Communicating Hazards—A Social Science Review to Meet U.S. Geological Survey Needs

Circular 1449

U.S. Department of the Interior
U.S. Geological Survey

Cover. Volcano (top): Lava within the braided portion of the Kīlauea Volcano Fissure 8 channel flows within its banks (photograph by U.S. Geological Survey [USGS] Hawaiian Volcano Observatory).
Earthquake (middle left): Damage to a road from fault offset (photograph courtesy of the National Information Service for Earthquake Engineering-Pacific Earthquake Engineering Research Center, University of California Berkeley, used with permission).
Graphic novel (middle right): Excerpt from a graphic novella that presents basic concepts of geomagnetic science (Big Time Attic and Love, 2006).
Flood (bottom): Flooding in Soldier Pond, Maine, following rainfall and snowmelt that led to high water levels in the Fish and St. John Rivers in April and May of 2018 (photograph by Henry Gilman, USGS).

Communicating Hazards—A Social Science Review to Meet U.S. Geological Survey Needs

By Kerry F. Milch, Suzanne C. Perry, and Jennifer L. Bruce

Circular 1449

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DAVID BERNHARDT, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2019

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit https://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit https://store.usgs.gov.

Suggested citation:
Milch, K.F., Perry, S.C., and Bruce, J.L., 2019, Communicating hazards—A social science review to meet U.S. Geological Survey needs: U.S. Geological Survey Circular 1449, 67 p., https://doi.org/10.3133/cir1449.

ISSN 2330-5703 (online)

Contents

Figures

Tables

Acknowledgments

Columbia University's Center for Research on Environmental Decisions (CRED) developed this report with funding from the U.S. Geological Survey and the National Science Foundation (NSF SES-0951516 and NSF SES-1463122).

Communicating Hazards—A Social Science Review to Meet U.S. Geological Survey Needs

By Kerry F. Milch,[1] Suzanne C. Perry,[2] and Jennifer L. Bruce[2]

Introduction

This report is for U.S. Geological Survey (USGS)—and any other—hazard scientists who want to improve the understanding and use of their scientific information, particularly by non-experts. In order for people to use science, they need to understand it. The highly technical, specialized nature of scientific information makes that difficult, particularly when few scientists are trained to communicate with people outside their fields. These issues are of special importance to the USGS because it has many users who are not scientists and because it develops and applies hazard science to help protect the safety, security, and economic well-being of our Nation (Holmes and others, 2012).

In 2010, the Science Application for Risk Reduction group at the USGS discovered the Center for Research on Environmental Decisions (CRED) guide, "The Psychology of Climate Change Communication" (Center for Research on Environmental Decisions, 2009). Ever since, a growing number of USGS staff who need to communicate about hazards have used that guide and have asked CRED for a companion report dedicated to hazard communication to harness knowledge from more than 50 years of social science research.

In 2016, the USGS and CRED launched a collaboration to develop that companion report. Ultimately, a CRED hazard communication guide would be a Columbia University publication with a wide focus and would include many hazards that are outside the USGS purview. This report is a first step and concentrates strictly on hazard communication needs at the USGS.

To identify those needs and tailor this effort to USGS hazard communication priorities, this collaboration began with telephone interviews and an online survey of USGS staff (see appendix 1 for details). This report is the result; it summarizes social science research and experience in the areas of hazard communication that USGS participants deemed most important to include.

Finding the Information You Need

This document provides research summaries in six broad sections: audience, framing, uncertainty, language, visuals, and crises. Each section covers a communication topic that is important to the USGS based on the interviews and surveys described in appendix 1; however, many items are interrelated, so similar points sometimes arise in different sections. Even if you are interested in only one topic, you may want to skim the whole document for related information.

Each section starts with a list of recommendations to improve hazard communication. Subsections then expand on and support the recommendations by summarizing the pertinent research. However, you won't find a one-to-one correspondence between recommendations and research summaries. For example, a body of research might lead to several recommendations or a single recommendation might encompass many studies.

If you focus on only one change in your approach to hazard communication, make that the "Audience" section. Getting to know an audience, working collaboratively with audience members where possible, and pretesting your messages/products with them will help you craft the most effective communication, earn their trust, and make it more likely that they'll use your information.

This report touches on activities that are outside the USGS domain, such as giving advice or persuading people to take certain actions. We included this research because USGS partners will use USGS information to do these things; thus, it is important for the USGS to have a general understanding of those issues. There's no single right answer for many of these communication challenges. There is no one-size-fits-all approach. Some of the recommendations may even seem to contradict each other. How people respond to your communication depends on them—the particular audience and the circumstances in which they process the hazard information. The important take-away points are to know your audience and, whenever possible, to try out different versions of products with them before you finalize.

[1]Center for Research on Environmental Decisions, Columbia University.

[2]U.S. Geological Survey.

This report is not a "how to" manual. Instead, it will give you a sense of key issues, attitudes, and approaches in hazard communication, so that you can sit down with consumers of hazard information and recognize what's in play with a particular audience as you work to craft the most effective products for those consumers.

About All These Boxes

Our interactions with USGS staff quickly made clear that USGS hazard communicators have much valuable experience to share. Consequently, the plans for this project evolved beyond a literature review. The document now includes a rich assortment of case studies from the USGS—wide-ranging, in-the-trenches experience with hazard communication. Case studies about the USGS experience appear throughout, in boxes called "USGS Point of View."

The main body of text in this document summarizes peer-reviewed, published research. Certainly, any summary requires interpretation, but we have tried to relay the published research results as purely as possible. However, early readers indicated that they wanted help getting started as they tried to absorb and apply this research. In response, we applied our own experience (summarized in appendix 2) to create the bullet lists of recommendations and, in a few places, boxes called "Authors' Point of View." We use distinct color and formatting to emphasize that these parts of the report are not strictly from peer-reviewed literature.

Audience

When you craft communication, it is essential to consider who will consume (read, hear, watch, apply) your information. The more you can identify and get to know your audience, the more you can tailor your message to them, which makes it more likely that your science will be understood and used.

The research suggests the following:

- If you want to reach an audience, find out what that audience needs, believes, and expects.
- Don’t target too broad an audience. For example, the “general public” is not one audience—it encompasses diverse groups with different communication needs.
- Use focus groups, interviews, surveys, and (or) informal interactions to understand your audience’s mental models (their personal frameworks about how the world works).
- You may need multiple communication channels (for example, internet, television, word of mouth, or translations) because different groups have varying access to and preferences for modes of communication.
- Engage in community outreach to uncover misconceptions, establish trust, and open channels for additional communication (which are crucial during crises).
- Use trusted emissaries to reach socially isolated groups and groups who may distrust governmental and (or) scientific authorities.
- Be mindful of the following:
    - People will pay more attention to a risk if you can point out a concrete action they can take to lower their risk. (Highlight one activity so they are not overwhelmed with possible actions.)
    - Most people expect future events to match those previously experienced and believe that protective measures that worked in the past will be sufficient for future events.
    - Emotions play an important but often hidden role in many risk assessments.
    - Social cues can have a big effect on risk perception.

Consider These Questions To Get Started

"Before you begin to craft a communication, it is essential to think about what you need to communicate. Your goals will determine which questions will be most helpful. A communications plan template is in appendix 3 of Driedger and Westby (in press). This template will guide you through the process of identifying your communication goals, your audience(s), your partners, controversial issues you should anticipate, and more.

At the start of any project, consider these "starter" questions and strategies to shape your communication to the needs and constraints of your audience.

- Why is the audience coming to you?
- Why should they be receptive to your information?
- Is there a crisis? (If so, some aspects of communication will change.)
- How much time will your audience be able to spend processing your communication?
- Will they have a chance to ask questions and seek clarifications, or are they processing the information on their own?
- Does your audience have a technical background?
- Are you trying to understand what people currently think about the hazard? (If so, try open-ended questions about the causes and effects of the hazard. This will allow people to discuss what they currently think without your expert knowledge pushing them toward one answer or another.)
- Are you trying to create or improve a product? (If so, ask questions to assess their understanding of the hazard. Also ask them to list the pros and cons of products they currently use, the conditions under which they use them, and what they hope to get from them.)"

Authors' point of view

Assess Your Audience's Needs and Preferences

Community engagement at local meetings, focus groups, and surveys can be invaluable to test how people understand and interpret a product and to assess what kind of information they are seeking (Carr and others, 2016a; Paveglio and others, 2009; Carr and others, 2016b). In general, people tend to want information that is specific to them and their exact location (Carr and others, 2016b; Wagner, 2007). Your communication will be most effective if it targets your audience's actual beliefs and motivations, rather than your assumptions about them (Fischhoff, 1995).

Interacting with potential audience members can also help you learn the intuitive language people adopt when they discuss particular scientific or policy issues. Craft communication that uses the terms your audience uses, and you will be effective in reaching those audiences (Fischhoff, Bostrom, and Quadrel, 1993).

Beyond simply getting to know your audience, partner with them in the development of products and services (fig. 1). Such partnerships create buy-in and engagement in a way that is hard to establish through any other means (Cadag and others, 2017).

The "General Public" is a Diverse Collection of Audiences

The "general public" is not one audience. It is a heterogeneous group of people who vary in their knowledge base, interests, literacy and numeracy, degree of experience with hazards, cultural background, familiarity with technology, trust in authority, and socioeconomic status (Stewart and Nield, 2013). For example, the following groups are all considered "general public" but have different hazard information needs: individuals, neighborhood associations, schools, hospitals, nursing homes, and small businesses. Historically, communication about hazard preparedness has targeted the individual household level, with less emphasis placed on neighborhood or community planning (Mileti, 1999).

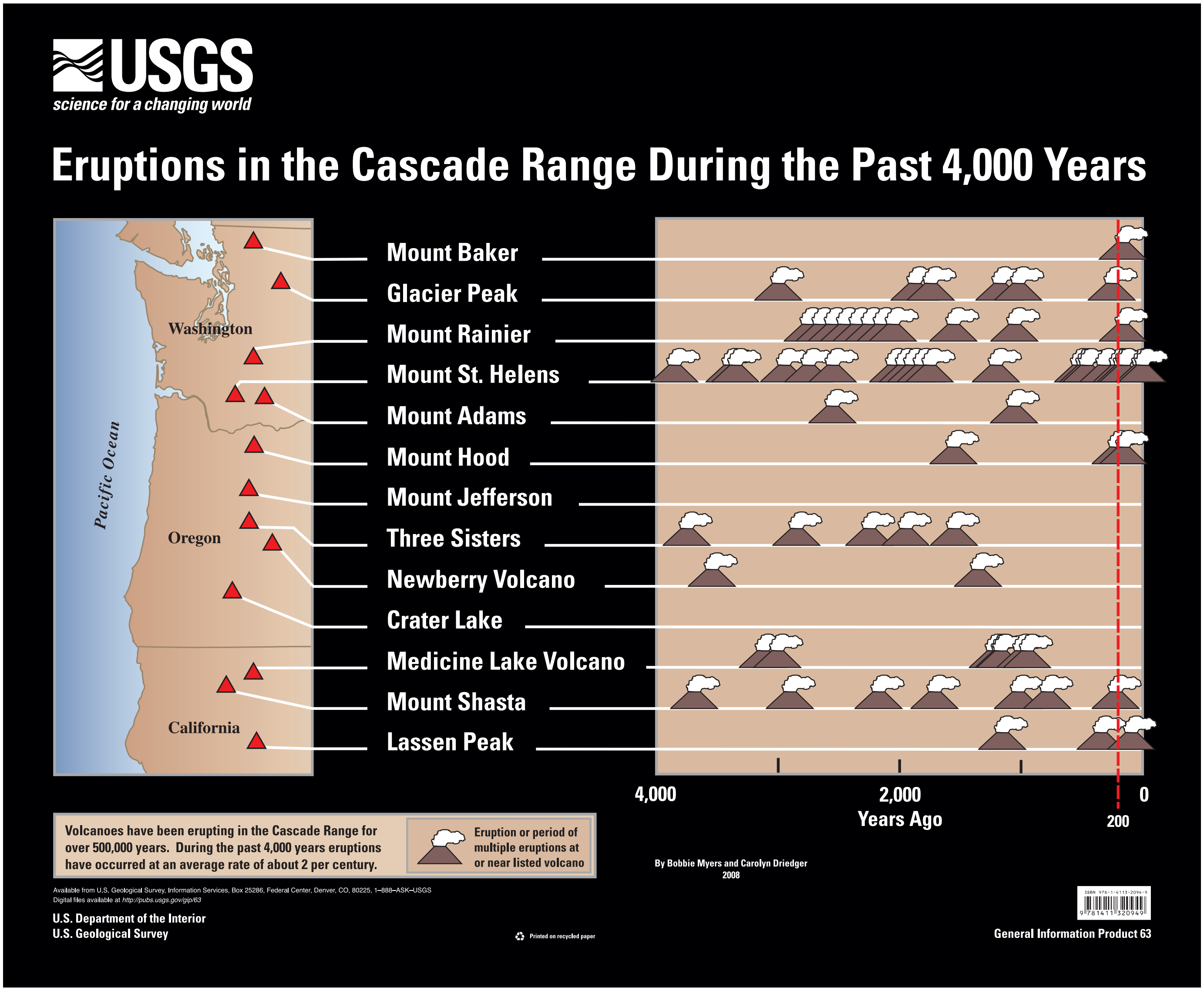

Figure 1. The U.S. Geological Survey (USGS) Cascades Volcano Observatory's most popular public information product (USGS General Information Product 63, https://pubs.usgs.gov/gip/63/). Local educators initially requested this product then worked closely with USGS during its development.

Businesses with transient populations, such as hotels and motels, may need different types of communication than residents who are more familiar with the local hazard(s) (Lindell and Prater, 2010). This is especially relevant for popular tourist destinations.

There are people who are interested in hazards and in learning more, who will seek out public lectures and other sources of information. These people tend to be above the community average in income, education, and home ownership (Lindell and Prater, 2010), and tend to be more resilient. However, it will take more effort to reach people who fall into one or more of the following groups (Lindell and Prater, 2010; Fothergill and others, 1999):

- the very young
- the very old
- people who are less educated
- people living in poverty
- people whose first language is not English
- people who rent rather than own their homes
- mobile populations, such as migrant workers and people who are homeless

People in these groups are more vulnerable to harm from natural hazards, so particular attention should be paid to communication with them.

Getting to Know Your Audience

"Throughout this report, we encourage you to interact with members of your audience to get to know them. There are many ways to do this. Interviews, surveys, focus groups, and informal conversation can all help you. The queries you receive after a presentation in person or by email can also help: consider what listeners asked and what they didn't know enough to ask.

When you interact with an audience, asking the right questions—and correctly interpret the answers you receive—takes experience, skill, and creativity. There are experts who spend years training to do this, and we encourage you to collaborate with or hire such experts. They will be invaluable allies in your effort to improve your hazard communication. Social scientists who work in this realm rely on theory, develop hypotheses, and use well-established analysis methods to interpret their findings—just like natural scientists. They also think hard about sampling design and seek to obtain a representative sample.

However, we also—and even more strongly—encourage you to reach out to members of your audience on your own. Every contact you make with a member of your audience will teach you something that you can apply to your current product and future products. In fact, we can pretty much guarantee that such interactions will be revelatory.

You'll want to reach out to those who are receptive to your science—and those who might not be. For most of us, receiving potentially negative feedback is difficult. Consider swapping this effort with an impartial colleague (you seek feedback about their products, they seek feedback about yours). This is also a good time to use social science experts.

However you make it happen, the benefits work both ways when you connect with members of your audience. When you invite audience members to participate in product development, however informally, that increases their buy-in, boosts the chances that they will understand and use the information, and helps to build trust and a long-term relationship.

Your efforts don't have to be exhaustive or comprehensive. Input from a single person, or a handful of people, will give you valuable insights. Many formal studies conducted by social scientists get valid results by working with 4–7 people (Zarcadoolas and Vaughon, 2016a, 2016b).

Be aware that, when it comes to asking questions of people, Federal employees may face restrictions under the Paperwork Reduction Act (U.S. Office of Personnel Management, 2011) depending on the number of people and who they are. If you question 10 or more people who are not Federal employees, the U.S. Office of Personnel Management must approve your questions (a process that can take months) and you must adhere to certain rules that can vary over time and across agencies. (The USGS assigns staff to help navigate the process. As of this printing, that is James Sayer, gs-infocollections@usgs.gov.)"

Authors' point of view

USGS POINT OF VIEW

Pitfalls in Audience Selection

While you always need to have a target audience in mind, you don't have control of who will access and use the report, visualization, analysis, or message. Focusing too much on one audience (emergency response, personnel, local government) could mean that the original report gets ignored by other groups. That opens a lane for a third party to generate a derivative, and possibly inaccurate, product.

—Anonymous USGS scientist

At first glance, this guidance seems to contradict the advice to tailor your message to a specific audience. The bottom line is that it is important to keep your message broadly readable by audiences without specialized training. Of course, this depends on the nature of your particular communication and particular audience; for example, products designed for city planners or building engineers will be different from those designed for residents. Broad comprehensibility will ensure that your target audience will interpret your message accurately and share it more readily, and will reduce the risk of misinterpretation by other audiences who might happen upon the product.

Mental Models—What Your Audience Already Believes

Everyone has mental models, which are cognitive representations or frameworks of how things work. Mental models help us understand the world and make predictions about future events, often without awareness. They are based on two types of reasoning: analytical (data-driven) and experiential (from emotion, imagery, values) (Leiserowitz, 2006).

Mental models shape what people attend to and how they perceive and evaluate new information (Johnson-Laird, 1983). Understanding mental models can be helpful for understanding how people think about hazards, and can also give insight into their perspectives about hazard management, science communication, and science more generally (Eiser and others, 2012).

Although mental models can be updated (Johnson-Laird 2010), literature indicates that there is a danger that people will ignore information that does not fit their mental model, even when that information dominates headlines. People are particularly likely to ignore dissonant information when they deem the topic "scientific or complicated" (Gross, 2006, p. 0680).

It can be hard for people to assimilate new information into existing mental models. Indeed, confirmation bias—the tendency to seek out information that confirms one's existing beliefs and to discount information that contradicts them—is well known in psychology (Nickerson, 1998). Prior beliefs about control and outcomes can be particularly hard to change among demographic groups that have historically felt disempowered (Vaughan, 1995). All of these factors may help to explain why perceiving a risk does not directly translate into taking action to mitigate the threat (Lindell and Whitney, 2000).

A mental models approach to hazard communication seeks out and gives value to non-expert information, establishing two-way dialogue that allows scientists and the audience to better understand one another's perspective (Gibson and others, 2016). This approach can draw attention to the existence and significance of misconceptions that might otherwise seem trivial or inconceivable to experts and create an opportunity to address them. For example, a survey of college students in California found that many students believed unusual animal behavior was a predictor of earthquakes. Following initial assessment of the students' earthquake beliefs, the researchers provided informational pamphlets on either earthquake facts or earthquake facts versus myths. Both were effective in correcting misbeliefs, with the facts versus myths format particularly effective in correcting misbeliefs about the predictability and warning signs of earthquakes (Whitney and others, 2004).

USGS POINT OF VIEW

Understanding Where They're Coming From

I try to work with people where they are – invite them to ask questions, to try to understand where they're coming from. I recognize that sometimes people ask questions that seem out of left field, but they're trying to make associations—associations with their lives, with something they heard on the news. You can take these questions and work with them.

—Jeffrey Love, Research Geophysicist, Geomagnetism

USGS POINT OF VIEW

Taking Their Perspective to Find Common Ground

After a fire, a multi-agency Burned Area Emergency Response (BEAR) team assembles to study the situation and advise on what to do to reduce post-fire flooding and loss. In 2011, the Las Conchas fire (fig. 2) was the largest in New Mexico's recorded history and created severe, complex flood risks. The BEAR team comprised members from the Park Service, Forest Service, and USGS with conflicting ideas.

Some BEAR team members wanted to use helicopters to put down grass seed. The scientific evidence for the effectiveness of this approach is mixed at best. You can waste money and introduce invasive, non-native species. Even though seed is required to be weed-free, the definition is 99.5 percent weed-free. Even a .01 percent contaminant of a very invasive species can transform a landscape quickly. On the Las Conchas BEAR team, the USGS position was "don't seed."

The leader of the "do seed" group was a soil specialist who was adamant that seeding was effective. When pressed, he couldn't point to data to support his position. During our discussions I realized that this was a philosophical difference. He's a soil scientist, so preserving the soil is a top priority. We had many tense but respectful conversations. The "don't seed" group couldn't eliminate seeding but got the acreage cut back. At the time it felt like we had lost.

About two years later, I invited that soil scientist to a conference I helped organize. At this conference, this scientist and other pro-seeding attendees sat by themselves. They felt ostracized, and they appreciated my joining their table. I was able to increase their appreciation for the "don't seed" position and the importance of data-driven decisions. I realize now that changing attitudes takes time.

If you don't take opposing decisions personally, you find opportunities to teach – and to learn. Early in the Las Conchas experience it became clear to me that everyone wanted what was best for the people who live there and the ecosystem they depend on. Once you realize you're all coming at it with the same goal, it's easier to disagree. When you build a relationship on that sense that you both want what's best, even when you disagree, it's hard to lose respect for the other person.

—Collin Haffey, Ecologist, Fort Collins Science Center

Mental Models About Science

Before you finalize your information or product, ask questions to gauge how much information the audience has, how accurate the information is, what gaps you need to fill, and how receptive they may be to your communication (Center for Research on Environmental Decisions and ecoAmerica, 2014).

Mental models can reveal what people understand about the causes of natural hazards and about appropriate precautions. For example, in the United States many believe losses from natural hazards are caused by "surprise extreme events" and not the result of choices, such as building in hazard-prone areas (Mileti, 1999, p. 144–145).

Wrongly held scientific beliefs may lead people to make incorrect inferences about the likelihood of a hazard. For example, some people believe that the occurrence of an earthquake makes another one unlikely to occur in the same area (Weinstein, 1989) when, in reality, having an earthquake increases the chance of additional earthquakes. Another potentially problematic belief is that the occurrence of a rare event means you don't have to worry about another one for a long time. Sometimes such misbeliefs are aided by scientific terms, such as when people conclude that a 100-year flood would be unlikely to strike twice in their lifetime (Ludy and Kondolf, 2012).

