regulatory frameworks, and public education.

This paper will specifically attempt to assess whether efforts to institute actionable policy for reducing landslide hazard at the state and local levels mirror the trend in our improved scientific understanding. Positive trends are needed to compensate for the greater need arising from both population growth and urban expansion. The reason for the state and local emphasis in this analysis is based on the authority for making land-use planning decisions and their regulatory enforcement throughout the United States, which rests almost entirely in the hands of state and local government (Burby et al., 2000; Berry, 2005; Hart, 2005; Mader, 2005; Preuss et al., 2005; Baum et al., 2008; and De Graff, 2012).

National direction and actions directed toward landslide hazard reduction are certainly important and necessary to support these local efforts. In 1999, Congress passed Public Law 106-113 requiring the USGS to develop a comprehensive strategy to address the widespread hazard posed by landslides in the nation (Spiker and Gori, 2003). The resulting strategy was termed "a framework for loss reduction" and received review and support from the National Research Council (Committee on Review of the National Landslide Hazards Mitigation Strategy, 2004). The elements of this strategy are identified as: (1) research, (2) hazard mapping and assessments, (3) real-time monitoring, (4) loss assessment, (5) information collection, interpretation, and dissemination, (6) guidelines and training, (7) public awareness and education, (8) implementation of loss reduction measures, and (9) emergency preparedness, response, and recovery (Spiker and Gori, 2003; Wieczorek and Leahy, 2008).

We think it is significant that the National Research Council titled its review assessment, "Partnerships for Reducing Landslide Risk." The strategy they reviewed identified new roles and partnership opportunities for state and local government and private individuals under each of the nine elements (Table 1 in Spiker and Gori, 2003). The importance of state and local governments in accomplishing landslide risk reduction is made especially evident by their roles in the elements of: (1) developing guidelines and training, (2) increasing public awareness and education, (3) implementing loss reduction measures, and (4) fostering emergency preparedness, response, and recovery.

METHODOLOGY

As noted in the introduction, the metrics for assessing landslide risk reduction need to reflect actions at the state and local government levels. Ideally, one of these metrics would be changes in monetary costs due to landslide occurrence. However, this type of assessment even at a state level has proven difficult to quantify comprehensively (Highland, 2012). Lacking consistent and clear cost figures, we looked for measures at the state and local government level that emphasize the national strategy elements.

We draw upon data from Internet searches and a questionnaire together with two case studies to yield qualitative and quantitative measures in our assessment of state- and local-level actionable policy for reducing landslide hazard. The data compiled focus on measures that ensure: (1) an appropriate level of training for professional geologists involved with landslide hazard assessment and loss reduction work, (2) ongoing efforts to educate the public about general and specific landslide hazards that might affect their lives and property, (3) actions taken to facilitate loss reduction measures, and (4) development of effective emergency preparedness, response, and recovery actions (per Table 1 in Spiker and Gori, 2003).

A review of publically accessible Web sites maintained by each state geological survey was completed during May and June 2015 and reviewed for changes in September 2015. Examination of the survey Web sites focused on identifying landslide information suitable for the needs of: (1) the general public, (2) residents and landowners, and (3) an employee of local government with responsibility for land-use planning or emergency response and geological professionals who may be providing support to governmental entities. This provided an objective, albeit qualitative, measure of a state survey's ability to use Internet technology to disseminate information for public education, professional development, and local government assistance. Each state geological survey Web site homepage was accessed using a common internet browser. On each homepage, a link to "landslides," "geologic hazards," "hazards," or similar keyword was sought on the assumption that these would be known to an interested member of the public, government employee, or practicing professional. This link was used to open related Web pages with subsequent links accessed depending on the options presented. It is important to note that this examination is suitable for understanding what is being communicated about landslides by a state geological survey's Web site but is not necessarily a complete look at their efforts to understand and reduce landslide hazard.

While homepages commonly had a link to publications, this link was not accessed as part of the examination because publications represent a different media. There were two exceptions. One exception was to identify published maps and documents in digital form that were reached via links found on the Web site. The other exception was to determine whether guidance documents for practicing geological professionals existed. Where the publications were searchable online, the search terms, "guidelines," "geologic hazard reports," and "preparing reports," were used. If the publications were not searchable online, the main publication list was downloaded in its portable document format (PDF) format, and the "find" function was used with the search terms to accomplish the search.

Series of questions were prepared to gather information on various aspects of landslide hazard assessment and prevention and compiled into a questionnaire. This questionnaire was sent to each of the state surveys represented in the American Association of State Geologists (AASG). Twenty-nine questionnaires were returned, representing a 58 percent return rate. Responses to questions directly relating to the topics in the following sections were compiled. The questionnaire results together with two relevant case studies, one drawn from a co-author's recent experience and the other from published data, are used to further illustrate the issues of loss reduction and emergency response, respectively.

ANALYSIS AND RESULTS

Guidelines and Training

Geologists are the primary professionals identifying and defining landslide hazards and investigating factors important to mitigation designs and regulatory requirements. States play a key role in ensuring that competent geologic professionals are available for assessing and carrying out investigations suitable for avoiding or reducing landslide risk. Ensuring the competence of geologic professionals is usually carried out by requiring certification or licensure, which often involves continuing education requirements.

A simple measure for assessing the way in which states are ensuring the availability of competent, trained geologists over the last 20 years is to look at professional registration of geologists. Figure 1 is a graph showing the number of states requiring professional registration of geologists between 1956 and 2014. The cumulative upward trend in the number of states enacting laws requiring registration visibly increased between 1991 and 2002. With the November 2014 passage of a licensure act in New York, 32 states have or are implementing this requirement for geologists practicing within their state (Figure 2). Figure 2 compares states that implemented registration of geologists to a generalized map of landslide hazard in the conterminous United States. Clearly, not just states where significant landslide hazard exists have enacted registration laws. This likely reflects the fact that requiring practicing geologists to be registered or licensed is deemed necessary for a broad range of environmental and engineering geologic work, including water resource protection, mineral extraction, and construction. While landslide hazard is certainly important in order to ensure public safety, it is only one reason for requiring competency among practicing geologists.

A related change has occurred in the way in which states determine which geologists will be granted registration or licensure. States where registration was established early, like California, generally required both academic and experience requirements before a geologist could apply for registration. Registration for those who met the requirements was then based on their performance on a state-administered test. Similar procedures were adopted as other states began registration of geological professionals. Testing varies among states in terms of both testing procedures and the substantive content of the tests. Those differences affect questions of reciprocity and associated issues for geologists registered in one state but needing to practice in another one. Some of the State Boards of Geology charged with the responsibility for registration came together to discuss these differences in 1988. This meeting and subsequent ones culminated in the 1990 formation of the Association of State Boards of Geology (ASBOG, 2015). One significant outcome from the formation of ASBOG is a standardization of written tests used to determine if a candidate is competent for registration. ASBOG also provides a means for state boards to facilitate uniformity of registration procedures, including more standardization of experience required to qualify to test and register. As of November 2015, 30 states used the ASBOG test as part of their registration process (ASBOG, 2015).