It can help to ask about confidence in beliefs. Incorrect beliefs held with high confidence and correct beliefs held with low confidence should both be targeted for intervention (Bruine de Bruin and Bostrom, 2013). It is a common technique to conduct interviews to identify beliefs and attitudes, then conduct surveys to determine the extent to which those beliefs and attitudes are widespread (Bruine de Bruin and Bostrom, 2013).

Figure 2. Burned trees and landscape in the Jemez Mountains, New Mexico, after the 2011 Las Conchas fire (Craig Allen, U.S. Geological Survey). After this fire, members of the Burned Area Emergency Response team had to deal with conflicting strategies about how to reduce post-fire flooding and loss.

Understanding mental models can also provide insight into the nature of your audience's concerns. Because of their mental models and a perceived lack of clarity about warning message contents, people have interpreted being "advised" to do something (such as being advised to stay off the beach) as optional, not an order (Sutton and Woods, 2016).

People are often more worried about flood levels than flood frequency, and they are more likely to understand specific, easily visualized information; thus, explaining flood risk in terms of "more than 1 foot of water in the house" is often more effective than talking about a "100-year flood" (Bruine de Bruin and Bostrom, 2013). In a related example, a focus-group study of tsunami warnings revealed misunderstandings and confusion about the specifics of the warning and the way tsunamis work: "3-foot [tsunami], what does that mean? 5-foot [tsunami]…?" (Sutton and Woods, 2016, p. 394).

The best way to ensure your intended audience understands your wording is to run it by them.

Expert Versus Non-Expert Perceptions of Risk

Experts and non-experts consider different issues when evaluating a risk, and this affects communication as well as decision making. Hazard experts typically adopt an objectivist perspective, which bases risk on the probability and magnitude of a negative outcome and on the assumption that risk can be assessed. Non-experts may adopt a constructivist perspective, which bases risk on judgments of the likelihood of a hazard and subjective valuations of what is important (Cvetkovich and Earle, 1992). For experts, risk assessment focuses on physical damage, whereas the public may consider indirect risks, such as loss of sentimental items and a sense of security in their homes (Mileti, 1999; Siegrist and Gutscher, 2008).

The constructivist perspective also takes into account stress brought on by living with direct threat. People who actually experience a major disaster can suffer from chronic health problems for years to come (Nomura and others, 2016). Historically, the relation between stress and hazards has been studied in the context of threats from nuclear facilities or environmental contamination, but it does not take a great leap of imagination to consider the impact of stress brought on by living in a natural hazard zone, particularly for those who lack resources to move or adequately prepare.

USGS POINT OF VIEW

The Power of Dialog

"Scientists take a lot of heat for living in the proverbial ivory tower. For not 'engaging with society.' For being uninteresting and difficult. Essentially for being poor communicators. When this perception spreads it threatens the effectiveness of our life work to build a better world and eventually dampens enthusiasm for publicly funded research.

I'm currently on a team tasked with drafting a new Water Mission Area communications plan. We grapple with why we don't communicate well with 'society' and how to address this problem. It is a complex, nuanced problem to be sure, but we have come to realize one key variable is familiarity. Scientists are generally pretty good at communicating with people like themselves, but generally poor at communicating with unfamiliar groups. What's worse, we often think we understand our audience, but in reality don't take time to actually engage in a dialog.

In my research as a human geographer, I have learned that when I make the effort to seek out and listen to people, to understand them, humbly, genuinely, and on their terms, several things happen. I gain their trust, we understand one another differently and empathize with one another. The walls to communication often come down. I learn who they are, what their problems are, what motivates them. When it works, it's actually hard not to learn how to communicate better with them."

—Brian Neff, Research Hydrologist, Colorado Water Science Center

Relative Risks and Tradeoffs

Lay audiences may have trouble understanding relative risks and tradeoffs. For example, during a hurricane or potential debris flow, people may not understand the relative risk of a late evacuation (and possibly getting stuck in a car) compared to finding a safe way to stay put (Eisenman and others, 2007; Lindell and Prater, 2010). People may respond to uncertainty by waiting for more information before deciding what to do. It helps to remind people that there is a cost (an opportunity cost) when they wait for better evidence before taking action or choosing to take no action (Fischhoff, 2015), and that scientists will always be presenting uncertainties.

Factors That Affect Taking Responsibility for Risk

In the United States, many people have historically viewed protection from natural hazards as the Government's responsibility, although that has shifted during the past few decades. Since Hurricane Katrina, there may be less trust in the Government for protection and more of an individual sense of being personally responsible for protection (Lindell and Prater, 2010). On the other hand, the United States has a strong culture of individualism, property rights, and the right to pursue profits (Mileti, 1999). Strong cultural attachment to a place may also affect decisions (Gaillard, 2008).

Risk perceptions are often affected by portrayals of natural hazards and environmental disasters in movies and other media (Bahk and Neuwirth, 2000; Leiserowitz, 2004). These vivid portrayals can lead to overblown perceptions of danger or even a false sense of security, when current warnings about a real event seem mild in comparison. In a tsunami focus-group study, participants with minimal direct tsunami experience used their memories of reports from the 2011 Tohoku or 2004 Aceh tsunamis to downplay the risk posed by a tsunami warning about waves with heights between 2 and 4 feet ("…that's not so bad. Calm down.") (Sutton and Woods, 2016, p. 395).

Prior Experience Affects Future Decisions

A large review of research on natural hazard risk perceptions concluded that the strongest determinants of risk perceptions were prior experience with the hazard and trust in authorities and experts (Wachinger and others, 2013). Prior experience with a particular hazard can significantly impact how a person will interpret new information. Most people interpret statistical information about risk (likelihood) through the lens of prior experience. Although risk and hazard experts are not as readily swayed by prior experience, it still colors their judgments of future risk (Dillon, Tinsley, and Cronin, 2011). Overreliance on past experience can lead to poor judgments about the future (Sellnow and Seeger, 2001).

The data are mixed on whether prior experience makes people more sensitive to information about a hazard or less sensitive. In part, this is due to different ways prior experience has been characterized (for example, experiencing a hazard directly but not suffering any damage versus family and friends experiencing a hazard versus suffering great losses) (Baker, 1991; Sharma and Patt, 2012). The fuzzy connection between prior experience and future intentions is also due to the variability in the lessons people draw from past experience. Demuth and others (2016) point out that the same negative feelings from having experienced a hurricane (dread, fear, worry) can make people more likely to evacuate in the future (because they know how bad it can be) and simultaneously less likely to evacuate (because previous experience has led to hopelessness and reduced feelings of self-efficacy.

The "Prison of Experience"

There is a tendency to expect that precautions that worked previously will be sufficient for all future events. Kates (1962) wrote about the "prison of experience," and described flood plain managers' inability to imagine any flood worse than what they have experienced, which limited their ability to take precautions. Meyer and others (2013) determined that for a simulated hurricane, prior experience with a hurricane, regardless of damage, decreased concern for the future hurricane and was associated with lower levels of preparedness.

However, research has also shown a positive correlation between prior experience and increased risk perception, as well as likelihood of preparing for a future hazard event (Dunn and others, 2016). The research on the relation between prior hazard experience and preparation for future events can seem contradictory or inconclusive because of the range of different ways "prior experience" has been defined (for example, experiencing serious damage, experiencing an event with no physical damage, living near an area that experienced an event but not actually experiencing it first-hand). Demuth and others (2016) discuss a range of cognitive and emotional factors that can mediate the relation between prior experience and future preparedness.

People who have experienced a previous event, such as a flood or volcanic eruption, are often aware of the severity of these types of events, but if they previously suffered little damage, they may underestimate the danger of future occurrences (Campbell, 2011; Halpern-Felsher and others, 2001; Eisenman and others, 2007). Mileti and O'Brien (1992) refer to this as the normalization bias. However, people with no experience of earthquakes anticipate more negative emotions than those who have actually experienced an earthquake (Dunn and others, 2016).

Other factors that can lead to misestimation of future risk include the following:

- Length of time since the last hazard. Burger and Palmer (1992) found that immediately after an earthquake, university students did not show an optimism bias (believing themselves to be just as vulnerable as the average person), but 3 months later, they did. Similarly, anxiety about earthquakes and nuclear accidents, measured 10 months after the 2011 Tohoku earthquake, was higher than pre-quake levels, but then decreased during the next 3 years (Nakayachi and Nagaya, 2016).
- Individuals' sense of self-efficacy. Some people may adopt a fatalistic attitude (There is nothing I can do, so why bother?) (Martin and others, 2009), and sometimes this is grounded in religious beliefs (If it is going to happen, it must be God's will.) (Ickert and Stewart, 2016).
- Lack of prior experience with a natural hazard. The absence of prior experience can lead to underestimation of likelihood and overconfidence in protective measures (Eiser and others, 2012).

First-hand accounts from people who have experienced a particular hazard can help inexperienced audiences better understand the risk (Bradford and others, 2012).

Near Misses and False Alarms

A "near-miss" or false alarm can affect beliefs about the likelihood of future damage and reduce the sense of risk, similar to what happens when a person experiences an event with little damage. Dillon and others (2011) looked at people who had experienced a near-miss, an event with a non-trivial probability of a negative outcome that by chance did not come to pass, and found that the near-miss people were less likely to take mitigating action (in this case, purchasing insurance) than others. In this study, even experts in risk analysis and natural disasters were influenced by near-misses, though it took more than one near-miss to impact their decisions. People without prior experience of a hazard believe that people who avoided hazard-related harm or damage in the past are likely to continue to escape it in the future (Weinstein, 1989).

There is a tendency to view warnings about hazards that did not come to pass as "false alarms" and "failures" (Campbell, 2011). Scientists' inability to reduce uncertainty can also be viewed as failure. Campbell (2011) reports that an over-reliance on media and public officials to communicate hazard science can lead to the belief that false alarms are scientific failures, rather than an inevitable fact of life when dealing with uncertain events.

In a study of who heeds evacuation warnings (Sharma and Patt, 2012), three aspects of prior experience were key:

1. severity of past experience
2. experience with false alarms (negative correlation)
3. quality of past experience in evacuation shelters

There is some evidence that previous false alarms may not reduce the likelihood of heeding future warnings (for example, Trainor and others, 2015). However, when a warning is—or appears to be—a false alarm, scientists should still address what happened because unaddressed false alarms could erode trust.

Given the uncertainties surrounding hazardous events, false alarms and seeming false alarms are inevitable. When an alarm is sounded for an event that doesn't occur, it's always best to be transparent. Explain as soon and as clearly as possible the reasons behind the seeming false alarm. ("We dodged a bullet this time! The storm veered north at the last minute, so only light rain fell on the recent burn areas, too light to create debris flows.") Mileti and Peek (2000) see these situations as opportunities to educate the public about hazards and warnings.

Why Some People Don't Take Natural Hazards Seriously

Conversations with your target audience can identify impediments to risk-mitigating behaviors, which can include costs, time, perceived inaction on the part of other organizations, the uncontrollability of the risk, or the uncertainty of the effectiveness of risk-mitigating behaviors (Martin and others, 2007). In fact, there is some evidence that simply participating in focus groups may increase motivation to take action, share information, and seek out additional information (Carr and others, 2016a).

People often have trouble understanding design capacity and fail to recognize the limits of structural protections. Over-trust in institutions and in existing defenses against natural hazards (such as levees, dams, and reinforced buildings) can lead people to underprepare for hazards (Terpstra, 2011; Viglione and others, 2014). Even if work on structural defenses is in progress and incomplete, it can give residents a false sense of security (Fox-Rogers and others, 2016). Increased development in regions that have some structural protections in place is sometimes called a "levee effect" and can lead to an oversized sense of security among residents (Montz and Tobin, 2008; Bohensky and Leitch, 2014; Bradford and others, 2012; Pierson and others, 2014). Ludy and Kondolf (2012) showed that among a well-educated, high-income group of homeowners in the Sacramento-San Joaquin Delta in California, which is below sea level, 82 percent underestimated their flood risk and incorrectly believed the "100-year" levee would protect them and their property in all situations.

Demographic factors like age, gender, education, and income affect risk perception and actions (Wachinger and others, 2013). Even for people living in the same hazard zone, there are differences among demographic groups in how they perceive risk and prepare for hazards (Fothergill and others, [1999] summarizes 20th century research on this topic). Younger people tend to react to warnings more quickly (Drabek, 1999), and women are more likely to evacuate than men (Morrow and Gladwin, 2005).

In studies of earthquake preparedness, Caucasians were more likely than other groups to have purchased insurance, made their homes more structurally secure, stockpiled supplies, and given their children instructions (Fothergill and others, 1999). In one southern California study, women were more likely than men to indicate an intention to prepare. The likelihood of people actually having prepared increased with age, although this study did not include participants over 50 years old. People living in apartments were less likely to "adopt seismic adjustments" compared to the rest of the sample (that is, those living in houses or "other," though the authors acknowledge homeowners were probably underrepresented in their sample) (Lindell and Whitney, 2000, p. 20).

Taylor-Clark and others (2010) surveyed 680 adults who evacuated to Houston during Hurricane Katrina and determined that unemployed people were less likely than people employed part- or full-time to have heard the evacuation orders. People with weaker social networks (measured by whether they had family or friends they could live with during an evacuation) were also less likely to have heard the evacuation orders. People in a financially precarious situation (no checking or savings account) were more likely to report that evacuation orders were unclear. People who owned homes were more likely to underestimate the severity of the storm than those who rented. Older people (who may have had memories of other similar events) were also more likely to underestimate the severity.

Social Elements of Risk Perception

Social context can affect perceptions of risk. During a crisis, people tend to turn to their social networks for information on what is happening and what they should do (Haynes and others, 2008; Paton and others, 2008). These social networks can amplify or attenuate risk perceptions (Kasperson and others, 1988; Campbell, 2011) and can misinterpret uncertainty to downplay risks (Hut and others, 2016), leading to reasoning like "The report said the chance of flooding is 'probable,' but that means they're not sure so there's no need to worry."

People may receive warnings in groups, whether the communicator intends this or not. Social networks and interorganizational links are important ways of communicating information and promoting risk-wise behavior. However, Martin and others (2007) recommend structuring communication to convey the efficacy of an individual's actions, even if the neighbors are not participating.

According to Wood and others (2012), the best predictor of household preparedness was observing that others had taken actions to be prepared, which supports the findings of Mileti and Fitzpatrick (1992) and Mileti and Darlington (1997). The latter study considered an earthquake preparedness campaign following the Loma Prieta earthquake. In that study, when people observed others preparing, that led them to seek information, which led to preparation. Similarly, a meta-analysis of hurricane evacuations found that social cues (observing others evacuating and observing businesses closing) were reliable predictors of evacuation choices (Huang and others, 2016).

Relatedly, evacuation orders are more likely to be ignored if people observe others ignoring them (Mileti and Peek, 2000). Meyer and others (2013) saw similar effects in their study of hurricane simulations: participants who observed others reacting calmly to the impending hurricane had lower levels of concern and indicated fewer preparation intentions than participants who observed others' anxiety. This ties back to the importance of community engagement—establishing relationships and communication channels with different groups (including churches, unions, civic associations) will facilitate the social contagion of preparedness and of heeding warnings.

Connecting Hazards with Actions Helps People Take the Risk More Seriously

When people think there is something they can do to lower their risk, they take the risk more seriously (Spence, and others, 2011). On the other hand, if people feel there is nothing they can do, then they do nothing (Fox-Rogers and others, 2016; Martin and others, 2007, 2009).

It is important to tie hazards communication to risk reduction actions but limit the number of actions you suggest. If your communication is trying to encourage a certain behavior, like hazard preparedness, it is best to identify one activity for your audience that would be most important and effective. A long list of possible ameliorative actions can be overwhelming, leading to choice overload, decision avoidance, and inaction (Bruine de Bruin and Bostrom, 2013).

The Value of Public Outreach Before a Crisis

People's first encounters with science often happen during crises (for example, the Deepwater Horizon spill) or controversies (for example, fracking). It is important to make sure there is a basic level of geological understanding in place before crises and controversies arise (Stewart and Nield, 2013). This is especially the case with natural hazards.

Although it can be time-consuming, reaching out to a community that you hope will use your science has several benefits and can: (1) help you get to know your audience so you can better tailor your communication, (2) build residents' understanding of the hazard science, (3) increase the community's trust in you and the information you provide, (4) help establish relationships that can facilitate future communication in both directions (Vaughan and Tinker, 2009), and (5) empower residents to take actions to lower their risk (Cadag and others, 2017).

Locals may have specialized knowledge that can be of value to hazard scientists. Building relationships can facilitate collaborative action to minimize hazard damage (Barclay and others, 2008; Pierson and others, 2014). Working with an audience before a crisis will help scientists understand that group's preferred communication style, level of understanding, and preparation (Sellnow and Sellnow, 2010).

People are more likely to engage with an issue when a group that is important to them (such as their church, union, neighborhood, or social media group) is engaged with it (Center for Research on Environmental Decisions and ecoAmerica, 2014; Martens and others, 2009). Groups with "strong, shared beliefs about questions of 'right and wrong'" often have strong social norms (shared implicit beliefs about acceptable and unacceptable behavior) and can be effective at encouraging/discouraging certain behaviors, including prioritizing readiness for natural disasters (Center for Research on Environmental Decisions and ecoAmerica, 2014, p. 18).

Local leaders of churches, labor unions, social clubs, and schools can play an important role in hazard communication (Eisenman and others, 2007; Fothergill and others, 1999; Glass, 2001; Merson, 2017). These groups can help pretest communication messages (Eisenman and others, 2007), as well as identify the unique needs of a community. Working with them before a crisis can establish trust and create an ongoing dialogue.

As the USGS knows from its long history of outreach, public lectures and face-to-face interactions can provide a sense of what people are understanding and where they need more explanation (Buchanan, 2005). There are many modern ways to make such outreach resonate. For example, in the United Kingdom ("Public Engagement with Science and Technology") is a movement to promote direct, face-to-face communications between scientists and the public, cutting out the "middle man" of the media (Peters, 2013, p. 14107). More recently, the hashtag "#actuallivingscientist" allowed Twitter™ users to virtually meet a wide range of scientists (Higgins, 2017).

Buchanan (2005) indicates that earth scientists have an advantage over other scientists in that geological science involves "the great outdoors." People generally like participating in fieldwork and field trips can be a very effective way to educate and reach groups.

The Importance of Building Trust

Trust is an essential component of effective communication. Trust in authorities is especially relevant when uncertainty is high. The development of community ties between residents and scientists can lay a foundation of trust and create channels for formal and informal communication (Catto and Parewick, 2008). Establishing community ties prior to a crisis may increase the likelihood the community will turn to the USGS for reliable information.

USGS POINT OF VIEW

Using Art to Bring Science to Life

We brought in artists to communicate some holistic science ideas about how we depend on forests for ecosystem services (water, clean air, jobs) and for less tangible benefits (spiritual and emotional connections). We wanted to challenge people to think about the role of fire in landscape. The art took the passion of the scientists and managers and got it to the local community. The effort inspired everyone involved, and really felt like a team effort.

A group of us camped together at the Grand Canyon - artists, ecologists, and fire managers, who'd done research in the local area. Every day we'd go out, dawn to dusk, driving to places that served as examples of particular points the experts wanted to make. We condensed a semester of fire ecology into three days! I was astonished at how much the artists could absorb, digest, and get right. At night we shared amazing fireside philosophical discussions. After the field trip, we set up an email list-serve for artists' questions.

The art show was a huge success. It brought new voices to a shared idea – a passion for maintaining the health of the landscape and the health of the community. After the show, we paired talks with artists and scientists, to emphasize the beauty and creativity in science.

Based on before and after surveys, people went from 57 percent to 95 percent acceptance of active fire management as a tool to create healthier forests and to combat climate change.

—Collin Haffey, Ecologist, Fort Collins Science Center

Outreach is particularly important with communities that may distrust authorities and government. When a community trusts local authorities, intentions to prepare for a hazard increase (McIvor, Paton, and Johnston, 2009). Outreach can also be helpful to identify leaders in the audience and to train target audiences to accurately and effectively communicate messages to others (Covello, 2003).

The general public tends to respect scientists but does not always trust them or their motives. Sometimes scientists are seen as trying to raise more money for research or advancing a particular agenda (Fiske and Dupree, 2014). Wachinger and others (2013) found that those who mistrust authorities and experts were less likely to believe the hazard communication.

Research further shows that perceptions of common interests and goals can help establish trust (Lupia, 2013). There is a strong drive to trust those who are viewed as similar to the audience (Fiske and Dupree, 2014), which is one reason it can be helpful to establish community ties prior to a crisis.

Acknowledging a non-technical audience's emotions and expectations, which may differ from those of scientists, can help build trust. In addition, scientists should be conscientious about listening as well as simply responding or pushing out information (Kohring, 2016).

Slovic (1993, 2000) notes that trust is more easily destroyed than built. Negative events are usually discrete and

USGS POINT OF VIEW

The Revelations of Audience Feedback

…We had a workshop recently where critical infrastructure and emergency managers let us know how they would like to have information communicated to them and how they want to use the information… We had this idea going in about what we needed to know from them to design communication templates for them, whereas what they really wanted was to be able to customize communications for their own purposes. They proposed a portal to enable them to construct their own statements about what's going on. It makes so much sense in retrospect, but at the time it seemed like a big revelation.

—Anne Wein, Operations Research Analyst, Western Geographic Science Center

visible (accidents, lies, discoveries of errors). Positive ones are often diffuse and indistinct (the absence of accidents, lies, errors).

Demographic and Cultural Variations

Different demographic and cultural groups vary in access to hazard information, understanding of hazards (Taylor-Clark and others, 2010), vulnerability to losses and casualties (Noriega and Ludwig, 2012), and levels of fatalism and trust in authorities (Eiser and others, 2012).

Often hazards are communicated in terms of their geological and economic impacts. But the hazard could also be framed in terms of distribution of risk and impact on different social groups, which relates to issues of vulnerability and injustice (Vaughan and Seifert, 1992; Slovic, 2010).

Children need targeted communication but are often ignored. According to 2011 census data, 4.2 million school-aged children care for themselves (that is, they are home alone) on a regular basis during the week (Laughlin, 2011). Many daycares and after-school programs lack emergency plans (Phillips and Morrow, 2007). Children can also be important communicators for their families, translating hazard information they have learned in school or after-care (Phillips and Morrow, 2007).