Another measure of how the states can ensure competency of geological professionals is by looking at the guidance provided for the ways in which they should carry out their work. While such guidelines may exist for specific projects, such as the state of Oregon's guidelines for proposed energy-related facilities (see http://www.oregon.gov/energy/Siting/docs/rules/div22.pdf), we will focus on those broadly covering environmental and engineering project work. Prior to 1995, California, Colorado, and Utah issued guidance documents describing what information should be included in geologic reports (Shelton and Prouty, 1977; Slosson, 1984; and Association of Engineering Geologists-Utah Section, 1986). These guidance documents ranged in size from two-page notes with a brief explanation and annotated report outline to a 67 page tome. To date, California has issued additional guidance documents (CGS, 2013a, 2013b). The Colorado Geological Survey has incorporated their current report guidance into their Web site (see http://coloradogeologicalsurvey.org/land-use-regulations/report-requirements/). In 1999, Oregon also issued *Guideline for Preparing Engineering Geologic Reports.* It was later updated and reissued as a 14 page document developed and adopted by the Oregon Board of Geologist Examiners (OSBGE, 2014). Because the search for documents, which provide guidance to practicing geologists, was confined to publications issued by state geological surveys, similar technical direction issued by State Boards of Geology overseeing registration or licensure may also exist (see http://www.dol.wa.gov/business/geologist/docs/georptguide.pdf). While it is not as comprehensive a measure nationally as the increased number of states requiring registration or their widespread adoption of a standardization of testing, the increase in updated or new guidance documents issued since 1995 is indicative of an effort to improve competency.

Registration of geological professionals can serve as a measure of how states have acted to ensure the availability of competent, trained geologists for involvement in landslide hazard reduction activities. From 1995 to present, there has been nearly a doubling of states requiring registration of practicing geologists. Because many of these states do host a significant potential for adverse impact due to landslides, it supports the concept that states have made progress in ensuring practicing geologists within their jurisdiction are well qualified to address landslide hazard issues. Similarly, this period coincides with a shift from individual state-prepared examinations as part of the registration process to adoption of a shared uniform examination (ASBOG, 2015). This uniformity in testing adds to the likelihood that geologists addressing landslide issues in different states are applying the same level of competency due to their training. There has also been an increase in the number of technical guidance documents for conducting engineering geology work applicable to landslides and slope instability. Less clear is whether the issuing of such technical guidance documents for practicing geological

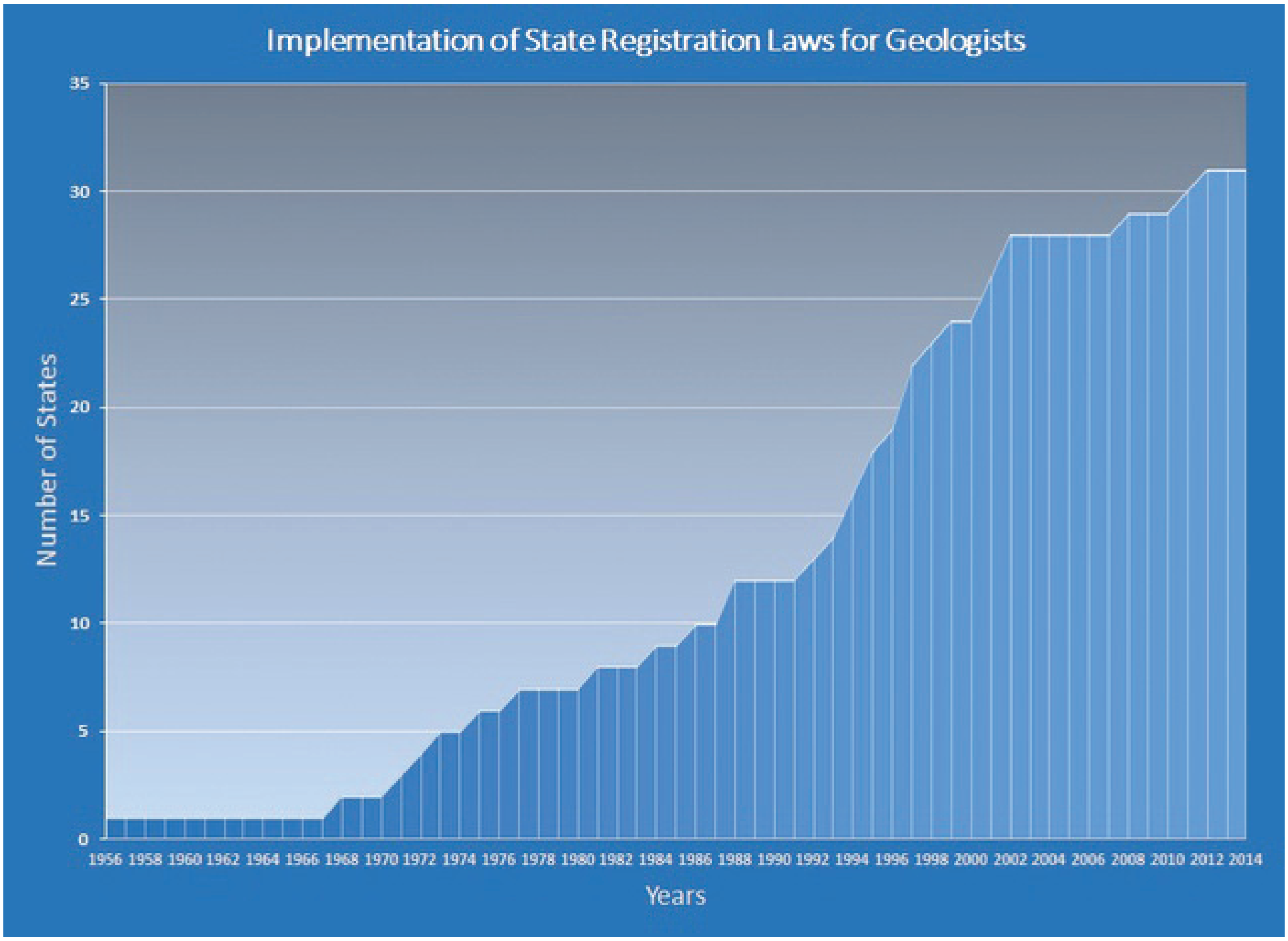

Figure 1. Cumulative graph of states requiring registration for practicing geological professionals between1956 and 2014. The year when implementation of registration occurred was used, which in some instances differed from the year the registration law was enacted. For example, the New York registration law was enacted in 2014, but the implementation will be in 2016 (ASBOG, 2015; NYSED, 2015).

professionals has kept pace with the increased number of states requiring registration.

Public Awareness and Education

Whether a geologic researcher is searching for relevant scientific articles or the public is trying to find personally useful information, Internet search engines are often the initial place to begin (Wishard, 1998; DeGraff et al., 2013). These search engines electronically survey the Internet to identify Web sites where information, linked to key words entered by the user, can be found. So, it is not surprising that all 50 state geological surveys have publically accessible Web sites for distributing information to both practicing professionals and the general public. This means such Web sites are a primary mechanism for public awareness and education. At the time of National Landslide Awareness Day, state geological surveys shared information with various interested parties mainly through publications, displays in public locations, and professional workshops. While these methods continue to be used, widespread computer accessibility and the ubiquity of Internet search engines make the state geological survey Web sites the current medium of choice for education and outreach. The present-day dominance of the Internet for this purpose is a consequence of privatization and governance efforts that have encouraged the widespread proliferation and accessibility of publicly accessible Web sites after 1995 (Leiner et al., 1997).

A recent example of the importance of the Internet occurred during the year after the Oso landslide. The March 22, 2014, Oso landslide (Washington) stimulated interest in landslide hazard in the Pacific Northwest. Consequently, the Statewide Landslide

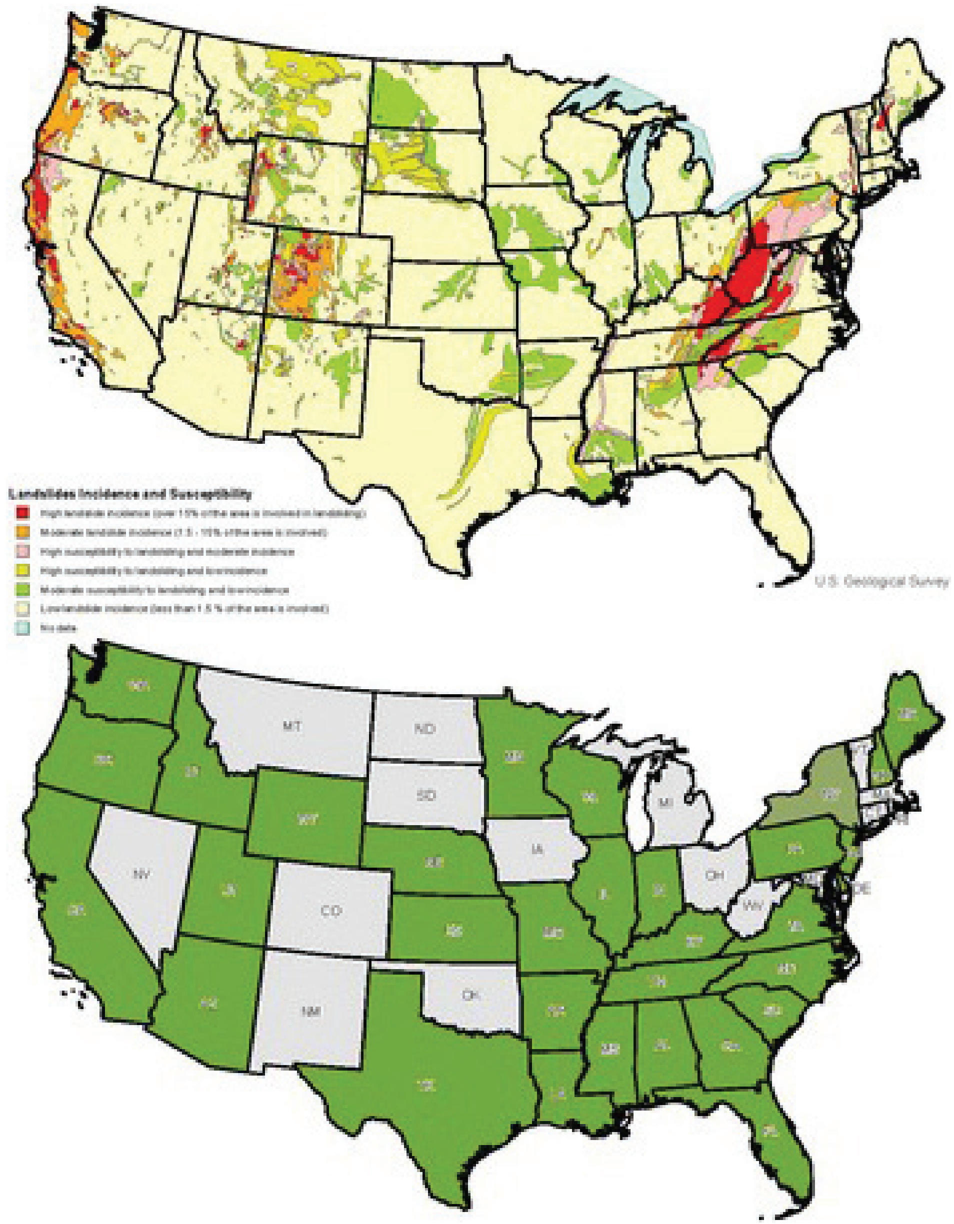

Figure 2. Two maps of the conterminous United States comparing landslide potential (upper map) to those states requiring registration of practicing geological professionals (lower map).The upper map was prepared from digital files (Godt, 1997). The lower map was compiled from the same sources noted for Figure 1.

Information Database for Oregon (SLIDO) experienced a 400 percent increase in views compared to 2013. SLIDO was the 25th most visited of all Oregon Department of Geology and Mineral Industries (DOGAMI) interactive Web maps in 2013. This page climbed to second most visited in 2014 and continues to have higher page views in 2015 (Alison Ryan Hansen, DOGAMI, personal communication, September 17, 2015).

The questionnaire to AASG members had posed the question: "Do you conduct education and outreach regarding landslide hazards?" This question referred to all media and was not limited to use of the Internet for this purpose. Of the 29 questionnaire respondents, nineteen (66 percent) stated they did do education and outreach to the general public about landslide hazards. Similarly, our review of state geological survey Web sites found that 32 (64 percent) of the 50 state geological surveys were providing some level of readily accessible landslide hazard information on their home Web page (Table 1). These results are suggestive that most state geological surveys providing landslide information to the public are currently making credible use of the Internet.

Table 1. *Categories of landslide hazard information found during examination of state geological survey Web sites. A through D represent information categories characterizing all 50 states. E and F in the lower table are two information types that may be provided.*

Landslide Information	No. of State Surveys	Surveys Listed by State*
A. Only identifies landslides as a hazard or includes a very brief or generalized description	8	MD, MO, MT, NH, NM, NV, NY, OH
B. Provides information specifically for the general public,residents/landowners, and local government/practicing professionals	12	AL, AR, CA, CO, ID, KY, ME, NE, NC, OR, UT, WA
C. Provides information for two of the above categorical groups	12	AK, AZ, IN, MA, ND#, NJ, PA, SC, VT, VA, WV, WY
D. Does not specifically mention landslide hazards	18	CT, DL, FL, GA, HI, IL, IA, KS, LA, MI, MN, MS, OK, RI, SD, TN, TX, WI
E. Provides access to landslide mapping and/or state-wide database	18	AL, CA, CO, ID, KY, MA, ME, NE, NV, NJ, ND, NC, OR, PA, SC, UT, WA, WV
F. Makes available a homeowner's guide to landslides or a listing of observable warning signs	9	AL, AZ, ID, IN, NC, OR, UT, WV, WA

*U.S. Postal Service abbreviations for states used.
#North Dakota provides only landslide maps on its Web site, which are mainly useful to local government/practicing professionals.

Of the 32 state geological survey home Web pages where landslide hazard information is accessible, eight surveys only make mention of landslides as being a hazard, provide very brief or general descriptions, or describe a very specific landslide-prone situation (Table 1). For example, the home Web page link to hazards for the New Hampshire Geological Survey only mentions landslides in the following statement: "While geologic hazards encompasses a multitude of natural phenomena, including landslides and earthquakes, flood inundation and river erosion constitute New Hampshire's #1 natural hazard risks."