The economically disadvantaged are more likely to live in old buildings that are structurally unsound, making them more vulnerable to natural hazard damage (Fothergill and others, 1999). Demographic factors can affect household preparations and responses. For example, people living in poverty may understand a natural hazard risk but lack the resources to protect themselves and their property (Gaillard, 2008).

Historically, disadvantaged groups are not always at greater risk for natural hazards. Grineski and others (2016) determined that in Miami, higher socioeconomic status is associated with a greater risk of living in a 100-year flood zone, and socioeconomic status is a greater determinant of flood risk than race or ethnicity.

USGS POINT OF VIEW

Validating Attitudes Before Imparting New Information

"At Mt. Rainier, we were very successful in working with the park to get consistent and accurate messages about the volcano conveyed about a variety of aspects. We were able to convey well to park staff and their contract exhibit makers the feel and message in a value-based way. In this very large exhibit, we acknowledge overall the value of this volcano and acknowledge that we all appreciate the beauty of this glorious, majestic peak. But at the same time you're getting a holistic view in showing how the mountain was made, and how the same processes today are hazards for us. The processes of the past are the same hazards that we have today. Getting a holistic view acknowledges the audience – the viewers' preconceived, natural attitude that Mt. Rainier is this glorious place, that it's all good. You really can't show them the hazards until we acknowledge all the positives about Mt. Rainier."

—Carolyn Driedger, Outreach Coordinator, Cascades Volcano Observatory

USGS POINT OF VIEW

Linking Impacts Across Areas

"People don't care about hazards that don't impact them physically, emotionally, or economically. Something that's worked well is getting people to realize that hazards impacting one geographic area have a ripple effect on economic and societal issues beyond that specific geographic area. For example, when we talk about tsunami and earthquake issues in Southern California, we talk about the ports of LA and the products that move through those ports on a daily basis. And we talk about the crippling effect that would have if those ports went down—it would impact Kansas and Missouri."

—Justin Pressfield, former Western Communications Chief, Office of Communication and Publication

USGS Point of View

Understand Why They're At Risk

Understanding how people are at risk and why they're at risk is important. For example, why are people living in certain areas, such as mobile homes in low-lying areas prone to catastrophic flooding? Perhaps that's all that's available to people living in poverty.

—Nathan Wood, Research Geographer, Western Geographic Science Center

In the digital age, when smartphones and online social networks seem ubiquitous, it is important to remember that not everyone has access or internet savvy. In times of crisis, some groups may still learn of an impending hazard from other *channels* (modes of communication) like television or word of mouth (Lee and others, 2009; Feldman and others, 2016). Gottfried and Shearer (2016) and Feldman and others (2016) showed that age was a main determinant of preference for information from traditional media sources versus social media. Some people may prefer to receive information through other channels, and some may not trust information on the internet.

Community forums and local groups can be an important way to reach people with more limited online access (such as the very young, very old, people with disabilities, people living in poverty, undocumented immigrants, and people who do not speak English).

Caucasians are more likely than non-Caucasians to report relying on just one channel (for example, word of mouth) for crisis preparation information (in this case, for hurricanes; DeYoung and others, 2016). Women and younger people turn to more communication channels, and non-Caucasians turn to community sources more often than do Caucasian respondents (Perry and Nelson, 1991; DeYoung and others, 2016). Some scientists have had success with using educational video games and internet-based simulations to educate people about natural hazards (Mani and others, 2016) and to understand how people respond to different sources of hazard information (Meyer and others, 2013).

USGS Point of View

One Simple Measure of Usability

My specific project is a pre-wildfire assessment of post-wildfire debris flow hazards. The Nature Conservancy (TNC) brings together state and federal agencies, tribes, local agriculturalists and local agencies for biannual meetings. The TNC uses the maps [I make] at meetings with decision makers to decide where they want to invest their resources.

—Anne Tillery, Hydrologist, New Mexico Water Science Center

Framing

Whether you are conscious of it or not, you make many choices about how to present information. How you present information is called "framing." One frame for hazards is in terms of harm—caused or avoided. Another useful frame considers impacts, such as impacts on the local economy or disruption to people's daily routines or relationships. In choosing a frame, you decide what to present, how much to present, and in what order to present. These choices shape your audience's perception of the information. Social scientists call this a "framing effect" (Tversky and Kahneman, 1981; Levin and others, 1998).

Understanding your audience will allow you to focus on how you present, or frame, your message or product. The framing of information affects how people believe, understand, and react. As with everything, which frame is right will depend on your audience.

The research suggests the following:

- Framing ideas in ways that match how your audience frames them will help your audience pay attention and remember the information.
- Consider how the positive or negative framing of an outcome can affect engagement and motivation.
- Words related to safety and obligations will resonate with some people, whereas words related to hopes and ideals will resonate with others. It all depends on whether their orientation is toward "prevention" or "promotion."
- Your audience is more likely to pay attention if you can relate the information to their priorities, such as safety, economic development, or constituent support.
- Match the timeframe you use to discuss a hazard with the one your audience adopts for decision making.
- Finding the right timeframe for probabilities is a balancing act—a longer time period will make the chance of occurrence seem more probable, but if the time period is too long, the event will seem irrelevant.

There Will Always Be a Frame—So Frame Deliberately

Although some mistakenly criticize framing as "spin" or "manipulation," framing is an inevitable part of communication and can be used to make information more accessible (Scheufele, 2013), more relevant, and more motivating.

Framing effects are especially relevant when a topic is ambiguous (Tversky and Kahneman, 1981). For non-expert audiences, new technologies and perceptions of hazards can be ambiguous or poorly understood. This is especially true when there is a controversy or perceived controversy over the validity of scientific findings (Scheufele, 2013).

Framing Can Change Willingness to Take Risks and Prepare

One of the most widely studied types of framing effects in psychology and economics involves risky choice. In their seminal work on prospect theory, Kahneman and Tversky (1979) showed that people make different choices depending on where their reference point is and whether outcomes are framed in terms of gains or losses. A reference point is like a starting place from which people make assessments. For example, a homeowner's reference point could be "My house is on solid ground and relatively secure from earthquakes." Another homeowner's reference point might be, "I live in an earthquake zone, and my property is at risk unless I take some action." An individual's reference point can be the status quo, whatever is most readily recalled, or an idea provided by a communicator.

Another key element of prospect theory is that losses loom larger than gains. For example, the pain of losing $100 is greater than the pleasure of winning $100, and people are more willing to take risks to avoid losses than they are to achieve comparable gains. Reminding people of potential losses they may suffer if they fail to prepare for natural hazards is likely to be more effective than reminding them of the safety they will enjoy if they do take precautions.

Results from a study of earthquake framing support the connection between loss framing and preparation. People were more likely to rate an earthquake risk as high and say they would prepare when the link between preparation and outcome was framed in terms of suffering harm (loss frame). Risk ratings and preparation intentions were lower when the link between preparation and outcome was phrased in terms of surviving unharmed (gain frame) (McClure and others, 2009).

Goals and Framing

People differ in their approaches to goal pursuit. This holds true for all kinds of goals, from becoming successful in a profession to taking care of a family. Regulatory focus theory (Higgins, 1997) describes two orientations that come into play when people try to achieve goals:

- A prevention orientation involves a concern with safety and avoiding negative outcomes. Prevention-oriented people approach goals vigilantly.
- A promotion orientation involves a concern with ideals and achieving positive outcomes or benefits. Promotion-oriented people pursue goals eagerly.
- Individuals tend to be high or low in one or both orientations, but situational factors can also increase a person's prevention focus or promotion focus (Crowe and Higgins, 1997).

USGS Point of View

Finding Images That Resonate

"A lot of people feel there's a fatefulness to earthquakes—it's almost biblical. It's important to give people new ways of thinking.

Before "ShakeOut" most people's idea of an earthquake was a pebble thrown in the water and an equidistant, bulls-eye target image. But earthquakes don't look like that. Earthquakes travel the length of a fault like a zipper. It pushes energy out. The energy is then translated into ground movement, in different ways because the ground is different in different areas… We used animations and images to show how earthquakes affect ground movement.

… We played [that scenario] out with all the consequences. X number of people live on one side of the fault but work on the other side of the fault. … When I did [the animated movie] "Preparedness Now," I insisted on showing a mother dropping off her child at a daycare center (fig. 3). This idea of separation is important. The idea of an earthquake that a lot of people have is death and destruction. But really, it's a lot about isolation and being apart."

—Dale Cox, Project Manager, Science Application for Risk Reduction

Figure 3. Screen captures from *Preparedness Now* (Alexopoulos, 2009). To help people recognize the potential for separation during a large earthquake like the hypothetical ShakeOut scenario earthquake, the movie used images and graphics to emphasize the spatial and communication isolation that could happen.

When promotion-oriented people approach a goal eagerly or receive an eagerly framed message, it "feels right" (Cesario and others, 2004). The same is true for prevention-oriented people who approach goals vigilantly or receive a vigilantly framed message. Crafting messages to include promotion terms as well as prevention terms will help the message resonate with a broader audience (table 1) (Center for Research on Environmental Decisions, 2009).

Hazard communication naturally fits with a prevention frame because of the focus on safety, protection, and minimizing losses. People with a strong prevention focus tend to respond more to risk communication (Botzen and others, 2013; de Boer and others, 2014). A reframing to reach people with a strong promotion orientation might emphasize how preparation can improve the community and increase the value of their homes.

Table 1. Promotion- and prevention-oriented words (Center for Research on Environmental Decisions, 2009).

Promotion	Prevention
Ideal	Ought.
Attain(ment)	Maintenance.
Maximize gains	Minimize losses.
Hope	Responsibility.
Advance(ment)	Protect(ion).
Eager(ness)	Vigilant/vigilance.
Promote	Prevent.
Aspire/aspiration	Obligation.
Support	Defend.
Nurture	Security.

Match Your Audience's Frame to Be More Relevant

As mentioned in the previous section, hazards are often framed in terms of harm or impacts. Many other frames are also viable. The important point is that when you frame the issues similarly to how your target audience frames them, your information can take on greater "legitimacy and influence" (Vaughan, 1995, p. 172).

USGS POINT OF VIEW

Reframing Hazard Readiness

ShakeOut was designed to foster a culture of preparedness. It's important to convey to people that they are not powerless in the face of a hazard. When people think of earthquakes, they think about response. Little attention is paid to preparedness. $1 in preparedness will save $8 in response. We worked with students to create a movie called "Preparedness Now". They helped people realize there's an alternative, something you can do. They picked out touchstones in the community – there are things in the movie that everyone in Southern California will identify with.

—Dale Cox, Project Manager, Science Application for Risk Reduction

USGS POINT OF VIEW

Help Them Answer Questions That Matter to Them

When the USGS published updated National Seismic Hazard Maps, I worked with the lead scientist to develop outreach materials for the media and public. We wanted to present the science accurately but in a way that would be easily understood by non-scientific audiences. The research was covered by every major news outlet. We provided simplified maps and broke down the story by state and region. People want to know specifically about their area and the relevance to themselves. Am I at risk? At what level?

—Jessica Fitzpatrick, Public Affairs Specialist, OCAP, Headquarters

Relate Hazards to Your Audience's Other Concerns

People balance many different risks every day—economic risks, health risks, and job security risks, as well as natural hazard risks and many others. Hansen and others (2004, p. 2) describe a "finite pool of worry:" there are only so many issues that an individual can be concerned about at any one time (fig. 4).

What concerns does your audience have? Figuring out the values, priorities, and worldviews of your audience will help you tailor your message for maximum effectiveness. If your audience is in a particular locale, in addition to talking to members of your audience, you can look at newspapers, ads, and types of businesses (such as restaurants, stores, and libraries) to identify local concerns. Local organizations will likely have websites and (or) mission statements. The Pew Research Center (http://www.pewresearch.org/) is a good source for larger trends among different social and political groups.

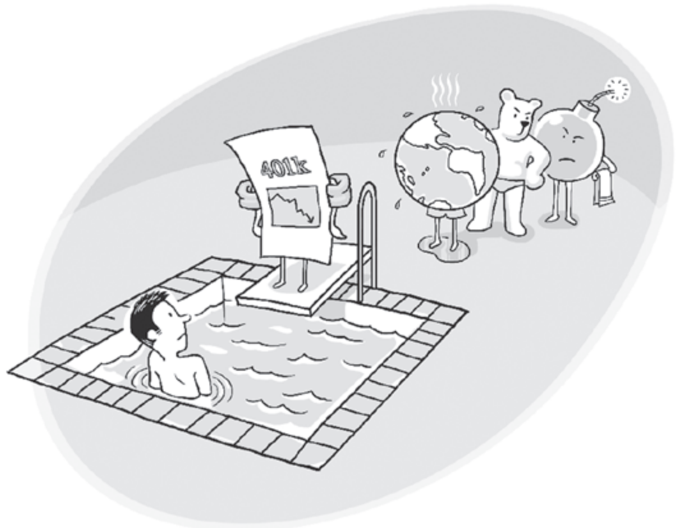

Figure 4. The *finite pool of worry*. Individuals have many serious concerns competing for their limited capacity to worry—and their capacity to take action. (Illustration by Ian Webster from Center for Research on Environmental Decisions, 2009; used with permission.)

USGS POINT OF VIEW

Tie the Hazard to the Audience's Values

"I try to meet people (the audience) where they are in terms of both knowledge and also values. We use values-based messaging and map out what really matters to people. Then we use that in our communication. For example, you don't say, 'Get to high ground. Prepare for the next eruption.' That doesn't engage people. Instead you say why it matters. 'Preparing this way will help your family to survive the next eruption of Mt. Rainier.' Or 'Your community will be able to rebuild and thrive if you have these measures in place prior to an eruption.' We're incorporating things that really matter to people. It doesn't have to be family. It could be 'Your bank account's going to be better.' I relate the message to larger issues that people care about."

—Carolyn Driedger, Outreach Coordinator, Cascades Volcano Observatory

Connect Hazards to Audience's Social Identity

You can also make information more personally relevant by framing it to relate to your audience's social identity (Are they parents? People of faith? Members of a corporation?). When you highlight audience members' relationships with each other, you make them more likely to work together and more likely to take actions that promote the best interests of the group (Arora and others, 2012).

The Importance of Choosing the Right Timeframe

Hazard probabilities for a short timeframe can seem negligible. For example, when processing a forecast of a 1-percent chance of a flood within 1 year (the definition of a "100-year flood"), many people interpret 1 percent as being highly unlikely to occur and therefore not deserving any preventive measures, despite the potentially large impact (Yechiam and others, 2015; Slovic and others, 1978).

On the other hand, probabilities for a large timeframe can seem irrelevant. When people hear discussion of an earthquake that could occur in 500 years, they discount it: the earthquake seems unlikely to occur during their lifetime or their children's lifetimes, so it doesn't warrant preventive action (Henrich and others, 2015).

The timeframe of a probability affects decisions. In a study of seatbelt use, people were unconcerned about the likelihood of being killed in a car accident when given the probability of its happening during a single trip (about

0.00000025 probability of being killed, and 0.00001 probability of being injured); however, participants were much more likely to buckle up when given the lifetime risk of death (about 0.01) or a serious injury (0.33) (Slovic and others, 1978). Similarly, people were more likely to purchase insurance when considering cumulative risk, as opposed to repeated individual risks (Slovic and others, 1977).

As Kates (1962, p. 96) notes, “From the broad view of nation or community the long-run average frequency has definite meaning. For an individual it may only serve as a source of bewilderment.” This is particularly relevant for natural hazards, where events can be rare but devastating. In some, but not all, situations, framing earthquake risk over a period more closely matching a lifetime (50 years) was more effective in motivating action than framing it over a larger timeframe (500 years), which made it seem irrelevant, or over a smaller time horizon (1 year), which made the risk seem minuscule (Henrich and others, 2015). Studies of flood risk judgments found similar effects: estimations of a flood in 40 or 80 years led to higher risk judgments than did the comparable 1-year estimate (Keller and others, 2006).

Trying different timeframes with your target audience is the best way to find the right one.

USGS POINT OF VIEW

Adjust Timeframes According to Your Audience

“*How you frame the hazard is different depending on your audience (for example, insurance salesperson, emergency manager, business owner, etc.). Being able to discuss hazards as probabilities and as possibilities, discussing recurrence intervals instead of focusing on a 20 percent chance of this thing happening is important. Probabilities may be important for insurance decisions, but are not as useful for evacuation planning.*”

—Nathan Wood, Research Geographer

Policymakers Have Shorter Timeframes

In an international survey on geoscience communication, one respondent noted, “Policy makers use other time scales than researchers. They have a more short-term view. The work of communicating science needs to be repeated again and again” (Liverman and Jaramillo, 2011, p. 31). Camerer and Kunreuther (1989) indicate that elected officials and policymakers tend to be more focused on the short term because of election cycles. Thus, timeframes for policymakers are likely to be shorter than those for building engineers.

USGS POINT OF VIEW

They Might Have Dangerous Gaps in Awareness

“*It is very important to increase the awareness of the potential for post-fire flooding, erosion, and sedimentation for miles downstream of a burned area immediately after the wildfire and for a period up to 15 years after the fire.*”

—Anonymous Online Questionnaire Respondent

Timeframe Terminology

As any scientist who has tried to communicate risk over time knows, timeframe wording is often interpreted differently than intended. As one of many examples, the commonly used “100-year flood” is regularly misinterpreted to mean that a flood of that magnitude will occur only once every 100 years, rather than a flood with an annual likelihood of 1-in-100 (Burningham and others, 2008). When given a phrase describing a risk over time, people tend to view the event as more likely to happen near the end of the time period. Using the phrase “within” (“within 10 years”) can help reduce this effect, although it does not eliminate it (Doyle and others, 2011).

For short-term forecasts (less than 1 week) of hypothetical volcanic eruptions, the use of “within” did not reduce the effect—not for emergency managers and not for geologists (Doyle and others, 2014a). The same study suggests this may be due to people using their personal experience as a base rate and overlaying the forecasts on top of that. The same effect was even present for statements that did not include probability, such as “threat of an eruption within 2–3 days” (Doyle and others, 2011).

Uncertainty

Some of the greatest challenges in natural hazard communication (and other scientific communication with lay audiences) are how to describe and explain uncertainty, how to make uncertain events credible, and how to encourage protective actions despite uncertainty.

The research suggests the following:

- Explain why there is always uncertainty ("These forecasts have a range of outcomes because…").
- Discuss likelihoods in terms of a range of outcomes ("Our best guess is…" or "The worst-case/best-case scenario would be…").
- When scientists argue publicly, it creates negative impact. Reduce this by explaining that skepticism and argument are part of the scientific process and by pointing out areas of agreement.
- Target the analytic and experiential systems of processing information by combining scientific information with vivid imagery, metaphors, and first-hand accounts.
- Use concrete images and examples to make uncertain or distant scenarios feel more urgent.
- Focus on what is known; emphasize the impact, not the timing or the probability. Highlight what you know will happen or is very likely to happen at some point.
- Where possible, use proportions, rather than percentages, to communicate probability.

USGS POINT OF VIEW

Boundaries are Not So Sharp in The Real World

It's challenging to show uncertainty on a hazard map. The boundaries look sharp—you're either in a flood zone or not. But of course there's always uncertainty just around the corner.

—Marie Peppler, Federal Liaison for Office of Surface Water

Uncertainty and Disagreement Create Negative Impressions

Scientists learn to be comfortable with uncertainty and recognize that future advances will involve disagreeing with colleagues and disproving current theories. Scientists are trained to thoroughly explain the limitations of their models and research. Lay audiences can misinterpret these aspects of scientific investigation and conclude that the science is unreliable.

When science changes, it can also seem unreliable. For example, wildfire management used to focus on preventing fires, but when efforts shifted to controlled burns, this led to reduced trust in the U.S. Forest Service (Paveglio and others, 2009). Additionally, a media focus on conflicting opinions about scientific information can lead to doubt about whether to trust the information, which can lead people to revert to their prior beliefs and judgments (Vaughan, 1995).

Discuss Uncertainty in Ways That Build Trust

Although uncertainty is often misunderstood by lay audiences, it is important to discuss it to establish trust and transparency (Campbell, 2011; Fischhoff and Davis, 2014). Uncertainty can make people feel anxious (Maslow, 1943). Direct communication of uncertainty, using the tips in this section, will help reassure an audience that the hazard is not inscrutable and that steps can be taken to minimize damage and loss. For example, rather than focusing on the uncertainty of when a particular event may occur, instead try, “We don't know exactly when an earthquake will happen, but an earthquake is likely to happen in this region resulting in damage to *x*, *y*, *z*” (Center for Research on Environmental Decisions and ecoAmerica, 2014).

USGS POINT OF VIEW

The Many Challenges of Uncertainty

The biggest challenge is communicating uncertainty. We think we're speaking the same language, but often the uncertainty isn't successfully communicated. Or they only incorporate a single number into their planning or procedures or thinking.

The National Weather Service needs the USGS stream discharge measurements to make a flood forecast. They'll plug in the number, but without the uncertainty – the forecast will be off. The uncertainty doesn't get to the weather forecaster – or the public. And if it does, they don't know how to interpret it.

Non-scientists don't understand why our “answers” change. During Hurricane Sandy, FEMA put out a preliminary flooding map quickly, and then 2 months later produced a final map based on final USGS data. People were really confused when the map changed, but we were just decreasing our uncertainty!

—Marie Peppler, Federal Liaison for Office of Surface Water

Focus on Impact and Precautions, Not Uncertainty of the Timing

The uncertainty of when a hazard will occur can make the hazard seem unworthy of attention. Focus instead on the impact, which is easier to convey and can be more engaging and motivating. One way to focus on the impact without ignoring uncertainty would be, “Our best estimate is that a geomagnetic storm causing damage *x*, *y*, and *z* will occur sometime within *w* years; the worst-case scenario is… and the best-case scenario is…” Providing a range of estimates, including best- and worst-case estimates can increase trust in scientists and lead to more accurate understandings of the likelihood of future events (Joslyn and others, 2011; MacInnis and others, 2014; Hmielowski and others, 2014).

USGS point of view

Understanding the Audience's Mindset

I talk with locals to say we don't know when the next earthquake will happen. Could be tomorrow, could be in 100 years. Are you prepared for 600 of your people to die tomorrow?

I try to put terms in the mindset of the person who has to make decisions. It's not dumbing it down. They don't care about the tectonics. They focus on the outcome rather than making sure someone understands the science.