The amount and detail of landslide hazard information and the potential user groups being addressed vary considerably among the remaining 24 state geological survey home Web pages offering more extensive content (Table 1). The Web site content was examined considering three user categories: the general public, residents and landowners, and local government staff and practicing professionals. Twelve state geological survey home Web pages offer access to landslide hazard information useful to all three of these user groups (Table 1). On Figure 3, these 12 states are indicated by their U.S. Postal Service abbreviation.

Table 2 explains how to access landslide hazard information on these state geological survey Web sites and provides thumbnail descriptions of the content available for the three different user groups. There are some noteworthy features among these 12 state geological survey Web sites. California, Colorado, and Utah Web sites all include information specific to landslide activity from areas burned during wildfires. Colorado provides brief, but very effective, videos of different landslide types narrated by their staff in a field setting. Online interactive interfaces for accessing landslide maps are present on the Colorado, Kentucky, Maine, Oregon, and Washington Web sites. The Utah Web site has a high degree of interconnectedness among subheadings and content, ensuring that relevant information is not overlooked.

The landslide hazard content of the other 12 state geological survey home Web pages is not responsive to the needs of all three defined user groups (Table 1). Of these 12 Web sites, the North Dakota Geological Survey has the only home Web page that gives access to landslide hazard information primarily useful only to one potential user group—local government staff and practicing professionals. A link to *Landslide Maps* enables those users to open a page showing the entire state index of 1:100,000 scale mapping. Clicking on a sheet in the index opens a page showing whether there are landslide maps available and, if so, providing an index for opening them. The North Dakota Geological Survey is one of only 18 state geological surveys that offer public access to landslide mapping or a state-wide database of landslides (Table 1).

The high proportion of state geological survey Web sites providing landslide hazard information begs the question of why the remaining 18 (36 percent) state geological survey are not doing so on their Web sites. Figure 3 enables comparison of 17 of these 18 states (excluding Alaska and Hawaii) within the conterminous United States to their relative landslide incidence and susceptibility. While there is not a similar map for Alaska and Hawaii, it is known that these states have both physical conditions favoring landslide occurrence and have experienced disastrous landslide events (Jibson et al., 2004; Deb and El-Kadi, 2009). For some states, such as Florida, Rhode Island, and Delaware, which show no landslide susceptibility or incidence,

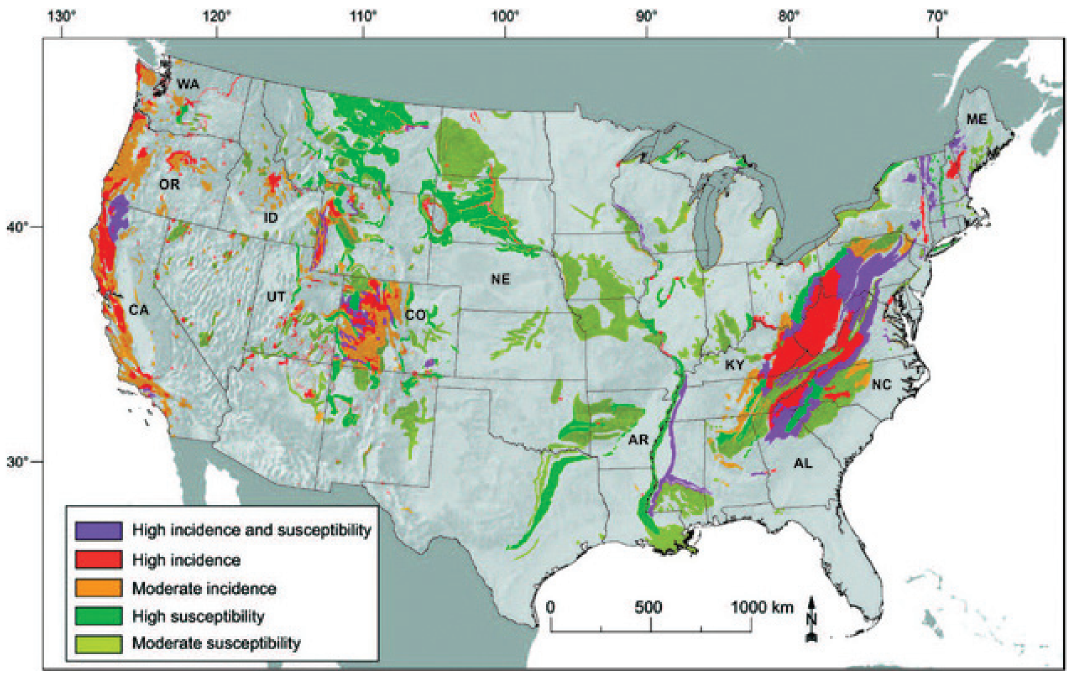

Figure 3. Overview map showing landslide incidence and susceptibility in the conterminous United States with the abbreviations for states added indicating those state geological surveys providing the widest range of landslide hazard information to the public (modified from Wieczorek and Leahy, 2008).

and Iowa, Kansas, Michigan, and Minnesota, which show only small areas of moderate susceptibility, not mentioning landslides as a hazard is understandable (Table 1). It is unclear is why states like Georgia, Oklahoma, and Tennessee, where there are either significant areas of high incidence and susceptibility or high susceptibility for landslides, make no mention of this potential hazard on their home Web pages. The fact that these states do not mention landslide hazard on their home Web pages may reflect their emphasizing mineral or groundwater issues, an internal financial limitation, or their being part of a larger agency where geologic issues are only a subset of the topics addressed via their agency home Web page. For example, Hawaii's failure to mention landslide hazards may stem from the fact that their State Water Commission serves as the only state entity addressing geologic survey issues.

Both the response to the questionnaire and the examination of state geological survey home Web pages are indicative of a significant number of state surveys recognizing a need to provide education and outreach to various public groups about landslide hazards in their state. The Web site review demonstrates progress in this aspect of landslide hazard reduction since 1995. The results described here show that much of their effort comprehensively reaches potential user groups and makes effective use of changing technology.

Implementation of Loss Reduction Measures

While important to landslide hazard reduction, the presence of well-trained practicing professionals and effective outreach and education to the public are insufficient to fully accomplish this task. There must be a response to the information provided by both knowledgeable professionals and the public to actually achieve loss reduction (DeGraff, 2012; DeGraff et al., 2015a). The state geological surveys provide a framework for this response as it is carried out at multiple levels involving state and local government. This perspective is supported by the responses to the questionnaire. Of the 29 AASG questionnaire respondents, only nine (31 percent) conducted their landslide hazard efforts in response to statutory regulation or mandates (Table 3). The questionnaire responses indicate that state geological surveys contribute to implementation of landslide loss reduction by working with other state agencies (15 [52 percent] of respondents) and federal agencies (16 [55 percent] of respondents; Table 3). State geological survey involvement for achieving landslide loss reduction appears most active at the local community level (cities and counties). Of the 29 AASG respondents, 22 state geological surveys (76 percent) are working with local communities (Table 3). Local community involvement is important because it is only at this governmental level that effective regulation permitting the establishment of geologic hazard districts, promulgation of zoning

Table 2. *An alphabetical listing of the 12 state geological survey Web sites where landslide information is available for the general public, residents and landowners, and local government staff and practicing geological professionals. These sites were last accessed on August 31, 2015.*