When communicating with the public, focus on controllable consequences not uncontrollable processes. For example, focus on where to build, how you build, and what you can do when a tsunami is on its way.

—Nathan Wood, Research Geographer, Western Geographic Science Center

Wood and others (2012) recommend communicating specific actions (for example, developing an emergency plan, stockpiling supplies, duplicating important documents) and why these are important if a hazard event occurs. This will increase the audience's sense of efficacy and counteract feelings of powerlessness in the face of the hazard (Frisby and others, 2013; Fox-Rogers and others, 2016).

Lindell and Whitney (2000) also recommend that communication focus on personal responsibility and the efficacy of preparation, rather than the nature of the risk. Framing uncertainty as an opportunity to shape the future—a chance for growth and change—can also alleviate some of the anxiety around uncertainty and be more motivating (Sellnow and Seeger, 2001).

People Process Information Using Two Different Systems

During the last 30 years, a large amount of research has used the framework of two information processing systems—one experiential and one analytic—to understand how we process information, form judgments, and make decisions.

USGS point of view

Communicating Uncertainty—A Success Story

We moved from doing short-term probabilities around foreshocks to doing impacts (scenarios) to share the information that we do know. After making that shift, our data became more widely used. The city of LA is undertaking the biggest seismic safety [measures] we've ever seen.

Because we focused on what we do know – we know exactly where the fault's going to break, we know exactly which pipelines are going to break and where because they cross the fault. We laid that all out and what the consequences of that were. We know which buildings are going to be damaged because we know what the bad buildings are. Now the city is working to fix them. Instead of saying, "These might fall down in an earthquake, but it depends on where the earthquake is…" we focus instead on what we do know.

—Lucy Jones, Seismologist Emeritus

This dual-systems concept has generated many insights into effective communication, and working knowledge of the two systems can help to relay information, including uncertainty. The two are often referred to as "System 1" and "System 2" (Kahneman, 2011; Stanovich and West, 2000) (table 2). Both systems affect how people form judgments and make decisions.

The experiential system (System 1) is automatic, associative, and operates with little effort. The experiential system is responsible for many of our snap judgments; it dominates under time pressure, cognitive constraints, or low motivation. The experiential system relies on heuristics (cognitive shortcuts) such as emotional associations or ease of recall (Visschers and Siegrist, 2008). The analytic system (System 2) is deliberative, relatively slow, and cognitively demanding. Scientific communication has traditionally targeted the analytic system, with its emphasis on statistical presentations of data.

Table 2. Two information processing systems of the brain (adapted from Center for Research on Environmental Decisions, 2009).

Experiential (System 1)	Analytic (System 2)
Holistic	Logical.
Intuitive	Deliberative.
Emotion-driven (for example: fear, dread, gratitude)	Analytic.
Perceives reality in concrete images and narratives	Perceives reality in abstract symbols, words, and numbers.
Automatic	Effortful, needs prompting.
Active in forming quick judgments based on general impressions	Active in processing traditional, statistical presentations of data.
Relies on cognitive biases and shortcuts	Provides justifications for impressions and preferences formed by System 1.
Responsive to immediate threats	Able to evaluate long-term, gradual threats.

Scientists may be uncomfortable with many aspects of experiential thinking; however, understanding and targeting the experiential system can improve the understanding and use of scientific information. Also, because experiential thinking is so important to decision making, trying to ignore it will limit the effectiveness of your communication. Slovic (2010) notes that disaster statistics lack feeling and fail to motivate preventive action.

The Experiential System Affects Risk Perception

Understanding the experiential system helps to identify legitimate concerns people have about hazards—concerns that are often omitted from formal conceptualizations of risk (Kasperson and others, 1988). Studies of risk perception have identified the feeling of dread as one of the key ways the experiential system alerts us to worry about a given risk and motivates societal responses (Fischhoff and others, 1978; Slovic, 1987).

The experiential system affects risk perceptions based on the ease with which similar examples can be brought to mind (known as the “availability heuristic”) (Tversky and Kahneman, 1973). For example, people may judge the probability of dying from a terrorist attack as greater than dying in a car accident because of the vividness of news reports of terrorism, which makes terrorist attacks easier to call to mind than car accidents. As another example, a non-expert may make judgments of earthquakes based on the ease with which that person can recall similar examples of earthquakes.

Events that were more recent and more emotional are easier to recall. People who have experienced a wildfire recently and suffered loss or damage are likely to judge the probability of another wildfire as greater than someone who did not suffer damage (Martin and others, 2007). People overrely on past experience when they prepare for future events. For example, voluntary flood insurance purchases can be predicted by the peak storm surge heights of the most recent hurricane for a given area (Shao and others, 2017).

Exacerbating this reliance on past experience, atypical events tend to stand out in our memories, making them easier to recall (Gilbert and Wilson, 2007). When people try to recall a set of similar examples from experience, they are more likely to recall unusual events (Morewedge and others, 2005).

Giving Urgency to Rare, Gradual, and Long-Term Threats

Experiential system thinking does not respond to rare, long-term, or gradual threats, or to threats that are perceived to be uncertain or distant. Trope and Liberman (2010) explain that events that are viewed as distant (in time, space, and likelihood) are considered in more abstract terms, reducing any sense of urgency. The converse is also true—presenting data in abstract terms makes an event feel distant.

People tend to think of distant events in terms of their central, core features, while thinking of close events in terms of their peripheral, goal-irrelevant features. For example, before a crisis (psychologically distant), someone may think about evacuation in terms of its core features—how it will lead to safety and be a wise decision. However, in the middle of a crisis (psychologically close), someone might be more fixated on the peripheral details of evacuation, such as the hassle of packing up and leaving.

The analytic system is better suited to the evaluation of uncertain, gradual, or distant threats, with its reliance on the rules of logic and evidence. However, presenting vivid descriptions of the impacts of distant threats can help activate the experiential system and orient people towards paying attention. Then the analytic system can kick in to process analytical information and make decisions as needed, including decisions about whether to learn more about the hazard.

Target Both Systems in Your Communications

Combining analytic information with images and personal stories of hazard effects will target the analytic and experiential systems and increase the chances of people heeding your information or taking protective measures. Information presented in an experiential manner can enhance perceptions of risk, retention, worry, and willingness to take action (Cooper and Nisbet, 2016; Center for Research on Environmental Decisions, 2009). In one study, images rich in negative affect, such as flooded houses, conjured bad feelings and led to higher judgments of risk of future flooding (Keller and others, 2006). Narratives from individuals who have experienced floods (or other hazards) could have the same effect.

However, it is essential that you do not neglect the analytic system. Communication that targets only the experiential system risks overwhelming the audience and leading them to tune out, a phenomenon known as "emotional numbing" (Linville and Fischer, 1991; Weber, 2006).

Group discussions increase the chance that experiential and analytic information (for example, personal stories and statistical data) will both be heard, which can improve understanding. When individuals evaluate risk by themselves, they are less likely to consider as wide a range of information (Patt and others, 2005; Roncoli, 2006). Hearing warnings in a group can lead to discussion and argument (Drabek, 1999) and can allow misunderstandings to be addressed.

USGS POINT OF VIEW

When They Listen to Each Other

"*The Tsunami Scenario rollout was really effective because we took it to the emergency managers, port officials, elected officials. At the rollout meetings (held mostly at port and emergency management facilities), we began with scientists presenting the results from the scenario (fig. 5), and then we facilitated discussion among the stakeholders about their potential vulnerabilities and concerns. It felt like they were really understanding it. Hearing from each other was more effective than hearing from us. Hearing from us about how they should run their ports – they wouldn't be receptive. But hearing from another port captain that it's important to keep the fishing boats docked instead of letting them go out during a tsunami… it was really important.*"

—Stephanie Ross, Tsunami Scenario Project Manager, Science Application for Risk Reduction

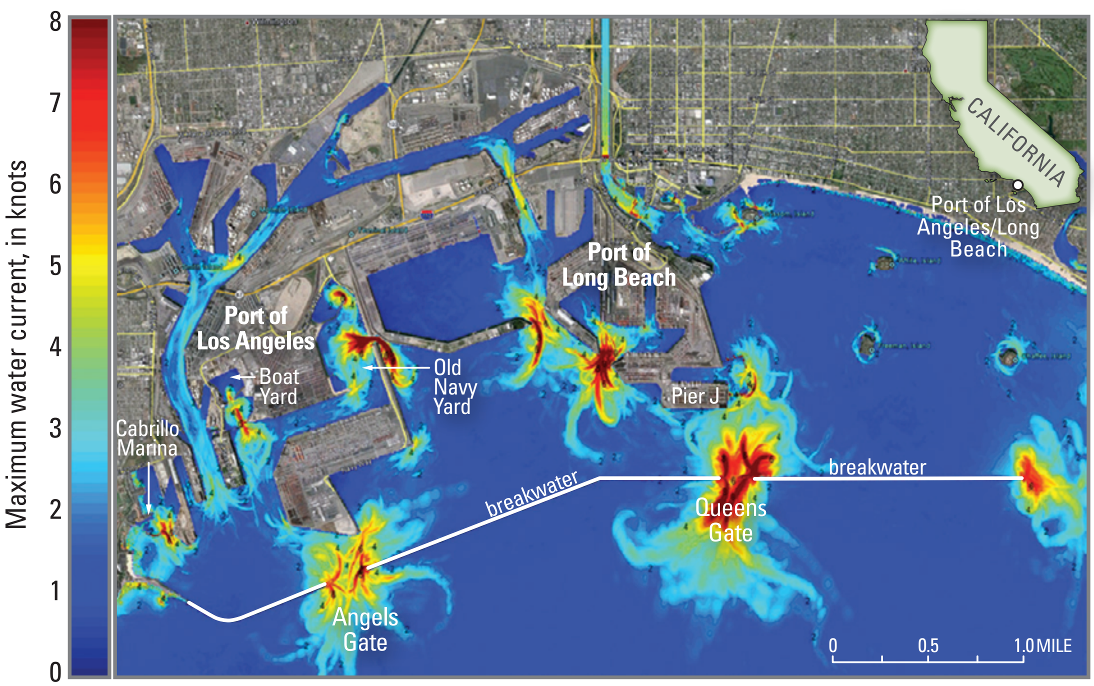

Figure 5. Maximum water current speeds for the Port of Los Angeles and Port of Long Beach from the U.S. Geological Survey Science Application for Risk Reduction (SAFRR) tsunami scenario. Port operators benefited from meeting together to discuss what to do about destructive currents that are common during tsunamis (U.S. Geological Survey, 2013).

Make Probability More Experiential for Non-Experts

Probabilities can be communicated numerically or verbally. Numerical descriptions are abstract and target the analytic system. Conversely, verbal descriptors ("highly unlikely") can target the experiential system and can be more motivating and easier for a non-technical audience to understand. As Slovic and others (2004, p. 320) stated, "Statistics are human beings with the tears dried off."

Different types of numerical descriptions have different impacts (Slovic and others, 2004; Slovic, 2010):

- Percentages ("1 percent" or "1%") make the risk seem more distant and less personally relevant, putting the focus on numbers that often are interpreted as indicating a low risk of harm.

- Decimals ("0.01") and percentages ("1 percent") are less evocative than proportions.

- Proportions ("1 out of 100" or "1/100") more readily conjure images of individuals rather than statistics and allow the audience to view the risk in terms of the harm that might befall a group of individuals.

- A proportion makes it easier for a person to view him/herself as being in that at-risk group. People identify with the numerator when thinking about their personal risk.

In a study of expert judgment, clinicians were asked to judge the likelihood that a patient with mental illness would commit a violent act after discharge based on an expert assessment. The expert assessment was presented as either a percentage (for example, "patients similar to Mr. Jones are estimated to have a 10 percent chance of committing an act of violence to others") or a frequency ("of every 100 patients similar to Mr. Jones, 10 are estimated to commit an act of violence to others"). With the percentage format, 21 percent of clinicians deemed the patient too dangerous to discharge. But with the frequency format, almost twice as many (41 percent) clinicians judged the patient to be too dangerous for discharge (Slovic and others, 2000). The authors attribute this to the frequency format conjuring more frightening images. Other research has shown that a frequency format may make risk more credible than a probability format. Siegrist (1997) found that people will pay more for a safer medication to avoid a high risk (dying of a serious illness) when it is presented in a frequency format (600 out of 1,000,000 people die) versus a probability format (0.0006 probability of dying).

Consider the context in which the audience will be interpreting the probabilities (for example, under time pressure or when there's strong motivation to understand the risk) and also the audience's numeracy skills (Garcia-Retamero and Galesic, 2009) to determine the most effective way to communicate a given likelihood to a given audience.

As always, pretest your product or communication with a target group to be sure that they interpret your communication as intended. You might provide participants with a probability description and a hazard map, then lead discussion of what they understand in each product and whether this communication makes them care about the risk or not (for example, Sutton and Woods, 2016).

Probabilities as Percentages Cause Misunderstandings

Probabilities expressed as percentages are often misunderstood. One reason for this is that the reference class is often ambiguous. In a focus group study, women were presented with data on the risk of a 50-year-old woman developing breast cancer. When told a woman's risk was 10 percent, one woman responded, "10 percent of what?" (Schapira and others, 2001). From health communication comes a vivid example of ambiguous reference class: a doctor described the risk of drug side effects as "a 30–50 percent chance of developing a sexual problem." This made patients very anxious because many of them interpreted that as, "I will have a sexual problem in 30–50 percent of my sexual encounters." The doctor's reference group was patients taking the drug, but the patients' reference group was sexual encounters. The doctor reframed communication as, "For every 10 patients who take this drug, 3–5 will develop a sexual problem," which reassured his patients (Gigerenzer and Edwards, 2003, p. 741).

Even a probability statement as simple and ubiquitous as a weather forecast is widely misunderstood (Gigerenzer and others, 2005). Does a 30-percent chance of rain refer to the likelihood of rain all day, the proportion of a given geographic area that will be affected, or the number of hours during the day that it will rain? In a study of weather forecast comprehension, fewer than 70 percent of American respondents chose the right interpretation. Carr and others (2016a) note that people often confuse probabilistic forecasts with forecast confidence, conflating the uncertainty of an event with the uncertainty of the model used to describe it.

Denominator Neglect and the Overweighting of Small Probabilities

Although frequency or proportion formats (1 out of 100 or 1/100), are often easier for non-technical audiences to interpret, these formats have their own challenges. Non-technical audiences can be vulnerable to the ratio bias or denominator neglect, judging a large numerator as more likely, even if the actual probability is lower. Thus, 8 out of 100 seems more likely than 1 out of 10 (Alonso and Fernandez-Berrocal, 2003; Denes-Raj and Epstein, 1994; Garcia-Retamero and Galesic, 2009). For example, people judged a disease that kills 1,286 out of 10,000 people as more dangerous than one that kills 24.14 out of 100 (Yamagishi, 1997).

Additionally, people tend to treat low-probability events as zero-probability events (Kahneman and Tversky, 1979), particularly when the event has strong emotional associations (Loewenstein and others, 2001). This may be due in part to an optimism bias: "It's never happened to me before so it won't happen" (Gifford, 2011). The optimism bias is often briefly trumped by circumstances. When a low-probability event does occur, it then becomes overweighed in future decisions (Weber, 2006).

USGS Point of View

Limited Understanding of Probabilities and Time

"People don't understand probabilities very well and don't understand they're tied to a timeframe. I can give you any probability of the earthquake you want by varying the magnitude and timeframe. We think that's what people want so we focus our energy on it. For earthquakes, we standardize on 30 years because that's the length of most people's mortgages and a timeframe in which people are making financial decisions. The public thinks 30 years is something we know ("But the scientists said it's going to happen in 30 years.") We are miscommunicating rather substantially by focusing on probabilities."

—Lucy Jones, Seismologist Emeritus

Beware Inconsistent Translations Between Descriptions

Scientists differ in how they translate between numerical probabilities and qualitative descriptors such as "likely" or "improbable" (Doyle and others, 2011). It is best when scientists can agree on the use of those qualitative terms. Nicholls (2001) describes El Niño forecasts that used unclear event descriptors, such as "significantly dry" or "significantly below average rainfall," which the non-technical audience then interpreted as disagreement among the scientific community.

Budescu and others (2009) studied perceptions of the verbal probability descriptors in the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment and found that terms such as "very likely" were ascribed a wide range of probabilities. Even when respondents had access to the IPCC's translation table, they still misjudged the verbal descriptors.

Another study determined that undergraduates interpreted probabilities and verbal descriptors differently depending on whether they were describing a "high-impact" event (a hurricane) or a "low-impact" event (snow flurries) (Patt and Schrag, 2003). Meanwhile, scientists were more likely to recommend evacuation for an impending volcanic eruption when the likelihood was presented as a numerical probability versus the equivalent verbal probability from the IPCC's translation table (Doyle and others, 2014b).

Fixing such communication glitches is important because using verbal descriptors (for example "very likely," "somewhat likely") in conjunction with probabilities will increase understanding across a range of audiences (Budescu and others, 2009, 2012; Fischhoff and Davis, 2014; Renooij and Witteman, 1999; Visschers and others, 2009).

Language

Once you have identified your audience and considered their goals and preferences, you will want to craft your language so that people pay attention to it and understand it.

The research suggests the following:

To help a non-technical audience understand:

- Keep it simple and relevant—don't try to share all you know.
- Avoid jargon and synonyms.
- Keep sentences to 15–20 words if possible.
- Introduce only the scientific concepts that you need for this communication. There is a limit to how much "new" information a person can absorb (and the limit falls during a crisis.)
- Pay attention to the terms the audience uses to discuss the hazard, and use the same terms in your communication with them. Correct inaccuracies gently and over time.
- Aim for a 7th or 8th grade reading level with a general audience and with audiences who provide information to general audiences.
- Beware of terms that have one meaning in hazard science and another in common usage and avoid or use sparingly.

To engage an audience and be memorable:

- Lead with what you know, not what you don't know.
- Always remember that your audience has limited time and attention. Don't spend much time explaining the science if the audience also needs to learn something else from you.
- Emphasize three (or fewer) key points to increase the chances of your audience remembering and using the information.
- Choose strong verbs that are in active, not passive, voice.
- Use metaphors, similes, and hypothetical situations.
- Include vivid, personal stories and narratives, not just statistical information.
- Don't rely strictly on words. The right visuals can help tremendously.

The guidelines above apply to many audiences, but the specific choices that will work best will depend on each audience, so—as always—you will need to try things with members of that audience to make sure you are tailoring correctly.

One finding applies across the board: everyday conversational language is easier for everyone to process, whether or not they are a scientist. It is hard for most people to understand the impersonal style that scientists use for journal articles (Liverman, 2008).

Communication with Peers Versus Non-Technical Audiences

If you're having trouble communicating outside your field, you're not alone. Scientific information is so specialized that scientists can have trouble even when communicating with their peers. In one international survey, 61 percent of geoscientist respondents reported the use of jargon and technical language as an obstacle to effective communication among scientists (Liverman and Jaramillo, 2011).

Graduate school and post-doctoral fellowships train scientists to communicate in a highly specialized, stylized way. Scientists tend to lead with what they do not know, are wary of overstating their findings, provide many qualifications about what can and cannot be inferred from their data, and are hesitant to publicly discuss work that has not yet been published in a peer-reviewed journal. Although these practices are encouraged in academic circles, they can interfere with reaching a broader, less technical audience (Hut and others, 2016).

It is understandable for scientists to default to themselves or their peers as a guide to their audience (Hut, and others, 2016), focusing on the topics that they, as scientists, find most interesting and important (Bruine de Bruin and Bostrom, 2013), but these are not necessarily the topics most important to the audience.

Communicating with those outside the sciences requires many adjustments. Leading with what is known and highlighting the societal implications with multiple examples will increase the chances of your science being understood and used. This observation from a congresswoman pertains to many non-technical audiences: "Scientists are taught to develop hypotheses and then work to disprove them. In Congress, we are typically trying to mesh your scientific knowledge into a broader policy or regulation issue or question" (Napolitano, 2011, p. 424).

Talking to the media is one of the ways scientists can reach the public, yet Hut and others (2016) state that concern about negative evaluation by other scientists can hamper many scientists' success with the media. Another concern, which was mentioned by multiple USGS scientists in interviews at the start of this project, is that the media will misinterpret the science or quote them out of context.

Pitch at the "Just-Right" Level of Complexity

Many of the USGS scientists interviewed for this guide expressed concern about not wanting to "talk down" to an audience. Being aware of what others know is critical to creating communication at the right level of complexity. If you assume they know too little, it sounds like you are talking down to them. If you assume they know too much, they will not understand you.

USGS Point of View

Meeting Your Audience Where They Are

"*It's important to make associations. Scientists also try to make associations. Does this thing relate to that thing? We can recognize that the general public is often trying to do a larger version of the things scientists want to do. Recognizing that is useful for considering your own response. For example, sometimes I get asked about astrology. I can say it was a science at one point and can work with a person's preconceived ideas. Everything is related, but some relationships and effects are more important than others. I'm able to work with the skepticism of an audience.*

Sometimes even scientists will say they don't know much about geomagnetism. I can ask them to recall a course they took on magnetism and electricity. I can work off of that and build on it and remind them of things, such as what a magnetic field is. Electricity and magnetism are often discussed together, magnetic fields and electricity. I remind them of associations. I build on associations and work with a person's concern that they haven't studied something in a long time."

—Jeffrey Love, Research Geophysicist, Geomagnetism

When making decisions, people tend to begin with a default idea and then make adjustments until they feel they have made a satisfactory decision. Moreover, familiarity with subject matter can lead to inflated judgments of the comprehensibility of communication (Glenberg and Epstein, 1987; Glenberg and others, 1987). In particular, scientists begin with their own knowledge base, and then adjust their beliefs about how much knowledge the audience has compared to themselves (Nickerson, 1999).

Even if you recognize that you are an expert and have more knowledge and experience than others, it can be hard to accurately adjust the level of complexity. Studies of perspective-taking have repeatedly demonstrated that even when there are incentives to do so, it is challenging to discount one's own privileged knowledge (Krauss and Fussell, 1991; Fussell and Krauss, 1992; Camerer and others, 1989). Some social scientists refer to this problem as "the curse of knowledge" (Zarcadoolas and Vaughon, 2016a).

Don't Lose Your Audience in the Technical Weeds

Communicating science with a non-technical audience involves different strategies than those required for scientific communication with colleagues (Hassol, 2008). Start with what you know and stick with the main point(s) you want to convey. This contrasts with traditional scientific communication in academic journals and presentations, which begins by providing context and describing what is not known.

Be mindful of limited attention and other demands on an audience's time, or you risk losing your audience. If presenting to a local community or coordinating with emergency management and local government, keep the discussion of the science brief. In a tsunami preparedness study, some participants noted that an entire morning of a community workshop was spent discussing the technical aspects of tsunamis, and many members of the audience had left before the emergency managers were able to talk about personal risk and preparedness (Lindell and Prater, 2010).

USGS POINT OF VIEW

Get Peer Review from Your Targeted Audience

"About 9 years ago I put together a general information product to help people understand the concept of a 100-year flood. Although I got the typical USGS peer review from my colleagues, I also gave it to several non-scientists, like my mother-in-law (a nurse) and my father-in-law (a civil engineer, but not in water), and a sister-in-law – educated lay people. I got the typical peer review we always have to get at the USGS, but I also got peer review from educated lay people. It really improved the document. Over my 30-year career, I've authored or co-authored numerous reports, journal articles and book chapters, but I think this one, relatively simple general information product gets more use than anything else I've ever written."

—Robert Holmes, National Flood Hazard Coordinator and Chief, Branch of Hydrodynamics

Expect Gaps in Basic Literacy, Numeracy, and Scientific Literacy

In the U.S. Department of Education's most recent literacy survey of U.S. adults (ages 16–65), one-half of U.S. adults performed at a level 2 (out of 5 levels, with 1 being lowest) or lower (Rampey and others, 2016). Lower socioeconomic status tends to be linked to lower literacy rates (Kontos and others, 2007). The public health community recommends aiming for a 7th or 8th grade reading level when addressing a general audience (U.S. National Library of Medicine, 2016), and this is applicable for hazard communication as well. Visual displays can also be helpful to reach audiences with low literacy levels.

Numeracy refers to an individual's ability to understand basic probability and mathematical concepts (Lipkus and others, 2001; Peters and others, 2006). U.S. numeracy and problem solving performance are comparably low to U.S. literacy levels (Rampey and others, 2016).

If your audience has trouble evaluating and interpreting the relative magnitude, importance, and validity of different scientific statements, the use of metrics, comparisons, and analogies can help. For example, hearing that floods led to $8 billion of damage in Louisiana in one month (Dolce, 2016) can be hard for people to interpret. The difference between millions and billions is hard to understand because both sound so large. Reframing the impact (almost one-third of the state's annual budget) can give audience-specific meaning and context (Center for Research on Environmental Decisions and ecoAmerica, 2014; Department of Administration, State of Louisiana, 2016).

Don't Use Common Words in Uncommon Ways

Misunderstandings arise when scientists take everyday words but assign specialized meanings to them. To reduce confusion, avoid using "common words in uncommon ways" (Fischhoff and Davis, 2014, p. 13665). In table 3 are lists of typical problem words, and suggested replacement phrases that can reduce misunderstandings. Note that not all of these phrases are pitched to a 7th/8th grade reading level—sometimes it will be appropriate to target a higher level of literacy. Also note that you may define some of these words differently because some of the scientific words have more than one scientific meaning.

Actually, They Won't Adjust Your Products

"When I talk with USGS people about U.S. literacy levels, the most common reaction is denial. They'll change the target audience to one they feel more comfortable reaching. Or hope that someone else will do the "translating." I've had so many conversations like these:

Scientist with product: "The target audience is the general public."

Me: "Got it. Someone with a 7th–8th grade literacy level and limited understanding of science. That's the majority of the general public."

(after reaction) "Hmm. In that case, my audience is a college-educated person who didn't major in science."

... or ....

"The target audience is ___ [a 'go-between' expert, usually a consultant or professor]. They'll adapt what we give them, they know how to reach that general audience."

But when I check with go-between experts, their reaction is "No way, we won't re-do USGS products! We don't have the resources or the confidence. Because of that, we use USGS products less often than we'd like. We wish the USGS would make products people can understand.""

—Sue Perry, Disaster Scientist, Science Application for Risk Reduction

Authors' point of view

Table 3. Words with different meanings for scientists and phrasing that can reduce misunderstanding (Center for Research on Environmental Decisions and ecoAmerica, 2014).

Scientific words	Non-scientific meaning	Better phrasing
Anomaly	Abnormal occurrence	Deviation from a long-term average.
Bias	Unfair and deliberate distortion	Offset from the observed value.
Enhance	Improve	Intensify, increase.
Error	Wrong, incorrect	Uncertainty associated with a measuring device or model.
Hypothesis	Conjecture	Framework for physical understanding.
Manipulation	Exploitation	Changes in experimental or model conditions to study the impact of that condition.
Positive feedback	Constructive criticism	Self-reinforcing cycle, vicious cycle.
Positive trend	A good trend	Upward trend.
Probable	Possible	Likely.
Risk	Low-probability event, danger, hazard	Probability.
Scheme	Conspiracy	Blueprint.
Sign	Indication	Positive/negative value, plus/minus sign.
Theory	A hunch, opinion, conjecture, speculation	Physical understanding of how this works.
Uncertainty	Not knowing	Range.
Values	Ethics, money	Numbers, quantity.

USGS Point of View

Word Choice, Shades of Meaning, and Unintended Consequences

"*For six years we had been doing outreach around Mt. Rainier, telling the public and officials about lahars—the terminological global standard for describing a type of volcanic landslide. Then some small lahars occurred, coming from beneath Rainier's glacier like little fresh rivers of concrete. Someone mentioned "lahar" on the radio and soon Seattle-area media were in a frenzy about a lahar coming down from Mt. Rainier. The fire chiefs didn't wait for the official word but started evacuations right away. No one mentioned that these lahars were tiny. At least one official lost their job because of the ensuing confusion. Because the USGS had remained involved with the community, after this event we brought together media, emergency managers, and scientists to agree on revised terminology. Going forward, we'd all say "lahar" to mean a mega-event that could impact communities, but we'd use "debris flow" for smaller events.*"

—Carolyn Driedger, Outreach Coordinator, Cascades Volcano Observatory

Good Practices for Plain Language

"Translating science to clear and simple language is not quick or easy at first. Like most skills, it takes practice. Fortunately, literacy experts, who are most often from public health, have widely shared their best practices (Zarcadoolas and Vaughon, 2016a). In fact, the Centers for Disease Control has an informative website on the topic (https://www.cdc.gov/healthliteracy/developmaterials/plainlanguage.html).

Follow these guidelines to make any writing more accessible:

- Keep most sentence lengths to 15–20 words (Ham, 2013).
- Vary sentence style and structure and don't be afraid to use clauses. Many people think that plain language requires simple, declarative sentences without exception; however, rigid use of that format can backfire by reducing cohesion and logical flow. For example, the next bullet has the same content as this paragraph but uses no clauses and few connections, creating a rigid declarative structure, which most people will find harder to read:
  You should vary sentence style. You should vary sentence structure. You should not be afraid. You can use clauses. "Plain language requires simple, declarative sentences." Many people believe this. They think the rule has no exceptions. The rule can backfire. Your text becomes harder to understand. That format reduces cohesion. It reduces logical flow.
- Limit the number of ideas in a single sentence or paragraph. Scientific writing is economical in the extreme and typically packs numerous concepts and information into every sentence. Writing for a non-technical audience takes more words. Give people some breathing room so they can absorb one idea before they move on to the next.

- Repetition aids understanding. Repeat key concepts throughout. Repeat subjects and other nouns within a paragraph.
- Keep your verbs active. Verbs in the passive voice and verbs that end with "ing" place greater demands on the reader/listener. A passive voice example is "greater demands are placed on the reader by…" and an "ing" example is "keeping your verbs active places greater demands…".
- Don't try to explain everything in one piece of writing. Select the most important terms and concepts and provide plain-language definitions of them.
- Avoid use of synonyms. In grade school we learned that good writing varies its words, but when communicating with people outside your field, it's better to choose a single term and repeat it.
  - For example, tsunami scientists may use these terms interchangeably:
    - teleseismic tsunami
    - distant source tsunami
    - far-field tsunami
    - distant tsunami
    - teleseismic source tsunami

But people who are not tsunami scientists will think each term is a distinct concept they must master and will quickly be oversaturated with new concepts. Remember that people can learn a limited number of new terms and concepts at one time.

- Use well-known words and avoid jargon. Specialized terms are often perceived as deceptive or exclusionary.
- Include a question-and-answer format to tackle perennial questions. People are comfortable receiving information in a "Frequently Asked Questions" format.

Figure 6 shows these principles in action.

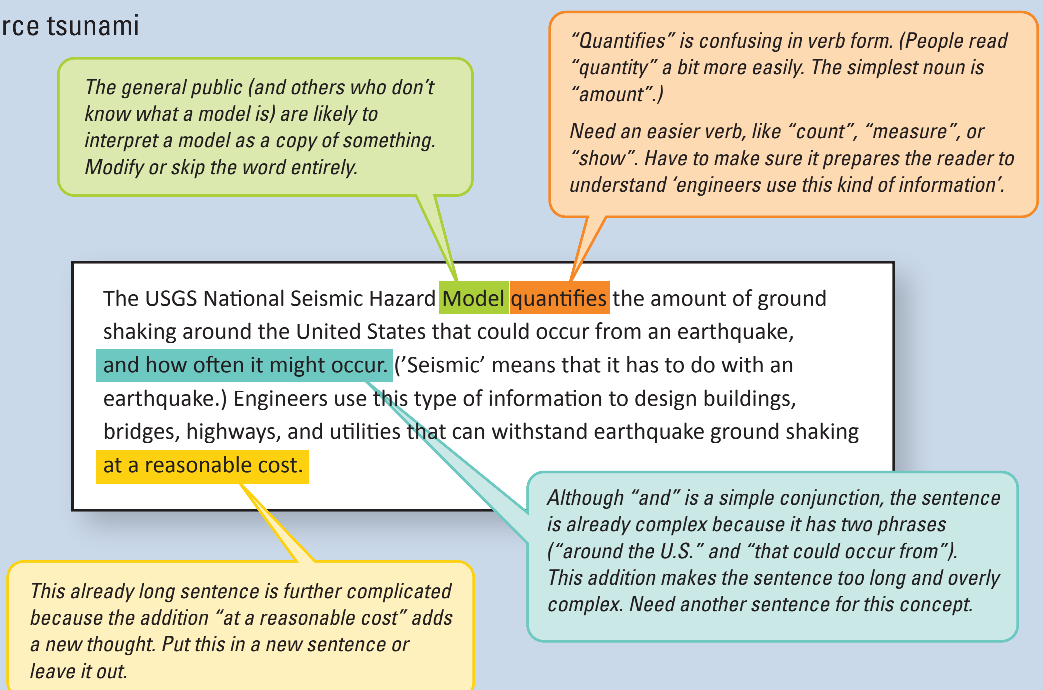

Figure 6. A snippet of web page text with comments (colored boxes) by literacy expert Christina Zarcadoolas, who advised the team that develops the USGS National Seismic Hazard Model on how to simplify web page content for a general, non-technical audience. Scientists tend to pack each sentence with numerous concepts and ideas. It usually takes more words to write simply.

AUTHORS' POINT OF VIEW

USGS POINT OF VIEW

Improve Comprehension With Familiar Comparisons

After 9/11, we had a report with high visibility that targeted emergency responders and their exposure to alkaline dust from the World Trade Center collapse. The report talked about pH but provided no measure that helped people understand the results. A reporter made the comparison for us, "the USGS found the dust was as caustic as drain cleaner." This taught us that we could help the public understand relative risk by comparing our findings to an everyday standard.

—Geoff Plumlee, Associate Director, Environmental Health

Captivating Language

If you want people to pay attention and remember, your language needs to be engaging as well as clear. The more engaged people are, the more motivated they will be to process the information and the more likely they will be to remember it.

Evocative language and figures of speech are powerful allies. To conjure images and draw in your audience, use the following:

- strong verbs and active—not passive—voice (for example, "The river will flood this street." not "This street could be affected by the river."),
- metaphors (for example, "a debris flow bulldozes everything in its path"),
- similes (for example, "a debris flow moves like a bulldozer"), and
- hypothetical situations (for example, "If you put out 30 sand bags, would they divert this debris flow?") (Ham, 2013).

A contrived situation can grab attention. For example, "What would life in Los Angeles be like if an 8.3-magnitude earthquake knocked out thousands of buildings, bridges, water, and power?" Even inserting "you" into a message can make it more relevant and thought-provoking. For example, "You may have noticed an increase in wildfires in the region lately."

Buchanan (2005, p. 2) notes, "Geology has some great sounding words, like 'hoodoo'…Use them (and define them). Let that excitement of your work show through. If you're not passionate about your work, nobody else will be. Have fun when you write."

Ham (2013) describes other ways to liven up topics not inherently interesting to broad audiences. He posits that the following topics are naturally interesting, and if you link your communication to one or more you will increase audience engagement:

- humans
- living things
- danger
- sexuality
- surprising facts
- novel things
- extreme age
- extreme size
- fast-moving things

USGS POINT OF VIEW

Science Helps Us See Our World

Science is beautiful for its own sake. I like to remind people of that. We pursue science for a variety of reasons. One of them is simple, human curiosity and that's something not to be diminished. We have an emphasis these days – especially within the government – for its societal importance, and I'm happy about that as well. But I also think it's great that science, and the universe, and the world we live in is beautiful and wonderful and we can appreciate it by understanding it. And that is what science is about. …That's another good reason to be doing science.

—Jeffrey Love, Research Geophysicist, Geomagnetism

Narratives

Narratives, or stories, can be particularly effective communication tools. There is a growing body of research indicating that narratives and logical-scientific arguments are not simply different forms of communication but may also represent different cognitive modes of understanding (Dahlstrom, 2014).

People tend to need less time to read narratives, compared to expository writing, and they tend to remember the information better (Zabrucky and Moore, 1999). The difference is not attributable to simplicity; narratives can be internally complex and may require a complex understanding of social and cultural context (Dahlstrom, 2014).

Narratives can be useful tools for scientific communication because they are engaging and emotionally evocative—people relate to the characters and want to follow the story to see how it resolves. In one study, participants more effectively integrated different data points to make more accurate predictions when the data were presented as text or narratives rather than when they were presented in graph format (Sanfey and Hastie, 1998). The authors attribute this to deeper processing of the information (participants seek explanations for their judgments or predictions).

Narratives can have different elements, but generally involve the following (Downs, 2014):

- a voice or character
- a conflict within a particular context
- some kind of action that over time resolves the conflict

Natural hazards lend themselves to narratives because they can involve humans and danger (Stewart and Nield, 2013). Natural hazard narratives allow you to show cause and effect, link science to stories about people, and focus on an individual (such as a hypothetical person who experiences a landslide, or the journey of an unmoored rowboat in a flood).

There is a caveat, though. Beware of narratives that rely too heavily on negative emotions such as fear or anxiety. These can activate self-protective behaviors such as denial and inaction, which are counterproductive if you want to inform people of risks and inspire or motivate them to take protective action (Hornik and others, 2016).

In general, narratives that elicit positive emotions are recommended. Positive emotions tend to broaden attentional focus and negative emotions may narrow attentional focus (Fredrickson and Branigan, 2005). As with other techniques, if you develop your narrative with input from your target audience, you'll be more likely to develop a narrative that works for that audience.

USGS Point of View

A Geomagnetic Storm Story

"*As the storm reached almost unprecedented intensity, geomagnetic activity induced electric fields in Earth's conducting crust and lithosphere, interfering with the operation of electrical power grids. Utility companies had to tap into reserve generating capacities. A high-voltage transformer was damaged, resulting in a temporary blackout in a mid-size metropolitan area.*

. . .

As dramatic as all this was, the effects of the storm could have been worse. Much worse. Fortunately, back in 2015, the U.S. government began planning for an extreme space-weather event. Led by NOAA and the Department of Homeland Security (DHS), and acting under the auspices of the White House's Office of Science and Technology Policy, numerous federal departments and agencies worked together to identify priority projects that needed to be pursued in order to stave off the consequences of extreme space weather. The release of a strategic plan was followed up with a detailed implementation plan. A mind-boggling set of issues needed to be addressed. The U.S. Congress even passed appropriation bills so the work could get done."

—Excerpted from Love, Jeffrey, February 2016, "Weathering a Perfect Storm from Space," Earth Magazine, p. 8–9.

Visuals

Visual aids (including maps, graphs, photos, drawings, graphic novels, and even cartoons) can inform, persuade, improve information retention, and affect feelings and beliefs; however, visual aids can also be sources of confusion and misinterpretation. By now you know what we recommend: test (or work with others to test) your visuals with members of your target audience to ensure they have the effect you intend.

The research suggests the following:

- Use images to increase memorability.
- Pair images of loss with specific instructions of actions to minimize loss so that the audience doesn't adopt a denial or avoidance approach to the hazard.
- Pictographic displays of populations at risk are more effective than numeric descriptions of risk for non-technical audiences.
- Make maps as simple as possible.
- Maps should enable users to identify whether their homes and workplaces are located in potentially hazardous areas.
- When to use text, visuals, or a combination depends on several factors. Visuals without text are best when the information must be absorbed under time pressure.

Images Are Memorable

Images can be powerful tools in the communication of risk. Images that show people and damage from hazards target people's emotions (Xie and others, 2011) and can be more memorable than text (Lopes, 1992). Photographs, images of people, cartoons, and logos can all make communication more memorable (Center for Research on Environmental Decisions and ecoAmerica, 2014).

It is important, however, that images not be overwhelmingly negative. People will tune out information that they deem too bleak and too full of despair (Linville and Fischer, 1991; Weber, 2006). This is another example of emotional numbing.

Images should be coupled with information on how to prepare for hazards, so people feel empowered and not helpless. Lopes (1992) determined that although hazard presentations with images of disaster impacts were more memorable, they also heightened denial and avoidance, which led to less preparation than presentations that did not feature images. By showing not only the dangers of hazards but also precautions that can minimize loss and damage, you can make your presentation both memorable and effective.

USGS POINT OF VIEW

A Geomagnetic Graphic Novella

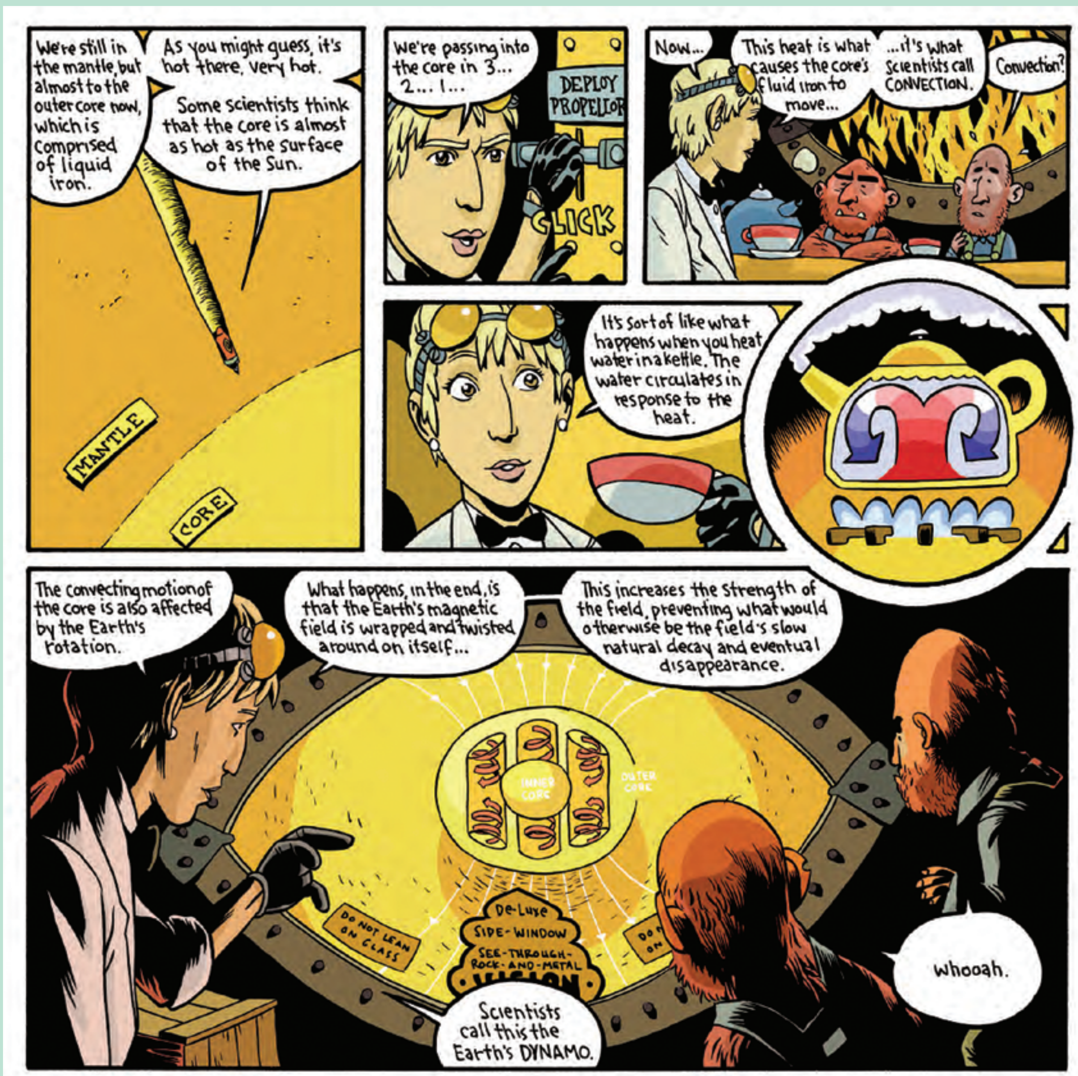

Figure 7. Excerpt from a graphic novella that presents basic concepts of geomagnetic science (Big Time Attic and Love, 2006). Images and stories can make information easier to understand.

Make Graphs, Charts, and Tables for Your Audience, Not You

The graphical needs of scientists are not the same as those of users. This is a common theme in the research. Ancker and others (2006) note that there may be significant differences, as well as a gap between the kinds of graphs people prefer and the kinds of graphs that aid understanding.