			Landslide Information		
State	Survey Name	Web Home Page and Path to Landslide information	General	Resident/Landowner	Local Government/Practicing Professionals
Alabama	Geological Survey of Alabama	http://www.gsa.state.al.us/ Click on "Geologic" on left panel of home page to reach Mapping & Hazards	Interactive descriptions of different slope instability	Lists of landslide warning signs and what to do before and after a slide movement	State-wide maps of factors affecting slope stability and general landslide susceptibility with links to additional information and listing of historical landslides by county
Arkansas	Arkansas Geological Survey	http://www.geology.ar.gov/home/index.htm Click on "Geohazards" in the header bar. Landslides are included under "Geohazards"	"Landslides" includes a description and link to a general information page	Another link provided reaches U.S. Geological Survey and FEMA sites useful to residents	Survey-prepared landslide case studies listed by county are accessible from this link
California	California Geological Survey	http://www.consrv.ca.gov/cgs/Pages/Index.aspx Click on "Geologic Hazards" in the header bar. Landslides are included under "Geologic Hazards"	A description of past and current survey landslide programs and general descriptions of landslide types	There is a link to Survey notes on emergency response and hazards from specific landslide types or events such as wildfire; information specific to residents' needs is provided by a link to a U.S. Geological Survey site	Landslides also has a link to maps and survey notes on landslide susceptibility and guidelines for geologic report preparations
Colorado	Colorado Geological Survey	http://coloradogeologicalsurvey.org/ Click on "Geologic Hazards" in the header bar for dropdown menu containing: "Debris flow-fan (mudflows)," "Landslides," "Mudslides," and "Rockfall"	Each category (debris flow-fan, landslides, mudslides, and rockfall) includes a definition and description of damages attributable to that hazard type; the "Geologic Hazards" page also contains videos of a debris flow, a landslide, and a rockfall	The definition page and the case histories provide insight useful to residents and landowners; the video on the "Geologic Hazards" page is also instructive	The rockfall category includes a rockfall event map of Colorado; the Landslide category includes a map tab that access a PDF map of landslides in Colorado and an interactive map viewer for the landslide map; it is possible to download geographic information system (GIS)–useable files
Idaho	Idaho Geological Survey	http://www.idahogeology.org/ Click on "Geologic Hazards" in left panel of home page. Landslides are 1 of 3 topics under "Geologic Hazards"	There is a general description of landslides, their causes, and relation to geology specific to Idaho	In addition to the general information for Idaho landslides, there are summaries of how landslides are studied, their relation to flood events, and landslide warning signs for residents and landowner's to observe	Further information is provided by links to a map of landslides in Idaho and a publication containing much of the same information found on the Web page
Kentucky	Kentucky Geological Survey	http://www.uky.edu/KGS/ Hover over "Research/Programs" in panel on left to choose "Other Hazards," where "Landslides" is listed	"Landslides" links to page with a map showing landslide locations in Kentucky	This page also provides many links to photos and information sources on landslides, mapping, and detailed reports	The Web site home page offers "Online Maps," which includes "Landslide Information," where a searchable map contains details on inventory maps
Maine	Maine Geological Survey	http://www.maine.gov/dacf/mgs/index.shtml Click on "Hazards" in left panel of home page. "Landslides" is 1 of 7 hazards categories listed	"Landslides" includes a virtual tour of Maine's geologic hazards; answers are provided to several frequently asked questions	Case histories explain past major landslides as well as landslides in coastal areas and landslide susceptibility mapping; a form is provided for the public to submit information on local landslides	An interface allows access online to landslide susceptibility maps for different areas and known landslide sites in the state

Table 2. *Continued.*

State	Survey Name	Web Home Page and Path to Landslide information	Landslide Information: General	Landslide Information: Resident/Landowner	Landslide Information: Local Government/Practicing Professionals
Nebraska	Conservation and Survey Division (Nebraska Geological Survey)	http://snr.unl.edu/csd/ Click on "Geology" and then on "Landslides in Nebraska" under the heading "Geologic Hazards"	Brief introduction to landslides with several photos and headings linked to "Definitions" and "Database"	Definitions provide diagrams, photos, and descriptions for each of the landslides types common to Nebraska; these are accessed by tabs, which also provide a Varnes classification diagram and a photo sequence of a developing landslide	A database of inventoried landslides in Nebraska; entries include type of slide with photos accompanied by panels giving details on location (township, latitude and longitude, topographic quad), classification (cause, geology, etc.), status (date of last movement, activity, dimensions etc.), and damage & repair (costs and comments)
North Carolina	North Carolina Geological Survey	http://portal.ncdenr.org/web/lr/geological_home Two ways are available to reach landslide information. One is to click on "Geologic Hazards" under quick links and then choose "Landslides"; the other is to click on "Landslide Information" listed in the left-hand panel on the opening Web page	The "Landslide Information" home page is a topical introduction with a few sentences and accompanying photos; it also states counties that have completed landslide inventory maps and links to other pages with more detailed information; it also gives links to maps and publications	A link of particular use to homeowners is called "How to recognize landslides and how to deal with them"; indicators of instability that a resident or landowner might observe and different mitigation possibilities for a variety of landslide types are provided	Links permit downloading of PDF versions of maps for the four counties where landslide mapping is complete; links to both other parts of "Landslide Information" and to other publications give background information on historical landslide events and important triggering storm events
Oregon	Oregon Department of Geology and Mineral Industries	http://www.oregongeology.org/ Click on "Hazards" in header bar	The "Hazards" page provides an alphabetical list of hazards; click on "Landslides" to access a range of landslide resources including links to general descriptions and safety information for landslides and debris flows	Among the resources on the "Landslides" page are downloadable versions of the *Landslide Hazards in Oregon Fact Sheet* and the *Homeowner's Guide to Landslides* (produced by Portland State University)	The "Landslides" page offers access to an interactive map of landslides throughout the state as well as access to recent reports on investigations and mapping of landslides; a fact sheet is available for *Understanding Landslide Deposit Maps*
Utah	Utah Geological Survey	http://geology.utah.gov/ Click on "Hazards" in header bar to reveal a page titled "Earthquake & Geologic Hazards" with seven major subheadings including: Landslides & Rock Falls, Geologic Hazard Assistance, Geologic Hazards Technical Information, and A Guide to Homebuyers & Real-Estate Agents	Click on the subheading "Landslides & Rock Fall" for general information and description of recent events in Utah; access to maps of landslide susceptibility and a landslide database is also gained from this site	Clicking on the subheading "A Guide to Homebuyers & Real-Estate Agents" reveals a wealth of information specific to both homeowners and realty agents; the subheading "Landslides & Rock Fall" also accesses a useful "how to reduce your risk" section	Maps and investigative reports are commonly grouped and accessed by county; many publications are able to be downloaded directly from links on the Web pages; certain important items such as guidelines for hazard reports and landslide investigation technical reports are included under two or more of these subheadings to facilitate their being located

Table 2. *Continued.*

State	Survey Name	Web Home Page and Path to Landslide information	Landslide Information		
			General	Resident/Landowner	Local Government/Practicing Professionals
Washington	Department of Natural Resources Geology & Earth Sciences	http://www.dnr.wa.gov/programs-and-services/geology-and-earth-resources Click on "Geologic Hazards" among Geology topics on the home page	On the "Geologic Hazards" page, click on the "Landslides" icon or in the listing on the left; the page offers links to general information under "why do landslides happen," "types of landslides," and "some historic landslides in Washington State"	The "Landslides" page offers "landslide warning signs and triggers" and "reduce your risk" links useful to residents and homeowners; the link "what we do" provides access to two PDF documents with general information on landslide mechanisms, types, and past Washington State landslides	On the "Landslides" page, the link "what we do" gives access to the interactive geologic hazards maps; the geologic hazards maps are also accessible by clicking that icon on the "Geologic Hazards" page or in the topical listing on the left

ordinances addressing slope stability, and building permit restrictions in landslide-prone areas can be accomplished.

A measure of how state geological survey involvement at the local community level has changed since 1995 involves looking at landslide reduction efforts focused on homeowners. Nine state geological surveys make available landslide hazard guides to homeowners and buyers, or a list of non-technical, observable changes that might indicate landslide movement (Table 1). Several guides are actual publications that may be purchased in print form or downloaded in a PDF (Harris and Pearthree, 2002; Potter et al., 2013; and WDGER, 2015). In some cases, landslides are one of several geologic hazards covered by the publication (Harris and Pearthree, 2002) and others are specific to landslide hazard (Potter et al., 2013; WDGER, 2015). Potter et al. (2013) produced "Landslides and Your Property" under a collaborative effort by the Indiana Geological Survey, Kentucky Geological Survey, and the Ohio Division of Geological Survey. Other Internet-accessible homeowner guidance and lists include: "Landslide Hazards and You" (Alabama Geological Survey), "Reducing Landslide Loss" (Idaho Geological Survey), "How to Recognize Landslides and How to Deal with them" (North Carolina Geological Survey), "Homeowner's Guide to Landslides" (Oregon Geological Survey), "A Guide to Homebuyers & Real-Estate Agents" (Utah Geological Survey), and "Homeowner's Guide to Geologic Hazards" (West Virginia Geological Survey), which are viewable on their respective state geological survey Web sites. In some cases, these Web-based guides are also freely downloadable in PDF format. Many of the guides and lists available only on state geological survey Web sites, if not all of them, were produced after 1995. Similarly, the three state geological survey–published homeowner guides have publication dates ranging from 2002 to 2015. This demonstrates that all of these efforts to communicate specific actions that the residents and landowners can take for landslide risk reduction were initiated during the last 20 years.

It is more difficult to fully gauge the extent of state geological survey involvement in achieving landslide risk reduction at the local level (communities and counties). The information provided on many state geological survey Web sites includes reports of damaging landslide incidents, which are certainly instructive for loss reduction efforts at the local level. Similarly, there are many landslide maps (location of past landslide events or features, landslide susceptibility or incidence, and landslide hazards) and some studies prepared specifically for guiding land use and development (Lund et al., 2008). As noted on the

Table 3. *Summary of responses to AASG questionnaire inquiries related to landslide loss reduction.*

Questions	Number of Respondents Answering "Yes"	Percent of Respondents Answering "Yes"
A. How are your efforts related to statutory regulations or mandates (state, local, federal) policies, and land use?	9	31
B. Do you work with other state agencies on landslide hazards?	15	52
C. Are you working with federal agencies (e.g., USGS, FEMA)?	16	55
D. Are you working with local communities (e.g., cities, counties, other state agencies)?	22	76

Web pages of the California Geological Survey (http://www.consrv.ca.gov/cgs/geologic_hazards/landslides/Pages/Index.aspx), specific studies were undertaken by their staff that produced maps and guidance documents to help local governments deal with landslide hazard where urban expansion was happening or was expected to happen in the near future. An example of the work done is *Geology for Planning in Western Marin County, California*, by David L. Wagner (Wagner, 1977). These publications and later ones instigated under California's Landslide Hazard Mapping Act are no longer mandated as a result of changes in state law.

While there is value in the landslide-related maps and documents produced by state geological surveys, the extent to which such technical assistance is effectively introduced into landslide risk reduction efforts at the local level is less clear. Given the potential number of local governmental bodies in the United States, determining how many have implemented mandatory measures to prevent or reduce landslide damage is difficult to assess. There are certainly documented examples in parts of California, Colorado, and Utah (Fleming et al., 1979; McCalpin, 1985; and DeGraff, 2012). While these examples of mandated measures generally remain in effect now, it should be noted that none of them was instituted after 1995.

Lacking a readily definable metric, we are left to find examples that are illustrative of landslide risk reduction resulting from such technical assistance. One such example is the California Geological Survey's involvement with timber harvest plans to limit landslide-contributed sediment degrading water quality as part of the Timber Harvest Plan (THP) Review project. Since 1975, California Geological Survey geologists conduct reviews of timber harvesting plans prepared by a state-licensed forester in an effort to limit the detrimental effect of landslide occurrence in California's watersheds. California Geological Survey geologists carry out an engineering geology review of planned timber sales to provide advisory comments on slope stability concerns to the California Department of Forestry and the Board of Forestry, the state regulatory agencies that grant approval of timber sale harvest plans. Under this program, the technical assistance from the California Geological Survey ensures that approved plans achieve the desired limits on landslide-generated sediment attributable to the harvest activities. The program's effectiveness is demonstrated by its continuing existence after 40 years of operation.

A case study undertaken by DOGAMI and the coastal City of Astoria, OR, provides a more comprehensive illustration of effective landslide risk reduction resulting from interaction between a state geological survey and local government. The Landslide Risk Reduction Process highlights the partnership between state surveys and the U.S. Geological Survey Landslide Program (USGS-LP) to facilitate implementation of risk reduction measures at the local government level.

To fully understand this case study, we need a brief description of how the Landslide Risk Reduction Process was developed. In the fall of 2012, the USGS-LP and DOGAMI completed a 5 year Collaborative Landslide Hazard Project in Oregon. The collaboration focused on research and methods development to improve the quality and capacity to deliver landslide hazard and risk information to the local governments in Oregon. During the project, groundbreaking new light detection and ranging (LiDAR)–based methods for detailed landslide inventory and susceptibility mapping fundamentally changed the abilities and understanding of the landslide hazard in Oregon.

This 5 year project focused on development of standardized methods of procedure based on recent research at the USGS-LP, North Carolina Geologic Survey, California Geologic Survey, and others (Schulz, 2004; Harp et al., 2006). The goal was to have the standardized methods in place, so that future projects could focus on performing the mapping, modeling, and risk analysis at an accelerated rate. Some of the methods have been finalized and published, including the landslide inventory and the shallow landslide susceptibility methods (Burns and Madin, 2009; Burns et al., 2012). Other methods are in progress, including deep landslide susceptibility and landslide risk analysis (Burns et al., 2013).

Throughout the USGS-LP/DOGAMI collaborative 5 year project and the years following, DOGAMI partnered with several local governments (Oregon state agencies, cities, and counties) to work on landslide risk reduction projects. These community projects helped to establish the Landslide Risk Reduction Process (Figure 4). DOGAMI discovered that completing these projects with a willing local partner is a very important piece of the process, because a large portion of the landslide risk reduction takes place at the community level. It is the partnership between state and local governments that results in the best available landslide hazard data being used to perform landslide risk reduction. Following the Landslide Risk Reduction Process and methods, DOGAMI continues to work with local partners on projects.