A few rules of thumb emerge:

- Visual aids that use pictures, grids, and tree and network diagrams are more memorable than traditional graphs and charts (Borkin and others, 2013). Graphs and charts tend to require prior knowledge and some technical skill to read correctly (Shah and Hoeffner, 2002).
- Graphical displays reduce risk-taking behavior more than numerical displays (Stone and others, 1997), probably due to their ability to highlight how many people out of a given population are at risk (Stone and others, 2003).
- Pictographs can be especially helpful in risk communication, as people tend to extract more accurate risk representations from frequency diagrams than from text (Garcia-Retamero and Galesic, 2010).
- Visual aids are particularly effective when they show the entire population at risk, and show the consequence of taking a particular action to reduce that risk (Garcia-Retamero and Galesic, 2010; Ancker and others, 2006).
- Horizontal arrays (where the rows change) are better understood than vertical arrays (where the columns change); however, a vertical array still communicates more effectively than text. Text takes more energy and attention to process (Price and others, 2007).

The graphical display in figure 8 demonstrates most of these concepts. It is a kind of pictograph called a frequency diagram and uses horizontal arrays to show the reduced risk of having a stroke when taking the hypothetical drug Vitarilen compared to a placebo. The black circles represent the patients who had a stroke; the clear circles represent patients who did not have a stroke. The top display (fig. 8*A*) focuses on the absolute risk (the numerator of the risk ratio) and the bottom display (fig. 8*B*) shows the relative risk (the risk reduction as a proportion of the entire population).

The words below convey the same information as the graphical displays in figure 8 (from Garcia-Retamero and Galesic, 2010):

- Absolute risk (fig. 8*A*): "Of the patients who took a placebo, 20 had a stroke. Compared to the group that took a placebo, 5 fewer patients had a stroke in the group that took Vitarilen."
- Relative risk (fig. 8*B*): "Compared to the group that took a placebo, the relative reduction in risk of having a stroke in the group that took Vitarilen was 25 percent."

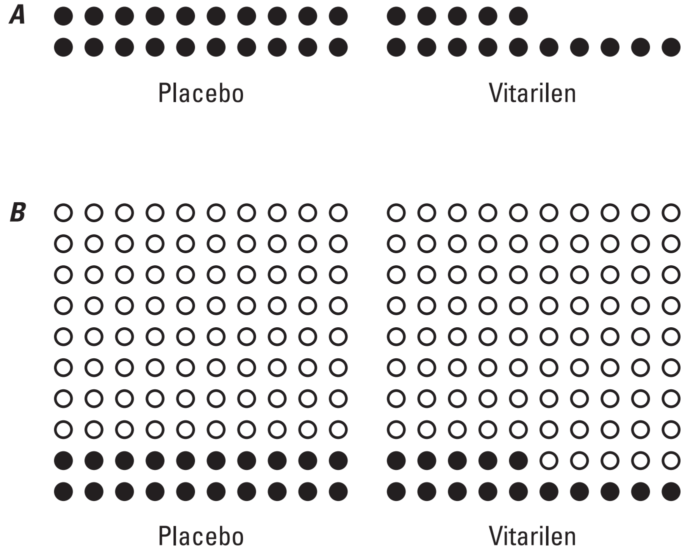

Figure 8. Frequency diagram that uses horizontal arrays to show *A*, absolute risk and *B*, relative risk of having a stroke when taking the hypothetical drug Vitarilen compared to a placebo (modified from Garcia-Retamero and Galesic, 2010).

As every scientist knows, changing the values on axes can change the interpretation of graphical data. Location on a "risk ladder" can also affect interpretation. A risk ladder is a vertical axis that shows different levels of risk (fig. 9). In one study, people perceived higher levels of threat when a certain threat level was posted three-fourths of the way up a risk ladder (marked by "X" in the "Displaced" column on right) versus one-fourth of the way up the ladder (marked by "X" in the "Base" column on left) (Sandman and others, 1994).

Considerations When Tailoring Maps to Audiences

Maps can be particularly effective communication tools in the right situations with the right users. Some, but not all, audiences prefer them. Individual differences in numeracy and graph literacy can affect map comprehension (Hawley and others, 2008). A non-technical audience better understood distances and directions when using a map about wildfire spread, compared to text description. With the map, users were better able to judge fire movement and time until fire was likely to arrive at their houses. In general, the maps led to higher perceived threats than did text, and users preferred maps over text communication (Cao and others, 2016).

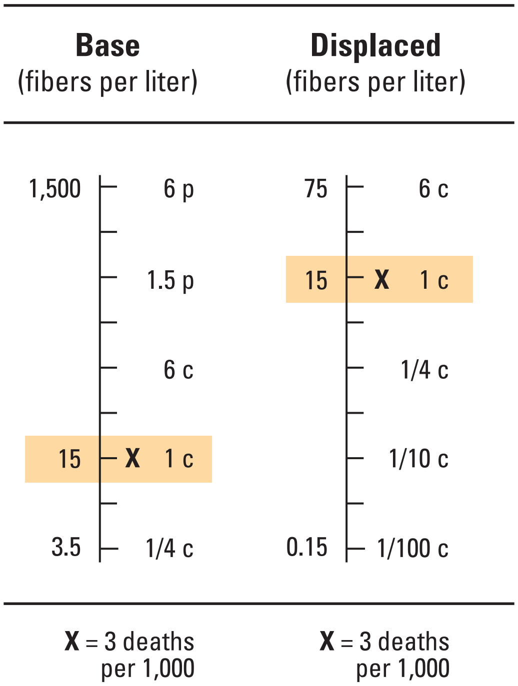

Figure 9. Risk ladder showing the risk of dying of cancer from asbestos exposure compared with cigarette smoking (modified from Sandman and others, 1994). The "Displaced" scale (right ladder) uses the same scale as the "Base" scale (left ladder), but shifts it so that exposure of 15 fibers per liter (the equivalent of 1 cigarette per day) appears higher up the scale (highlighted in orange). People who viewed the "Displaced" scale rated the risk as greater than those who viewed the "Base" scale. [c, cigarettes per day; p, packs of cigarettes per day]

In a study of wireless emergency alerts, participants generally preferred alerts that contained a map that showed their location in relation to the hazard zone (Bean and others, 2016), and there is some evidence that seeing one's location on a hazard map increases comprehension of hazard warnings (Liu and others, 2017).

Ways to Make A Map Relevant

The maps that scientists make are often not the maps that users want. What makes a map right will depend on both the audience and the situation. As discussed throughout this report, collaborating with potential users to develop the map can help you create the most useful map and can facilitate map comprehension (Cao and others, 2016).

Expect the following issues to arise as you work with users in map development:

- People want to be able to locate their homes, offices, schools, or other important locations (Prater and Lindell, 2010) (fig. 10).
- Some users need a "worst-case scenario" map when scientists provide a probability map (Zarcadoolas and Vaughon, 2016b).
- Sometimes the same users need different versions of the same map to convey different elements of the same message to their various constituents (Zarcadoolas and Vaughon, 2016b).
- In some situations, it's helpful to show walking and biking time scales rather than "traditional scale bars" (Haynes and others, 2007, p. 126).

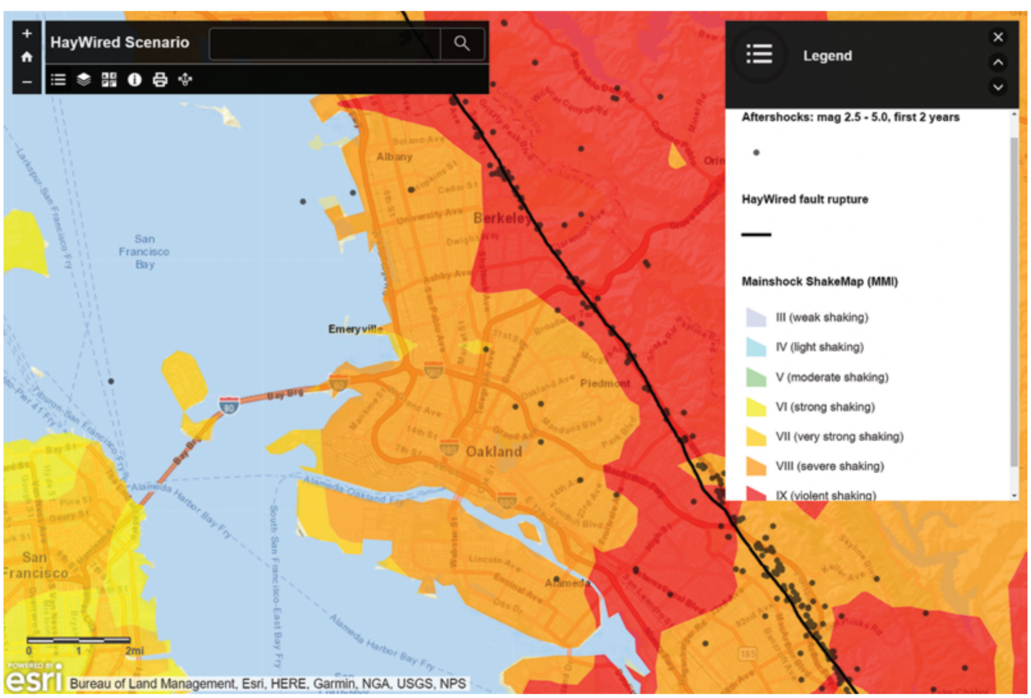

Figure 10. Screenshot showing earthquake ground shaking in the hypothetical HayWired scenario earthquake story map (Perry and Bruce, 2017). When reviewing an interactive product about the HayWired earthquake, Mike Diggles (U.S. Geological Survey Bureau Approving Official) commented, "I zoomed right into my street… Yup, it'll shake." His impulse supports research findings that, when interpreting a map, people want to be able to find locations that are important to them.

Thompson and others (2015) provide an in-depth look at working with users in a “bottom-up” approach to hazard map design. Bostrom and others (2008) provide an overview of many considerations related to visual representations of risk.

Take Extra Time on Map Symbols and Legends

Where possible, test the use of symbols with members of your target audience. In one study, California firefighters reliably and correctly identified only 6 out of 28 symbols from the Federal Geographic Data Committee Homeland Security Working Group (Akella, 2009). Symbols that described “action events,” such as emergency evacuation points or fire suppression operation, were hardest to identify. The firefighters also struggled to interpret symbols with ambiguous shapes (for example, a teardrop shape could represent water or flammable liquid).

It is hard to locate and differentiate points of interest in any display that contains numerous symbols (Smith, 1963). During crises, people will have time constraints that limit their ability to check legends carefully (Akella, 2009), and cognitive limitations due to fear and anxiety that will make simpler maps particularly desirable.

The legend and any categories contained within should be “readable at first sight” (Hagemeier-Klose and Wagner, 2009, p. 568); that is, free of jargon. Legend text should use bold fonts and (or) attention-grabbing colors (Cao and others, 2016). In an interactive web-based format, many users benefit from “rollover” explanations for different features (Cao and others, 2016).

Maps Versus Text Versus Photographs

When it comes to decision making, simple text may be the best way to communicate uncertainty, even when users prefer color hue (fig. 11; Cheong and others, 2016). In Cheong and others (2016), study participants preferred having uncertainty represented with color hue (fig. 11*B*), but they tended to make better decisions, at least when there was no time pressure, when they simply read text (fig. 11*F*).

Color, shapes, and images can communicate quickly, but often supporting text is needed to communicate complexity. Other research supports the value of graphics for a quick snapshot, and text to provide more detailed, contextualized information (Carr and others, 2016a). Maps with text descriptors may be ideal (Thompson and others, 2015; Cao and others, 2016).

Sometimes photographs are better than maps at communicating hazards and associated risks. A non-technical user group had more success locating their homes, identifying topographic features, and understanding volcanic hazards when they used photographs rather than contour maps (Haynes and others, 2008).

Simple maps or photographs can help users quickly determine if they are in the path of danger. When time is not an issue, text may be preferable for communicating complex information or more abstract concepts, such as “out of control” (Cao and others, 2016).

The decision about whether to use maps, photographs, or text (alone or in combination) will again depend on your audience and situational factors. Multiple maps may be needed to answer different questions or to show different regions or scales (Pickle, 2004).

USGS POINT OF VIEW

The Challenge of Communicating Uncertainty

“*Another problem with uncertainty is the confusion between deterministic and probabilistic boundaries. On FEMA’s flood insurance map, the boundaries indicate that you’re either in a flood zone or you’re not, which only refers to your need for flood insurance. The boundaries on the [USGS] flood inundation maps (FIMs) look very similar to those on the FEMA maps, but the FIM boundaries are showing the potential areas that could be affected by a given flood today or tomorrow. Thinking the FIM was a prediction, one homeowner sent an angry email because the flood inundation map “said” his driveway would be flooded to the halfway point – but the actual flood only reached the bottom. Meanwhile, we’re thinking, “Wow, we nailed that one!”*”

—Marie Peppler, Federal Liaison for Office of Surface Water

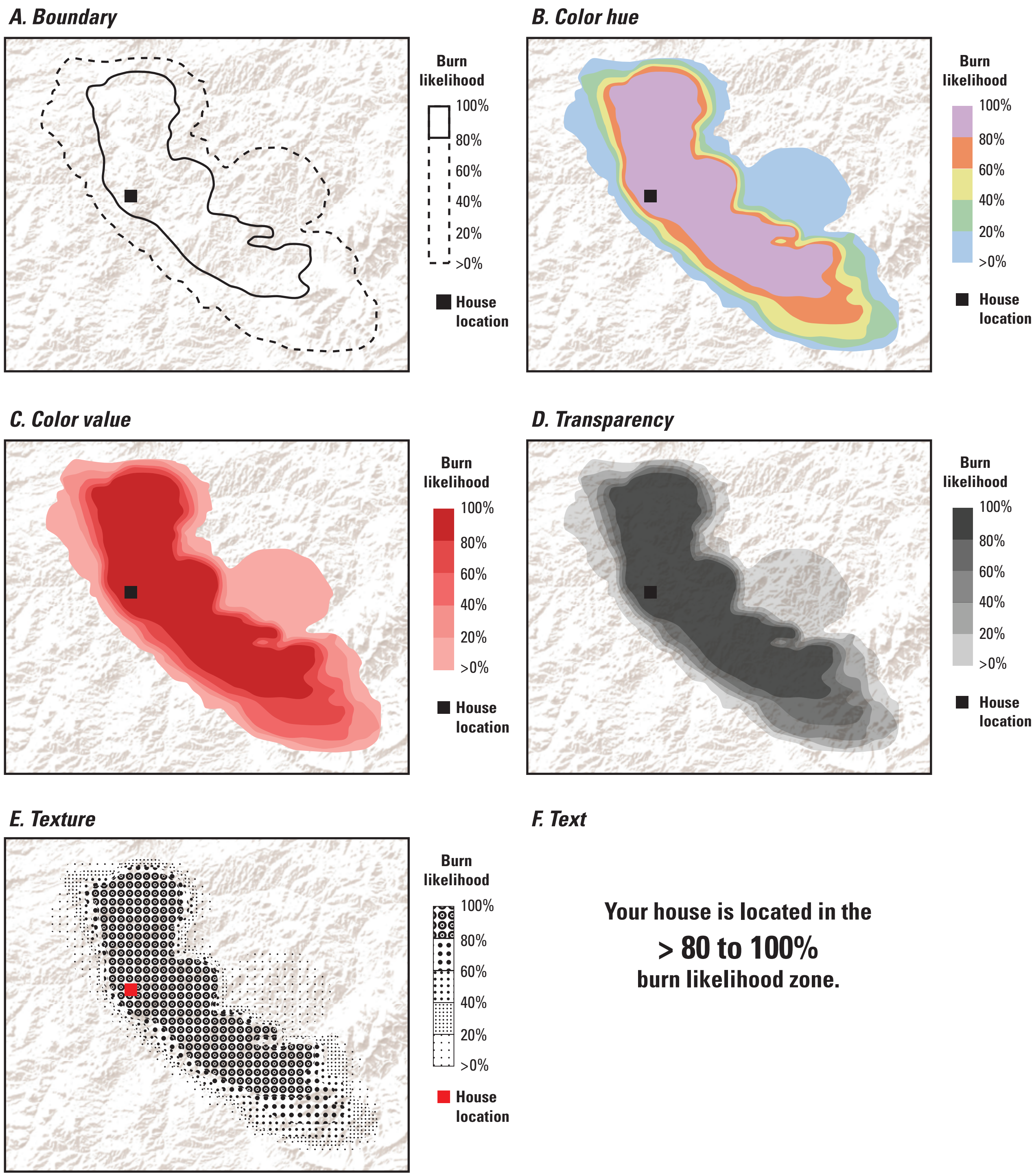

Figure 11. Six ways to depict uncertainty surrounding wildfire risk (modified from Cheong and others, 2016). Options A through E use visual strategies to communicate risk: *A*, boundary lines; *B*, color hues; *C*, color shading; *D*, transparency; and *E*, texture. The sixth option (*F*) uses text with no map. [%, percent; >, greater than]

Map Features That Increase Confusion

Communicating risk in maps can be challenging. The following features commonly cause misunderstandings:

- Many people assume there is a linear relationship between distance from the hazard and risk, so that the farther from the hazard, the lower the risk (Monmonier, 1995).
- When polygons are used to outline risk zones, people assume risk is highest in the center of the polygon, with lower risk near the edge (Ash and others, 2014; Lindell and others, 2016).
- Lines that indicate different features (roads, contours, boundaries) can be confused with each other (Haynes and others, 2008).
- A static map can make it hard to interpret a dynamic hazard such as flood or wildfire; however, animations can be distracting and should be used sparingly (Kunz and Hurni, 2011).

Two-Dimensional Versus Three-Dimensional Maps

Some hazards may be better communicated through three-dimensional (3D) versus two-dimensional (2D) maps. Preppernau and Jenny (2015) considered maps of mudflows from Mount Hood in Oregon. Study participants were just as able to find their locations on the 2D map as on the 3D map, but they were better able to answer questions about elevation and slope when they used the 3D map and better able to find safe evacuation routes on the 3D map.

USGS POINT OF VIEW

2D Versus 3D Maps

“*Many people don’t understand 2D maps. 3D maps or oblique photography can increase awareness.*”

—Nathan Wood, Research Geographer, Western Geographic Science Center

Crises

During a crisis, people will feel anxious and overwhelmed. They may turn to you for not only scientific information, but also reassurance that someone understands what is happening and knows how to respond.

Although the USGS is not the agency responsible for making recommendations or decisions during a crisis, its scientific information supports such statements and decision making (most effectively, of course, where the USGS has already worked with these decision makers and knows what they need). In addition, USGS scientists are often called upon to be in the field where they respond to events as they unfold and interact with emergency responders, government entities, the media, and communities.

The research suggests the following:

- In a crisis, simplicity, specificity, and repetition will increase the odds of your message being heeded.
- Describe in simple terms and as soon as possible: what the danger is, why it is a threat, and how likely it is.
- Lead with what you know about the situation instead of all the unknowns.
- Mention actions that are already underway to understand the situation.
- Correct errors quickly.
- Explain when information is likely to change and (briefly) why.
- Be explicit about which locations are and are not at risk. (Are there high-risk locations, such as automobiles, that require special actions?)
- Acknowledge emotions the audience may experience (including fear, anxiety, outrage, helplessness) and offer measured reassurance.
- Repeat a warning again and again to reduce the likelihood of misinformation and to increase the perceived validity of the warning.
- Protective actions need to be specific and include timeframes (for example, by what time do people need to be on higher ground? How long will the danger last?).
- During a crisis, people need to know what to do. Be ready to refer them to sources of such information.

USGS Point of View

In a Crisis, Reassure as Well as Explain

In the wake of a natural hazard,…. people need to deal with what they might be feeling as well as the physical consequences…. After the earthquakes in Christchurch we found that people were reassured to know that what's going on is "normal," not out of control, not a mystery. We also found that endless questions to scientists could be a sign that the person needs emotional support, not necessarily more information.

—Anne Wein, Operations Research Analyst, Western Geographic Science Center

After a natural hazard occurs… hearing that someone understands the event makes it less frightening. I give [the earthquake] a name, I give it a number, I give it a fault, it puts it back into the understandable box. Fear is reduced by showing it's not unforeseen.

—Lucy Jones, Seismologist Emeritus

Crises Demand Clarity, Specificity, and Honesty

During a crisis, people try to make sense of what is happening. Their prior knowledge and experience serve as filters through which they interpret new information and revise—or do not revise—what they previously believed. Crises involve complex systems and often a degree of chaos. Attempts to make sense of novel, chaotic situations can lead decision makers to communicate more certainty and predictability than may actually exist (Sellnow and others, 2002). Moreover, when attention is focused on a threat, people have fewer cognitive resources available to absorb and understand additional information.

Crisis communication messages should be as clear and specific as possible, even when there is uncertainty (Mileti and Fitzpatrick, 1992; Mileti and Peek, 2000). An assured, certain tone will facilitate compliance with protective actions, even if there is ambiguity. Mileti and Peek (2000, p. 187) provide the following example: "There is no way for us to know if there really is going to be an explosion in the reactor, but we have decided to act upon the potential for an explosion by recommending that all those within 2 miles of the nuclear power plant evacuate now."

During a crisis, communicators should be as specific as possible about the locations at risk and not at risk (Drabek, 1999). It is important to specify who is not in harm's way to avoid unnecessary travel, which can clog highways and leave people vulnerable in their cars, among other problems (Lindell and Prater, 2010; Morss and others, 2015). If the threat from a hazard is moving across an area, people need to know if the danger is moving towards their homes (Taylor and others, 2007).

Information that is too general in terms of geography or timeframe is not helpful (Taylor and others, 2007). There may be different problems threatening different areas, and this should be detailed as well. For example, as a storm nears, some people may be more vulnerable to storm surge and flooding, whereas others may face a loss of electricity (Broad and others, 2007).

USGS Point of View

Transparency Builds Trust During Crises

Following the Christchurch earthquake sequence, we held focus groups in 2013 with the public, elected officials, engineers, responders, recovery leaders, critical infrastructure, and some folks from communications. We looked at what our audience had been through, what kinds of decisions they were making, how they wanted the information. There's a temptation to withhold information to control for panic, but this can undermine trust for members of the public.

—Anne Wein, Operations Research Analyst, Western Geographic Science Center

Uncertainty Gets Reinterpreted During Crises

The process of natural hazard communication can propagate uncertainty, and this is especially likely during crises. A scientist reports the data and an emergency manager or forecaster then makes a judgment about the uncertainty and when to issue a warning. A newscaster may also make a judgment about the uncertainty, which affects the reporting. Having multiple people making interconnected judgments based on the same risk-related information can cause a "compounding of precaution" throughout the system, which can delay issuing warnings (Morss and others, 2015). There are no easy answers about how to mitigate this, but being aware of the problem is always the first step.

USGS POINT OF VIEW

Crises Bring Complicated Information Needs

"*We need to be able to convey that one disturbance may create conditions that make a landscape more susceptible to a subsequent disturbance. I am thinking of the example of an area burned by wildfire being more susceptible to post-fire flooding and erosion, risks that may persist for several years after the wildfire. Also, different agencies may be responsible for managing hazard communication during a wildfire compared to hazard communication during the sustained period after a wildfire where flooding and erosion risks are elevated. We need to be able to communicate that there is the potential for the conveyance of hazardous materials downstream or downwind of the original footprint of an event, for example the release of hazardous materials into a stream and downwind effects of any type of airborne hazardous materials.*"

—Anonymous Online Questionnaire Respondent

Elements of Effective Warnings

There is a substantial amount of research about what makes a warning effective. The wording of a warning, the information conveyed, the source of the warning, and the frequency with which a warning is repeated can all change the likelihood of its being understood and acted upon.

Warnings Should Be Specific

Evacuation messages often fail to communicate how bad an event may be and where or how to avoid danger. In a study conducted in Houston evacuation shelters in the aftermath of Hurricane Katrina, people reported understanding evacuation messages but could not recall specifics about where or how to evacuate (Eisenman and others, 2007). There was also reported confusion about whether evacuation was "recommended" or mandatory. A similar result comes from a focus group study of tsunami warnings, where participants reported that warnings that "advised" staying off the beach communicated a lower risk than warnings that "ordered" staying off the beach (Sutton and Woods, 2016).

When people don't evacuate, it is often because they don't understand how severe the event could be. Moore (2005) studied people who did not evacuate during Hurricane Katrina and found that the majority did not believe it would be as bad as it turned out to be. More than twice as many people gave this reason compared to people who said they lacked financial or transportation resources to leave (Elliott and Pais, 2006). Similarly, in a survey of people living in areas being threatened by Hurricane Isaac and Hurricane Sandy in 2012, 75 percent of people who were aware they were in an evacuation zone indicated no intention to evacuate because they felt safe where they were (Meyer and others, 2014).

A warning should convey a specific, appropriate action that the audience should take, and it should be reinforced locally and socially (Sims and Baumann, 1983). If evacuation is recommended, the warning should specify who should evacuate (and to where it is safe to evacuate), who should shelter in place, and what it means to safely shelter in place (Prater and Lindell, 2010).

Concrete, specific examples can help a non-technical audience understand potential impacts and warnings, such as "a seismic shake severe enough to bring down half the unreinforced brick buildings in the city" (Mileti and Sorensen, 1990, p. 3–9). For warnings, do not say simply "go to higher ground" but explain what "higher ground" means; for example, "ground higher than the top of City Hall" (Mileti and Sorensen, 1990). Another example comes from a shelter-in-place warning in Mileti and Peek (2000, p. 186): "We are unable to say which buildings in the city are the safest, but we do know that residents of the following communities will be protected best if they stay inside and do not attempt to evacuate."

Again, although USGS scientists don't tell anyone to evacuate, they provide essential information about what the event could be like and this needs to be specific enough for people who do communicate evacuation particulars.

USGS POINT OF VIEW

Targeted Communication is Especially Important in Crises

[We] need to be aware / sensitive to the fact that most people live in a non-crisis mode most of the time. When an emergency arises, it is "out of the norm." When a hazard communication is heard, the target audience needs to be clearly identified -- for example, a particular neighborhood or an area bounded by certain streets-- so that those in harm's way will pay attention to the message and act on it rather than ignore it because they think it does not pertain to them.

—Anonymous Online Questionnaire Respondent

Trusted Sources Should Reinforce Warnings

The perceived credibility of the information source affects whether a warning is heeded (Zhu and others, 2011). Trusted local leaders can be effective to help spread urgent messages (Fiske and Dupree, 2014). People have a strong drive to trust those who are viewed as similar to them (Fiske and Dupree, 2014), which is why it can be helpful to establish community ties prior to a crisis and rely on local leaders to communicate during a crisis.

USGS POINT OF VIEW

Local Expertise Adds Credibility

After the deadly Oso landslide in Washington, I was able to use my knowledge of how landslides work to assure families [of the victims] that their loved ones likely didn't suffer. The speed and impact of the landslide were so great that they were likely spared prolonged suffering. I had a level of understanding of the physical process that enabled me to speak from the position of an expert, and the audience was very much in need of that expertise. I also grew up in a rural community, so I could "speak the language" of that culture.

—Jonathan Godt, Landslide Hazards Program Coordinator

After Christchurch, New Zealand, was hit with a series of damaging earthquakes [in 2010-2011], it became very important for the locals to hear what might happen next. From what I observed, they were skeptical of scientific experts from far away. However, there was a local scientist who became very popular. He explained the science – and he showed a lot of analysis! But he could also be seen in his backyard with a shovel, fixing damage – he experienced the earthquakes along with his audiences and that made him a credible source of scientific information.

—Anne Wein, Operations Research Analyst, Western Geographic Science Center

Warnings Should Explain Limitations of Different Actions

People need to know the tradeoffs and limitations of different actions. For example, in the case of evacuation, explain that evacuation is safer than staying, but if you evacuate too late, you can become stuck in your car, which is often more dangerous than sheltering in place (Lindell and Prater, 2010). Communication would then need to explain how to shelter in place safely if evacuation is not practical (Lachlan and Spence, 2010).

The Importance of Repeated Warnings

Messages should be clear, accurate, comprehensive, and repeated often (Drabek, 1999; Mileti and Peek, 2000). Sometimes during a crisis, officials prefer to keep messages short so people will remember them. People will not retain all the information if warnings are lengthy and delivered only once, which is why repetition is important.

Repetition reduces the likelihood that rumors will spread and increases the perceived validity of warnings. There is some evidence that after an extended period of time, repeated warnings can become counterproductive; however, in a crisis situation people will pay attention and heed warnings for "quite a while" (Mileti and Peek, 2000, p. 186).

People rarely take action after only one warning. They may confer with friends, relatives, neighbors, or coworkers; look elsewhere for information; or just ignore a single warning. Unless there is a clear explanation of why immediate action is necessary, they will wait for a second, third, fourth, or even more warning(s) (Mileti and Peek, 2000). Although there is a concern that people will ignore repeated messages, Wood and others (2012, p. 612) say the opposite is true—rather than tune out, repetition is necessary for people to "tune in." Information delivered by way of multiple channels (for example, print, online, in-person, by sirens) and from a variety of trusted sources (for example, government agencies, university scientists, a local Red Cross chapter) is most effective (Mileti and Sorensen, 1990; Mileti and Peek, 2000).

In the Absence of Clear Information, Other Sources Will Fill the Gap

When the official message is unclear, there is a tendency for an audience to fill in the gaps in a way that minimizes the risk (Drabek, 1999). Given insufficient information during a crisis, people will seek it themselves, and what they find may not be accurate or helpful.

In the absence of adequate, specific communication, local sources will often spring up to fill in the gap. During wildfires in southern California in 2003, residents did not see many reports by regional news media outlets and criticized those they did see as being more sensational than informative. People turned to local sources for information, such as http://www.fireupdate.com, a website by mountain resident "Ranger Al," which filled the void with real-time, geographically specific information (Taylor and others, 2007). In the case of Ranger Al, the information was helpful, but there may not always be a source as accurate or helpful as Ranger Al.

Emotions During A Crisis

During crises, people need reassurance. In fact, their ability to process information and make good decisions may depend on it. During and immediately after an event, empathize with the audience. Avoid comments that minimize the significance of even one death, such as "We were expecting much worse." A more empathetic framing of that situation would be "Any death or injury is a tragedy."

In the wake of a crisis, feelings of vulnerability and insecurity can be high. Economic instability has been linked to greater emotional tolls, perceived loss of control, and worries about "increased indebtedness" (Fothergill and others, 1999). Sensitivity with historically disenfranchised groups is critical to their longer-term recovery.

People often underestimate the negative emotions such an event will cause. In one study, people were asked to imagine or to recall the worst part of a severe flood. People who had never experienced a flood imagined the worst part would be "casualties and destruction." In fact, those who had experienced a severe flood reported the worst part as feelings of "uncertainty, insecurity, fear, shock, and helplessness" (fig. 12) (Siegrist and Gutscher, 2008, p. 773).

The Importance of Consistency During Crises

Inconsistency in information from different sources can lead people to conclude that the situation is not that bad and that no action is required (Drabek, 1999). Consistency requires much coordination because during a crisis, multiple people and agencies disseminate information, including scientists, public officials, emergency managers, media, and members of the general public (Morss and others, 2015).

Particularly during a crisis, it is important for scientists to "speak with one voice" and not disagree publicly, because public disagreement creates negative impressions (for example, people will begin to think that scientists don't know much, their information can't be trusted, or they have personal agendas). When such disagreements happen, be sure to point out that they are a common and important part of how science moves forward.

As new information is obtained that may alter warnings, repeat previous messages and explain what has changed and why (Mileti and Sorensen, 1990; Mileti and Peek, 2000). As messages evolve, continue to coordinate among different agencies. If any particular behaviors are proposed in conjunction with the warning (for example, evacuate or shelter in place),

Figure 12. Feelings of uncertainty, insecurity, fear, shock, and helplessness are the worst parts of a flood, according to people who have experienced one. By contrast, people who have not experienced a flood expect the worst part to be "casualties and destruction." People often underestimate the negative emotions a disaster will cause. (Photograph credits, clockwise from top: Vadim Ratnikov; Bad River Tribe; Andrea Booher, Federal Emergency Management Agency; Robert Atkinson, U.S. Geological Survey)

explain the rationale for those recommendations (Mileti and Peek, 2000). In June 2005, conflicting tsunami warnings from the West Coast/Alaska Tsunami Prediction Center and the Pacific Tsunami Prediction Center caused confusion about which area was in danger and if/when the warning was canceled (Lindell and Prater, 2010).

The USGS provides information, not recommendations for actions; however, during a crisis, people want to know not only about the geological event, but also what they should do (Carr and others, 2016b). During a crisis, it is important for the USGS to refer people to other resources to obtain that information.

Simulating or practicing crisis communication will increase effectiveness during an actual crisis (Mileti and Peek, 2000). As many in the USGS already know, tabletop exercises conducted with members of partner organizations can help prepare for real events by simulating crises and having people think through all the small actions that can add up during a hazard.

Interactivity Reduces Feelings of Helplessness

The interactive nature of digital content helps people to access information relevant for them (Downs, 2014). Perhaps more important during a crisis, interactive products like the USGS's "Did You Feel It?" maps give an audience a sense of control and agency. Maps can also include information about community activities or talks, in addition to just risks or real-time hazard event information (Verrucci and others, 2016).

The Importance of Social Media Communication During a Crisis

Some scientists dismiss social media as trivial and too informal of a means to communicate science; however, during a crisis, many people turn to the internet and in particular to social media (Lindsay, 2011; Sweetser and Metzgar, 2007). Social media allows people to check in with loved ones, learn what is happening, obtain information on what to do, and feel some connection in a time of uncertainty and fear. Pew Research Center (2013) reported that approximately one-fourth of the American population used social media sites like Facebook™ and Twitter™ to track information about the 2013 Boston Marathon bombings. Just as face-to-face community engagement is helpful prior to a crisis, engaging in dialogue online before a crisis will encourage people to turn to the USGS on social media during a crisis.

According to Waters and Williams (2011), the public perception of government communication is poor, and expectations of government engagement with the public are low. In a crisis, one-way communication may be appropriate to ensure safety, but two-way communication during non-crisis times can build trust and credibility.

USGS Point of View

OCAP Can Help

"Within the USGS, the Office of Communication and Publication (OCAP) can help with hazard communication in many ways. OCAP staff:

- *have experience in journalism and politics.*
- *are expert in communicating with media and Congress.*
- *can help craft press releases and research summaries for non-technical audiences.*
- *can review and advise on presentations for non-technical audiences.*
- *manage USGS social media.*

Each OCAP office has additional resources important to their region. Contact your public affairs specialist to find out what's available in your region."

—Donyelle Davis, Public Affairs Specialist, OCAP Western Region

Final Remarks

This report summarizes many key issues in hazard communication. Such issues dictate whether people will accept your hazard information, understand it, and make appropriate decisions based on it. Understanding these issues can help you to recognize which issues are factors in your current effort to communicate.

As we mentioned at the outset, hazard communication is not a one-size-fits-all, always-do-this activity. What works will depend on the audience, your information, the situation, and human nature. Understanding information and making decisions are activities within dynamic, complicated behavioral systems—every bit as complex as the natural systems that USGS research strives to explain.

When you communicate hazard science, two outcomes are inevitable: you will make mistakes and you won't find a solution that works all the time. However, if you maintain contact with members of your audience, especially if you collaborate with them to develop your products, your successes will grow. In the process, you'll be more likely to make noteworthy contributions to public safety and science awareness.

Related Resources

A popular 2009 publication, "The Psychology of Climate Change Communication," has much relevance to hazard communication because it focuses on understanding the psychological phenomena and processes that underpin effective communication. (Center for Research on Environmental Decisions, 2009). A 2014 companion guide, "Connecting on Climate—A Guide to Effective Climate Change Communication," (Center for Research on Environmental Decisions and ecoAmerica, 2014) has some overlap but also contains distinct material. This 2014 guide concentrates on strategies and actionable tips based on social science research.

A wide range of social and behavioral scientists use the same strategy to make products that people need and use. Perry and others (2016) summarizes this strategy. In addition, to help USGS scientists begin to work with users, the Science Application for Risk Reduction project enlisted social scientists to create two online tutorials:

- "An Introduction to User-Centered Design" (Zarcadoolas and Vaughon, 2016a)
- "Task Analysis as a Part of User-Centered Design" (Zarcadoolas and Vaughon, 2016c)

You also might want to explore these publications:

- Bruine de Bruin and Bostrom (2013) for guidance on structuring and analyzing interviews and surveys.
- Paveglio and others (2009) for an example of using focus groups to evaluate the effectiveness of a particular communication.
- Wagner (2007) for an example of using mental models to study understanding of landslides and floods.
- Thompson and others (2015) for questions to ask when testing different map designs.
- Lundgren and McMakin (2013) for examples of presentation of risks in visual format.
- Driedger and Westby (in press) for a Communication Plan Template that will walk you through many of the considerations discussed in this report.
- Final reports of usability studies of particular USGS hazard products are downloadable from the Science Application for Risk Reduction web page at https://www.usgs.gov/natural-hazards/science-application-risk-reduction (Science Application for Risk Reduction, 2018).

Authors' point of view

References Cited

Akella, M.K., 2009, First responders and crisis map symbols—Clarifying communication: Cartography and Geographic Information Science, v. 36, no. 1, p. 19–28, accessed May 2018 at https://doi.org/10.1559/152304009787340179.

Alexopoulos, T., 2009, Preparedness Now, The Great California Shakeout [Theo Alexopoulos, director, producer, animator]: U.S. Geological Survey video, 00:04:31, accessed May 2018 at https://www.youtube.com/watch?v=8Z5ckzem7uA.

Alonso, D., and Fernandez-Berrocal, P., 2003, Irrational decisions—Attending to numbers rather than ratios: Personality and Individual Differences, v. 35, no. 7, p. 1537–1547. [Also available at https://doi.org/10.1016/S0191-8869(02)00368-9.]

Ancker, J., Senathirajah, Y., Kukafka, R., and Starren, J., 2006, Design features of graphs in health risk communication—A systematic review: Journal of the American Medical Informatics Association, v. 13, no. 6, p. 608–618. [Also available at https://doi.org/10.1197/jamia.M2115.]

Arora, P., Peterson, N.D., Krantz, D.H., Hardisty, D.J., and Reddy, K.S., 2012, To cooperate or not to cooperate—Using new methodologies and frameworks to understand how affiliation influences cooperation in the present and future: Journal of Economic Psychology, v. 33, no. 4, p. 842–853. [Also available at https://doi.org/10.1016/j.joep.2012.02.006.]

Ash, K.D., Schumann, R.L., III, and Bowser, G.C., 2014, Tornado warning trade-offs—Evaluating choices for visually communicating risk: Weather, Climate, and Society, v. 6, no. 1, p. 104–118, accessed May 2018 at https://doi.org/10.1175/WCAS-D-13-00021.1.

Bahk, C.M., and Neuwirth, K., 2000, Impact of movie depictions of volcanic disaster on risk perception and judgments: International Journal of Mass Emergencies and Disasters, v. 18, no. 1, p. 63–84.

Baker, E.J., 1991, Hurricane evacuation behavior: International Journal of Mass Emergencies and Disasters, v. 9, no. 2, p. 287–310.

Barclay, J., Haynes, K., Mitchell, T., Solana, C., Teeuw, R., and Darnell, A., Crosweller, H.S., Cole, P., Pyle, D., Lowe, C., Fearnley, C., and Kelman, I., 2008, Framing volcanic risk communication within disaster risk reduction—Finding ways for the social and physical sciences to work together: Geological Society, London, Special Publications, v. 305, no. 1, p. 163–177, accessed May 2018 at https://doi.org/10.1144/SP305.14.

Bean, H., Liu, B.F., Madden, S., Sutton, J., Wood, M.M., and Mileti, D.S., 2016, Disaster warnings in your pocket—How audiences interpret mobile alerts for an unfamiliar hazard: Journal of Contingencies and Crisis Management, v. 24, no. 3, p. 136–147, accessed May 2018 at https://doi.org/10.1111/1468-5973.12108.

Big Time Attic and Love, J. J., 2006, Journey along a fieldline: 8 p., accessed June 1, 2018, at https://geomag.usgs.gov/publications/comicbook/GeomagComic.pdf.

Bohensky, E.L., and Leitch, A.M., 2014, Framing the flood—A media analysis of themes of resilience in the 2011 Brisbane flood: Regional Environmental Change, v. 14, no. 2, p. 475–488, accessed May 2018 at https://doi.org/10.1007/s10113-013-0438-2.

Borkin, M.A., Vo, A.A., Bylinskii, Z., Isola, P., Sunkavalli, S., Oliva, A., and Pfister, H., 2013, What makes a visualization memorable?: IEEE Transactions on Visualization and Computer Graphics, v. 19, no. 12, p. 2306–2315. [Also available at https://doi.org/10.1109/TVCG.2013.234.]

Bostrom, A., Anselin, L., and Farris, J., 2008, Visualizing seismic risk and uncertainty—A review of related research: Annals of the New York Academy of Sciences, v. 1128, no. 1, p. 29–40, accessed May 2018 at https://doi.org/10.1196/annals.1399.005.

Botzen, W.J.W., de Boer, J., and Terpstra, T., 2013, Framing of risk and preferences for annual and multi-year flood insurance: Journal of Economic Psychology, v. 39, p. 357–375. [Also available at https://doi.org/10.1016/j.joep.2013.05.007.]

Bradford, R.A., O'Sullivan, J.J., van der Craats, I.M., Krywkow, J., Rotko, P., Aaltonen, J., Bonaiuto, M., De Dominicis, S., Waylen, K., and Schelfaut, K., 2012, Risk perception—Issues for flood management in Europe: Natural Hazards and Earth System Sciences, v. 12, no. 7, p. 2299–2309, accessed May 2018 at https://doi.org/10.5194/nhess-12-2299-2012.

Broad, K., Leiserowitz, A., Weinkle, J., and Steketee, M., 2007, Misinterpretations of the "Cone of Uncertainty" in Florida during the 2004 hurricane season: Bulletin of the American Meteorological Society, v. 88, no. 5, p. 651–667, accessed May 2018 at https://doi.org/10.1175/BAMS-88-5-651.

Bruine de Bruin, W., and Bostrom, A., 2013, Assessing what to address in science communication: Proceedings of the National Academy of Sciences of the United States of America, v. 110, suppl. 3, p. 14062–14068, accessed May 2018 at https://doi.org/10.1073/pnas.1212729110.

Buchanan, R., 2005, Five things I've learned in 25 years of popularizing geology: Palaios, v. 20, no. 1, p. 1–2, accessed May 2018 at https://doi.org/10.2110/palo.2005.s01.

Budescu, D.V., Broomell, S., and Por, H.-H., 2009, Improving communication of uncertainty in the reports of the Intergovernmental Panel on Climate Change: Psychological Science, v. 20, no. 3, p. 299–308, accessed May 2018 at https://doi.org/10.1111/j.1467-9280.2009.02284.x.

Budescu, D.V., Por, H.-H., and Broomell, S.B., 2012, Effective communication of uncertainty in the IPCC reports: Climatic Change, v. 113, no. 2, p. 181–200, accessed May 2018 at https://doi.org/10.1007/s10584-011-0330-3.

Burger, J.M., and Palmer, M.L., 1992, Changes in and generalization of unrealistic optimism following experiences with stressful events—Reactions to the 1989 California earthquake: Personality and Social Psychology Bulletin, v. 18, no. 1, p. 39–43. [Also available at https://doi.org/10.1177/0146167292181006.]

Burningham, K., Fielding, J., and Thrush, D., 2008, 'It'll never happen to me'—Understanding public awareness of local flood risk: Disasters, v. 32, no. 2, p. 216–238, accessed May 2018 at https://doi.org/10.1111/j.1467-7717.2007.01036.x.

Cadag, J.R., Driedger, C., Garcia, C., Duncan, M., Gaillard, J.C., Lindsay, J., and Haynes, K., 2017, Fostering participation of local actors in volcanic disaster risk reduction, in Nemeth, K., ed., Advances in volcanology: Berlin, Heidelberg, Springer, p. 1–17. [Also available at https://doi.org/10.1007/11157_2016_39.]

Camerer, C.F., and Kunreuther, H., 1989, Decision processes for low probability events—Policy implications: Journal of Policy Analysis and Management, v. 8, no. 4, p. 565–592, accessed May 2018 at https://doi.org/10.2307/3325045.