The specific example mentioned previously was a project carried out by the City of Astoria and DOGAMI (Burns and Mickelson, 2013). In 2007, the city was experiencing several active landslides and contacted DOGAMI for assistance. DOGAMI and the City of Astoria government applied and received funding from the Federal Emergency Management Agency (FEMA) Hazard Mitigation Grant Program to conduct a landslide risk assessment and risk reduction project. The first step was to create a landslide inventory using LiDAR-generated base maps. In total, 120 landslides were found within the city boundary. Eighty-three landslides in this inventory were estimated or known to have moved during historic time. Seventeen of these had caused significant damage. For instance, the Irvine Road landslide destroyed 23 homes in 1950. The second step was to create shallow and deep landslide susceptibility maps. It was found that 55 percent of the city was classified as highly susceptible to shallow landslides, and 37 percent was classified as highly susceptible to deep landslides. Exposure risk analysis was performed, and it was found that 59 percent of the tax lots intersected with existing landslides (Burns and Mickelson, 2013). FEMA's HAZUS software was used to model a variety of earthquake scenarios and estimate regional damages such as building damage, lifeline damage, and injuries (FEMA, 2005). However, the HAZUS software does not have a landslide-only module, so an earthquake was modeled with and without the seismic-induced landslide hazard. This was done to estimate the range of potential damage and losses that can be expected from landslides during a major earthquake in the Astoria area. The loss ratio (ratio of total losses to the inventory of assets) was found to increase from 12 percent to 21 percent when the landslide hazard was included. These results indicate a significant increase in losses caused by the landslides triggered by an earthquake. This increased hazard effect is likely to occur in other localities with high seismic and landslide hazard, like many portions of the Oregon coast.

The City of Astoria is now using this landslide hazard and risk information to inform their land-use planning and update their regulations related to grading and development proposals. For example, the city has purchased lands associated with historic landslides and is using them as parks and open space. The city has begun to implement the integration of the landslide data into a Geologic Hazard and Hillside Development Ordinance.

Emergency Preparedness, Response, and Recovery

Whether effective landslide loss reduction efforts are in place locally or not, unexpected landslide events may still occur. Consequently, there is a need for state geological survey involvement in subsequent emergency response actions. The AASG questionnaire included three questions pertinent to emergency situations. Among the 29 questionnaire respondents, only Maryland and Vermont indicated an actual involvement with installation or construction of mitigation or stabilization measures when an unexpected landslide takes place (Table 4). This is not surprising given that the landslides are most likely to be occurring on private or non-state public land. It is unlikely the state geological survey would have the authority to undertake mitigation or stabilization actions or to incur the liability of taking on such a responsibility. In situations where the interest of the state may be paramount, there are likely to be other entities such as departments of transportation, parks and recreation, and forestry or local county departments with the authority and engineering capability for carrying out mitigation or stabilization.

Landslide warning systems are a means for ensuring public safety by notifying people of an impending landslide threat. Often such warnings are part of a comprehensive emergency management plan involving evacuation, temporary shelters, and other support measures. This can be particularly effective when other mitigation or stabilization measures are not practical or have yet to be implemented. There are only a few examples in the United States of such systems being used in real-time so that notification and other emergency response measures can be effectively initiated before the threatened movement occurs (Reid et al., 2012; NASA, 2013). As noted by Baum and Godt (2010), many of the landslide warning systems that are or have operated in the United States are for occurrence of shallow landslides or debris flows triggered by precipitation events. Because shallow landslide prediction depends on precipitation thresholds, it means the

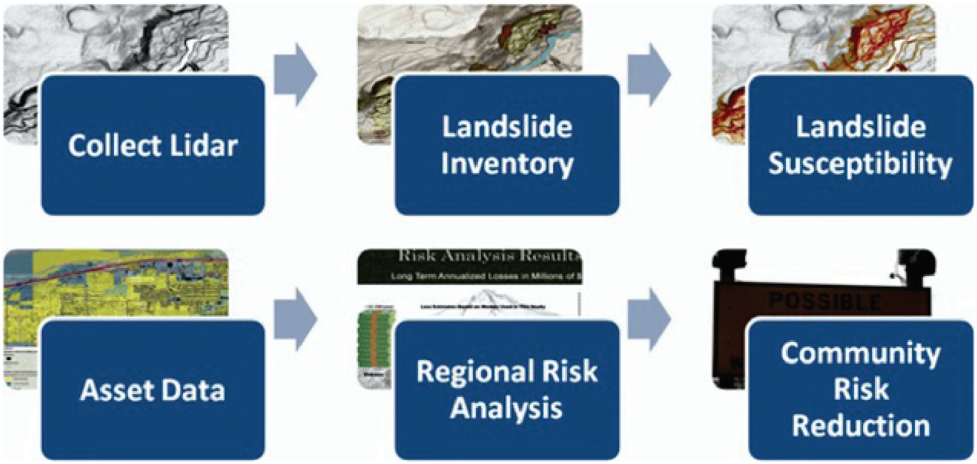

Figure 4. Diagram of the steps in the Landslide Risk Reduction Process as applied by the Oregon Department of Geology and Mineral Industries.

National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA) is typically a partner in operating these systems (Baum and Godt, 2010; Cannon et al., 2011). Such warning systems use precipitation duration or intensity thresholds linked to the relative likelihood of movement or possible landslide occurrence (Baum and Godt, 2010; De Graff et al., 2015b). In 1986, the USGS successfully deployed a warning system based on precipitation thresholds in California (Keefer et al., 1987). More recently, similar systems in California provided early warning for locations burned by wildfires in conjunction with emergency response plans developed by affected counties (USGS, 2005; Cannon et al., 2011). Colorado, North Carolina, Oregon, and Washington (representing 14 percent of respondents) indicated participation in landslide warning systems as part of the AASG questionnaire response. Because technological and scientific advances since 1995 have made an increased use of landslide warning systems possible, it provides us with one measure indicating progress by state geological surveys in emergency response.

The third question related to emergency response in the AASG questionnaire asked whether the state geological surveys worked with their respective department of emergency management. Twenty-one State geological surveys (72 percent of the respondents) answered affirmatively to this question. Unfortunately, there are no comparative data with which to assess whether this is greater involvement than existed in 1995.

The case study of the Rockville rock-fall response in 2013 is an example showing rapid, effective emergency response to a current landslide event (Lund et al., 2014). On its Web site, the Utah Geological Survey identifies providing geologic hazard assistance as one of the services it offers to local governments. More specific to emergency response, the mission of the agency as defined in the state code includes: "...determine and investigate areas of geologic and topographic hazards that could affect the safety of, or cause economic loss to, the citizens of the State" (Bowman, 2015). Any such work is done by assisting both the local government and the Utah Division of Emergency Management (UDEM). Bowman (2015) highlights the following important questions that guide the Utah Geological Survey's response actions:

- "Is the site likely safe for first responders and others to enter and work?"
- "What geologic information is needed to reduce the risk?"
- "Is geologic monitoring needed to increase safety?"
- "Is another event likely to occur within a short time frame?"

Table 4. *Summary of responses to AASG questionnaire inquiries related to emergency response.*

Questions	Number of Respondents Answering "Yes"	Percent of Respondents
A. Do you work on any hard mitigation (e.g., stabilization)?	2	7
B. Landslide warning system?	4	14
C. Do you work with your state Department of Emergency Management?	21	72

- "Are other nearby areas at risk from geologic hazards?"

The town of Rockville is located on Utah State Route 9 about 6.5 km west of Springdale, UT, and the south entrance to Zion National Park. The town lies on the floodplain of the Virgin River between the river channel and the base of a cliff forming the southern edge of Rockville Mesa (Lund et al., 2014). The cliff exposes the interbedded sandstone and shale bedrock of the Moenkopi Formation capped by the Shinarump conglomerate member of the Chinle Formation. This stratigraphy is conducive to basal erosion of the sandstone and shale, resulting in undermining of the more resistant conglomerate rocks. At approximately 5:00 p.m. on December 12, 2013, a large block of Shinarump conglomerate detached and bounded down the cliff face (Lund et al., 2014). When the fast-moving rock-fall debris reached the base of the cliff, it destroyed a Rockville residence along with its garage and car. More importantly, it killed two people in the home (Lund et al., 2014). Two Utah Geological Survey geologists arrived at first light the following day to assist the Springdale chief of police, who was serving as the incident commander for the emergency response (Bowman, 2015). A reconnaissance of the rock-fall source area and the area leading to the destroyed residence was carried out to determine the safety of emergency responders (Bowman, 2015). In addition to collecting the geologic circumstances of this particular event, the geologists carried out a rapid assessment of expected rock-fall runout (Lund et al., 2014). This was an important part of the geologic information needed to determine whether risk could be reduced. From observations made of the capping conglomerate and downslope rock-fall deposits, it was concluded that hazard from rock fall remained high, but predicting the timing of future events was not possible (Lund et al., 2014). This conclusion was consistent with Rockville experiencing at least five other large rock falls over the past 35 years prior to the 2013 event. The destroyed residence and other nearby ones are within a zone of mapped rock-fall hazard (Knudsen and Lund, 2013). Consultation between the local government authorities and the Utah Department of Transportation determined that standard engineered rock-fall mitigation measures were not feasible for protecting at-risk residences (Lund et al., 2014). The report outlined options for the residents remaining within any high-hazard area: (1) continue to reside there knowing the consequence of the decision could include significant property damage and may prove fatal or (2) relocate from high-hazard areas (Lund et al., 2014). A recommendation was made that the Town of Rockville ensure that present and future residents and land owners in the high-hazard areas be made fully aware of the hazard. It further noted that some local governments had purchased or retired the properties of homeowners who wished to relocate or to move their houses to safer locations (Lund et al., 2014). These recommendations represented a response to the question, "Are other nearby areas at risk from geologic hazards?" (Bowman, 2015).

DISCUSSION AND CONCLUSIONS

It is evident that both our understanding of landslide processes and the technology that can be applied to furthering this knowledge have undergone significant improvement during the 20 years since National Landslide Awareness Day. Emphasizing the actions taken at the state level of government, we can see an improvement in actionable policy for reducing landslide hazard. Table 5 shows some of the metrics from our analysis for comparing pre- and post-1995 changes for accomplishing landslide risk reduction for the categorical elements of developing guidelines and training, increasing public awareness and education, implementing loss reduction measures, and achieving emergency preparedness, response, and recovery (Table 5).

Changes in the number of states requiring practicing geologists to be registered, the uniformity introduced into tests used to determine which individuals are qualified to be registered, and the guidelines available for conducting geological investigations are indicative of improvement in the categorical element of guidelines and training. Table 5 shows that states requiring registration or licensure for practicing geological professionals has nearly doubled since 1995 and is now instituted in 64 percent of the states. The testing used to determine which geologists are qualified for registration was up to individual states prior to 1995. Now this testing employs the same procedures in nearly all states requiring registration (Table 5). Only three states provided guideline documents applicable to landslide hazard work prior to 1995. Now five states have such guidance documents, including recently updated versions for two of the three states with pre-1995 guidance documents (Table 5). It is recognized that none of these measures is directed solely toward landslide risk reduction. If practicing geologic professionals are generally more skilled and knowledgeable, we assume those who specialize in landslide-related issues will be too. The end result is to have a greater workforce capacity at the state level to accomplish landslide risk reduction.

Public awareness and education are enhanced by the adoption by all state geological surveys of Internet-

Table 5. *Change in measures between pre- and post-1995 for the four categorical elements.*

Category	Metric	Pre-1995 (No. States)	Post-1995 (No. States)
Guidelines & training	Registration/licensure	19	32
	ASBOG testing	0	30
	Guidance documents	3	5
Public awareness & education	Landslide hazard information on Web page	0	31
Implementation of loss reduction	Lists or guides directed at homeowners	0	9
Emergency response	Warning systems	1	5

based outreach to the general public, residents, and landowners, and local government staff and practicing professionals. Table 5 indicates that 31 state geological surveys (62 percent) use this technology specifically to communicate landslide hazard information. Consequently, a post-1995 communications medium is facilitating dissemination of information on landslide hazards to these stakeholder groups.

Implementation of risk reduction due to landslide activity requires incorporating our current understanding of the landslide process into land-use planning and construction. Schwab et al. (2005) published a notable national-level handbook assisting planning professionals with facilitating implementation of landslide risk reduction. Certainly, efforts to ensure that residents and landowners are able to recognize early signs of landslide activity represent progress. Such recognition enables residents and landowners to determine if their property's intended use might be impaired or to take early action to forestall damage. Table 5 shows that prior to 1995, there were no guides specifically directed at individual homeowners that would enable them to make such determinations. Currently, there are nine states where the state geological survey site offers lists of observable indicators of impending or ongoing landslide activity or an actual publication providing such information. The Oregon case study involving DOGAMI and the City of Astoria clearly demonstrates how an effective landslide risk reduction effort can be implemented at the local government level.

Many state geological surveys have an ongoing relationship with their state's agency for emergency management. As such, they have an important role in providing geological information for emergency personnel and disaster response planning. Warning systems provide an indicative measure of progress by state geological surveys in conducting emergency response actions. Table 5 shows that one state, California, had effectively used an early warning system before 1995. During the last 20 years, five states have established early warning systems to some degree and with varying success. All of these efforts have been fostered to a greater or lesser extent by the USGS. The case study explaining the work done by the Utah Geological Survey during the 2013 rock-fall emergency in Rockville, UT, is illustrative of how a state geological survey can contribute to emergency preparedness, response, and recovery actions.

Based on the metrics presented in this paper, we conclude there are signs of progress during the last 20 years toward implementing actionable policy changes and programs to achieve landslide risk reduction in the United States. Local communities can accelerate progress toward greater landslide risk reduction by implementing land-use requirements based on our improved understanding of landslide hazard. State geological surveys are key actors in furthering this trend because of their public education efforts and partnership with local communities to develop mandatory measures that assure risk reduction at the local level. Motivations for reducing landslide risk would be helped by more comprehensive efforts to document actual losses, particularly on a monetary scale. Data of this type would not only be meaningful to elected officials, but also the insurance and banking sectors. Population growth and urban expansion mean that efforts toward the following will need to continue and expand: having an appropriate level of training for professional geologists involved with landslide risk reduction work, fostering efforts to educate the public about general and specific landslide hazards that might affect their lives and property, taking actions at the local government level to implement risk reduction measures, and developing effective emergency preparedness, response, and recovery actions.

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