Camerer, C., Loewenstein, G., and Weber, M., 1989, The curse of knowledge in economic settings—An experimental analysis: Journal of Political Economy, v. 97, no. 5, p. 1232–1254. [Also available at https://doi.org/10.1086/261651.]

Campbell, P., 2011, Understanding the receivers and the reception of science's uncertain messages: Philosophical Transactions of the Royal Society A—Mathematical, Physical and Engineering Sciences, v. 369, no. 1956, p. 4891–4912, accessed May 2018 at https://doi.org/10.1098/rsta.2011.0068.

Cao, Y., Boruff, B.J., and McNeill, I.M., 2016, Is a picture worth a thousand words? Evaluating the effectiveness of maps for delivering wildfire warning information: International Journal of Disaster Risk Reduction, v. 19, p. 179–196, accessed May 2018 at https://doi.org/10.1016/j.ijdrr.2016.08.012.

Carr, R.H., Montz, B., Maxfield, K., Hoekskstra, S., Semmens, K., and Goldman, E., 2016a, Effectively communicating risk and uncertainty to the public—Assessing the National Weather Service's flood forecast and warning tools: Bulletin of the American Meteorological Society, v. 97, no. 9, p. 1649–1665. [Also available at https://doi.org/10.1175/BAMS-D-14-00248.1.]

Carr, R.H., Montz, B., Semmens, K., Maxfield, K., Hoekstra, S., and Goldman, E., 2016b, Motivating action under uncertain conditions—Enhancing emergency briefings during coastal storms: Weather, Climate, and Society, v. 8, no. 4, p. 421–434, accessed May 2018 at https://doi.org/10.1175/WCAS-D-16-0028.1.

Catto, N.R., and Parewick, K., 2008, Hazard and vulnerability assessment and adaptive planning—Mutual and multilateral community–researcher communication, Arctic Canada: Geological Society of London, Special Publications, v. 305, no. 1, p. 123–140, accessed May 2018 at https://doi.org/10.1144/SP305.12.

Center for Research on Environmental Decisions, 2009, The psychology of climate change communication—A guide for scientists, journalists, educators, political aides, and the interested public: New York, 54 p.

Center for Research on Environmental Decisions and ecoAmerica, 2014, Connecting on climate—A guide for effective climate change communication: New York and Washington, D.C., 96 p.

Cesario, J., Grant, H., and Higgins, E.T., 2004, Regulatory fit and persuasion—Transfer from "feeling right": Journal of Personality and Social Psychology, v. 86, no. 3, p. 388–404. [Also available at https://doi.org/10.1037/0022-3514.86.3.388.]

Cheong, L., Bleisch, S., Kealy, A., Tolhurst, K., Wilkening, T., and Duckham, M., 2016, Evaluating the impact of visualization of wildfire hazard upon decision-making under uncertainty: International Journal of Geographical Information Science, v. 30, no. 7, p. 1377–1404, accessed May 2018 at https://doi.org/10.1080/13658816.2015.1131829.

Cooper, K.E., and Nisbet, E.C., 2016, Green narratives—How affective responses to media messages influence risk perceptions and policy preferences about environmental hazards: Science Communication, v. 38, no. 5, p. 626–654, accessed May 2018 at https://doi.org/10.1177/1075547016666843.

Covello, V.T., 2003, Best practices in public health risk and crisis communication: Journal of Health Communication, v. 8, suppl. 1, p. 5–8, accessed May 2018 at https://doi.org/10.1080/713851971.

Crowe, E., and Higgins, E.T., 1997, Regulatory focus and strategic inclinations—Promotion and prevention in decision-making: Organizational Behavior and Human Decision Processes, v. 69, no. 2, p. 117–132. [Also available at https://doi.org/10.1006/obhd.1996.2675.]

Cvetkovich, G., and Earle, T.C., 1992, Environmental hazards and the public: The Journal of Social Issues, v. 48, no. 4, p. 1–20. [Also available at https://doi.org/10.1111/j.1540-4560.1992.tb01942.x.]

Dahlstrom, M.F., 2014, Using narratives and storytelling to communicate science with nonexpert audiences: Proceedings of the National Academy of Sciences of the United States of America, v. 111, suppl. 4, p. 13614–13620. [Also available at https://doi.org/10.1073/pnas.1320645111.]

de Boer, J., Botzen, W.J.W., and Terpstra, T., 2014, Improving flood risk communication by focusing on prevention-focused motivation: Risk Analysis, v. 34, no. 2, p. 309–322. [Also available at https://doi.org/10.1111/risa.12091.]

Demuth, J.L., Morss, R.E., Lazo, J.K., and Trumbo, C., 2016, The effects of past hurricane experiences on evacuation intentions through risk perception and efficacy beliefs—A mediation analysis: Weather, Climate, and Society, v. 8, no. 4, p. 327–344, accessed May 2018 at https://doi.org/10.1175/WCAS-D-15-0074.1.

Denes-Raj, V., and Epstein, S., 1994, Conflict between intuitive and rational processing—When people behave against their better judgment: Journal of Personality and Social Psychology, v. 66, no. 5, p. 819–829. [Also available at https://doi.org/10.1037/0022-3514.66.5.819.]

Department of Administration, State of Louisiana, 2016, Comparison of existing operating budget to recommended by functional area: accessed May 2018 at http://www.doa.la.gov/opb/pub/FY17/SupportingDocument/EOBvsRecommend_FA.pdf.

DeYoung, S.E., Wachtendorf, T., Farmer, A.K., and Penta, S.C., 2016, NOAA radios and neighbourhood networks—Demographic factors for channel preference for hurricane evacuation information: Journal of Contingencies and Crisis Management, v. 24, no. 4, p. 275–285, accessed May 2018 at https://doi.org/10.1111/1468-5973.12123.

Dillon, R.L., Tinsley, C.H., and Cronin, M., 2011, Why near-miss events can decrease an individual's protective response to hurricanes: Risk Analysis, v. 31, no. 3, p. 440–449, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2010.01506.x.

Dolce, C., 2016, Louisiana's historic August flooding cost more than $8 billion, officials say: The Weather Channel website, accessed May 2018 at https://weather.com/news/weather/news/historic-august-louisiana-flooding-billion-dollar-disaster?_escaped_fragment_.

Downs, J.S., 2014, Prescriptive scientific narratives for communicating usable science: Proceedings of the National Academy of Sciences of the United States of America, v. 111, suppl. 4, p. 13627–13633. [Also available at https://doi.org/10.1073/pnas.1317502111.]

Doyle, E.E.H., Johnston, D.M., McClure, J., and Paton, D., 2011, The communication of uncertain scientific advice during natural hazard events: New Zealand Journal of Psychology, v. 40, no. 4, p. 39–50.

Doyle, E.E.H., McClure, J., Johnston, D.M., and Paton, D., 2014a, Communicating likelihoods and probabilities in forecasts of volcanic eruptions: Journal of Volcanology and Geothermal Research, v. 272, p. 1–15, accessed May 2018 at https://doi.org/10.1016/j.jvolgeores.2013.12.006.

Doyle, E.E.H., McClure, J., Paton, D., and Johnston, D.M., 2014b, Uncertainty and decision making—Volcanic crisis scenarios: International Journal of Disaster Risk Reduction, v. 10, p. 75–101. [Also available at https://doi.org/10.1016/j.ijdrr.2014.07.006.]

Drabek, T.E., 1999, Understanding disaster warning responses: The Social Science Journal, v. 36, no. 3, p. 515–523. [Also available at https://doi.org/10.1016/S0362-3319(99)00021-X.

Driedger, C.L., and Westby, E.G., in press, USGS Cascades Volcano Observatory news media management guide—General protocols and templates: U.S. Geological Survey Circular 1462.

Dunn, P.T., Ahn, A.Y.E., Bostrom, A., and Vidale, J.E., 2016, Perceptions of earthquake early warnings on the U.S. West Coast: International Journal of Disaster Risk Reduction, v. 20, p. 112–122, accessed May 2018 at https://doi.org/10.1016/j.ijdrr.2016.10.019.

Eisenman, D.P., Cordasco, K.M., Asch, S., Golden, J.F., and Glik, D., 2007, Disaster planning and risk communication with vulnerable communities—Lessons from Hurricane Katrina: American Journal of Public Health, v. 97, suppl. 1, p. S109–S115. [Also available at https://doi.org/10.2105/AJPH.2005.084335.]

Eiser, J.R., Bostrom, A., Burton, I., Johnston, D.M., McClure, J., Paton, D., van der Pligt, J., and White, M.P., 2012, Risk interpretation and action—A conceptual framework for responses to natural hazards: International Journal of Risk Reduction, v. 1, p. 5–16. [Also available at https://doi.org/10.1016/j.ijdrr.2012.05.002.]

Elliott, J.R., and Pais, J., 2006, Race, class, and Hurricane Katrina—Social differences in human responses to disaster: Social Science Research, v. 35, no. 2, p. 295–321, accessed May 2018 at https://doi.org/10.1016/j.ssresearch.2006.02.003.

Feldman, D., Contreras, S., Karlin, B., Basolo, V., Matthew, R., Sanders, B., Houston, D., Cheung, W., Goodrich, K., Reyes, A., Serrano, K., Schubert, J., and Luke, A., 2016, Communicating flood risk—Looking back and forward at traditional and social media outlets: International Journal of Disaster Risk Reduction, v. 15, p. 43–51, accessed May 2018 at https://doi.org/10.1016/j.ijdrr.2015.12.004.

Fischhoff, B., 1995, Risk perception and communication unplugged—Twenty years of process: Risk Analysis, v. 15, no. 2, p. 137–145. [Also available at https://doi.org/10.1111/j.1539-6924.1995.tb00308.x.]

Fischhoff, B., 2015, Four steps for effective science communication: accessed August 2016 at http://www.scidev.net/index.cfm?originalUrl=global/communication/opinion/four-steps-effective-science-communication.html.

Fischhoff, B., Bostrom, A., and Quadrel, M.J., 1993, Risk perception and communication: Annual Review of Public Health, v. 14, no. 1, p. 183–203, accessed May 2018 at https://doi.org/10.1146/annurev.pu.14.050193.001151.

Fischhoff, B., and Davis, A.L., 2014, Communicating scientific uncertainty: Proceedings of the National Academy of Sciences of the United States of America, v. 111, suppl. 4, p. 13664–13671, accessed May 2018 at https://doi.org/10.1073/pnas.1317504111.

Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S., and Combs, B., 1978, How safe is safe enough? A psychometric study of attitudes toward technological risks and benefits: Policy Sciences, v. 9, no. 2, p. 127–152. [Also available at https://doi.org/10.1007/BF00143739.]

Fiske, S.T., and Dupree, C., 2014, Gaining trust as well as respect in communicating to motivated audiences about science topics: Proceedings of the National Academy of Sciences of the United States of America, v. 111, suppl. 4, p. 13593–13597, accessed May 2018 at https://doi.org/10.1073/pnas.1317505111.

Fothergill, A., Maestas, E.G.M., and Darlington, J.D., 1999, Race, ethnicity and disasters in the United States—A review of the literature: Disasters, v. 23, no. 2, p. 156–173, accessed May 2018 at https://doi.org/10.1111/1467-7717.00111.

Fox-Rogers, L., Devitt, C., O’Neill, E., Brereton, F., and Clinch, J.P., 2016, Is there really “nothing you can do”? Pathways to enhanced flood-risk preparedness: Journal of Hydrology (Amsterdam), v. 543, p. 330–343, accessed May 2018 at https://doi.org/10.1016/j.jhydrol.2016.10.009.

Fredrickson, B.L., and Branigan, C., 2005, Positive emotions broaden the scope of attention and thought-action repertoires: Cognition and Emotion, v. 19, no. 3, p. 313–332, accessed May 2018 at https://doi.org/10.1080/02699930441000238.

Frisby, B.N., Sellnow, D.D., Lane, D.R., Veil, S.R., and Sellnow, T.L., 2013, Instruction in crisis situations—Targeting learning preferences and self-efficacy: Risk Management, v. 15, no. 4, p. 250–271. [Also available at https://doi.org/10.1057/rm.2013.7.]

Fussell, S.R., and Krauss, R.M., 1992, Coordination of knowledge in communication—Effects of speakers’ assumptions about what others know: Journal of Personality and Social Psychology, v. 62, no. 3, p. 378–391. [Also available at https://doi.org/10.1037/0022-3514.62.3.378.]

Gaillard, J.-C., 2008, Alternative paradigms of volcanic risk perception—The case of Mt. Pinatubo in the Philippines: Journal of Volcanology and Geothermal Research, v. 172, no. 3–4, p. 315–328. [Also available at https://doi.org/10.1016/j.jvolgeores.2007.12.036.]

Garcia-Retamero, R., and Galesic, M., 2009, Communicating treatment risk reduction to people with low numeracy skills—A cross-cultural comparison: American Journal of Public Health, v. 99, no. 12, p. 2196–2202. [Also available at https://doi.org/10.2105/AJPH.2009.160234.]

Garcia-Retamero, R., and Galesic, M., 2010, Who profits from visual aids—Overcoming challenges in people’s understanding of risks: Social Science & Medicine, v. 70, no. 7, p. 1019–1025. [Also available at https://doi.org/10.1016/j.socscimed.2009.11.031.]

Gibson, H., Stewart, I.S., Pahl, S., and Stokes, A., 2016, A “mental models” approach to the communication of subsurface hydrology and hazards: Hydrology and Earth System Sciences, v. 20, no. 5, p. 1737–1749, accessed May 2018 at https://doi.org/10.5194/hess-20-1737-2016.

Gifford, R., 2011, The dragons of inaction—Psychological barriers that limit climate change mitigation and adaptation: American Psychologist, v. 66, no. 4, p. 290–302. [Also available at https://doi.org/10.1037/a0023566.]

Gigerenzer, G., and Edwards, A., 2003, Simple tools for understanding risks—From innumeracy to insight: British Medical Journal, v. 327, no. 7417, p. 741–744. [Also available at https://doi.org/10.1136/bmj.327.7417.741.]

Gigerenzer, G., Hertwig, R., van den Broek, E., Fasolo, B., and Katsikopoulos, K.V., 2005, “A 30% Chance of Rain Tomorrow”—How does the public understand probabilistic weather forecasts?: Risk Analysis, v. 25, no. 3, p. 623–629, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2005.00608.x.

Gilbert, D.T., and Wilson, T.D., 2007, Prospection—Experiencing the future: Science, v. 317, no. 5843, p. 1351–1354, accessed May 2018 at https://doi.org/10.1126/science.1144161.

Glass, T.A., 2001, Understanding public response to disasters: Public Health Reports, v. 116, suppl. 2, p. 69–73. [Also available at https://doi.org/10.1016/S0033-3549(04)50146-2.]

Glenberg, A.M., and Epstein, W., 1987, Inexpert calibration of comprehension: Memory & Cognition, v. 15, no. 1, p. 84–93. [Also available at https://doi.org/10.3758/BF03197714.]

Glenberg, A.M., Sanocki, T., Epstein, W., and Morris, C., 1987, Enhancing calibration of comprehension: Journal of Experimental Psychology—General, v. 116, no. 2, p. 119–136. [Also available at https://doi.org/10.1037/0096-3445.116.2.119.]

Gottfried, J., and Shearer, E., 2016, News use across social media platforms 2016: Pew Research Center, 20 p.

Grineski, S.E., Collins, T.W., Chakraborty, J., and Montgomery, M., 2016, Hazard characteristics and patterns of environmental injustice—Household-level determinants of environmental risk in Miami, Florida: Risk Analysis, v. 37, no. 7, p. 1–16, accessed May 2018 at https://doi.org/10.1111/risa.12706.

Gross, L., 2006, Scientific illiteracy and the partisan takeover of biology: PLoS Biology, v. 4, no. 5, p. e167. [Also available at https://doi.org/10.1371/journal.pbio.0040167.]

Hagemeier-Klose, M., and Wagner, K., 2009, Evaluation of flood hazard maps in print and web mapping services as information tools in flood risk communication: Natural Hazards and Earth System Sciences, v. 9, no. 2, p. 563–574. [Also available at https://doi.org/10.5194/nhess-9-563-2009.]

Halpern-Felsher, B.L., Millstein, S.G., Ellen, J.M., Adler, N.E., Tschann, J.M., and Biehl, M., 2001, The role of behavioral experience in judging risks: Health Psychology, v. 20, no. 2, p. 120–126, accessed May 2018 at https://doi.org/10.1037/0278-6133.20.2.120.

Ham, S.H., 2013, Interpretation—Making a difference on purpose: Golden, Colo., Fulcrum Publishing, 320 p.

Hansen, J., Marx, S., and Weber, E., 2004, The role of climate perceptions, expectations, and forecasts in farmer decision making—The Argentine Pampas and South Florida: Palisades, N.Y., International Research Institute for Climate Prediction Technical Report No. 4–1, 142 p. [Also available at https://iri.columbia.edu/~jhansen/RoleOfClimatePerceptions.pdf.]

Hassol, S.J., 2008, Improving how scientists communicate about climate change: Eos, v. 89, no. 11, p. 106–107. [Also available at https://doi.org/10.1029/2008EO110002.]

Hawley, S.T., Zikmund-Fisher, B., Ubel, P., Jancovic, A., Lucas, T., and Fagerlin, A., 2008, The impact of the format of graphical presentation on health-related knowledge and treatment choices: Patient Education and Counseling, v. 73, no. 3, p. 448–455, accessed May 2018 at https://doi.org/10.1016/j.pec.2008.07.023.

Haynes, K., Barclay, J., and Pidgeon, N., 2007, Volcanic hazard communication using maps—An evaluation of their effectiveness: Bulletin of Volcanology, v. 70, no. 2, p. 123–138, accessed May 2018 at https://doi.org/10.1007/s00445-007-0124-7.

Henrich, L., McClure, J., and Crozier, M., 2015, Effects of risk framing on earthquake risk perception—Life-time frequencies enhance recognition of the risk: International Journal of Disaster Risk Reduction, v. 13, p. 145–150, accessed May 2018 at https://doi.org/10.1016/j.ijdrr.2015.05.003.

Higgins, E.T., 1997, Beyond pleasure and pain: American Psychologist, v. 52, no. 12, p. 1280–1300. [Also available at https://doi.org/10.1037/0003-066X.52.12.1280.]

Higgins, P., 2017, We are SVP, and we are each an #ActualLivingScientist: Society of Vertebrate Paleontology blog, accessed November 5, 2017, at http://vertpaleo.org/Society-News/Blog/Old-Bones-SVP-s-Blog/February-2017/We-are-SVP,-and-we-are-each-an-ActualLivingScient.aspx.

Hmielowski, J.D., Feldman, L., Myers, T.A., Leiserowitz, A., and Maibach, E., 2014, An attack on science? Media use, trust in scientists, and perceptions of global warming: Public Understanding of Science (Bristol, England), v. 23, no. 7, p. 866–883. [Also available at https://doi.org/10.1177/0963662513480091.]

Holmes, R.R., Jr., Jones, L.M., Eidenshink, J.C., Godt, J.W., Kirby, S.H., Love, J.J., Neal, C.A., Plant, N.G., Plunkett, M.L., Weaver, C.S., Wein, A., and Perry, S.C., 2012, U.S. Geological Survey natural hazards science strategy—Promoting the safety, security, and economic well-being of the Nation: U.S. Geological Survey Circular 1383–F, 79 p.

Hornik, J., Ofir, C., and Rachamim, M., 2016, Quantitative evaluation of persuasive appeals using comparative meta-analysis: Communication Review, v. 19, no. 3, p. 192–222, accessed May 2018 at https://doi.org/10.1080/10714421.2016.1195204.

Huang, S.-K., Lindell, M.K., and Prater, C.S., 2016, Who leaves and who stays? A review and statistical meta-analysis of hurricane evacuation studies: Environment and Behavior, v. 48, no. 8, p. 991–1029, accessed May 2018 at https://doi.org/10.1177/0013916515578485.

Hut, R., Land-Zandstra, A.M., Smeets, I., and Stoof, C.R., 2016, Geoscience on television—A review of science communication literature in the context of geosciences: Hydrology and Earth System Sciences, v. 20, no. 6, p. 2507–2518, accessed May 2018 at https://doi.org/10.5194/hess-20-2507-2016.

Ickert, J., and Stewart, I.S., 2016, Earthquake risk communication as dialogue—Insights from a workshop in Istanbul's urban renewal neighbourhoods: Natural Hazards and Earth System Sciences, v. 16, no. 5, p. 1157–1173, accessed May 2018 at https://doi.org/10.5194/nhess-16-1157-2016.

Johnson-Laird, P.N., 1983, Mental models—Towards a cognitive science of language, inference, and consciousness: Cambridge, Mass., Harvard University Press, 513 p.

Johnson-Laird, P.N., 2010, Mental models and human reasoning: Proceedings of the National Academy of Sciences of the United States of America, v. 107, no. 43, p. 18243–18250, accessed May 2018 at https://doi.org/10.1073/pnas.1012933107.

Joslyn, S., Savelli, S., and Nadav-Greenberg, L., 2011, Reducing probabilistic weather forecasts to the worst-case scenario—Anchoring effects: Journal of Experimental Psychology—Applied, v. 17, no. 4, p. 342–353. [Also available at https://doi.org/10.1037/a0025901.]

Kahneman, D., 2011, Thinking, fast and slow: New York, Farrar, Strauss, and Giroux, 499 p.

Kahneman, D., and Tversky, A., 1979, Prospect theory—An analysis of decision under risk: Econometrica, v. 47, no. 2, p. 263–291. [Also available at https://doi.org/10.2307/1914185.]

Kasperson, R.E., Renn, O., Slovic, P., Brown, H.S., Emel, J., Goble, R., Kasperson, J.X., and Ratick, S., 1988, The social amplification of risk—A conceptual framework: Risk Analysis, v. 8, no. 2, p. 177–187, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.1988.tb01168.x.

Kates, R.W., 1962, Probability and hazard evaluation, chap. 4 of Hazard and choice perception in flood plain management: University of Chicago, Department of Geography, Research Paper No. 78, p. 45–103, accessed May 2018 at http://rwkates.org/pdfs/b1962.01_CH4.pdf.

Keller, C., Siegrist, M., and Gutscher, H., 2006, The role of the affect and availability heuristics in risk communication: Risk Analysis, v. 26, no. 3, p. 631–639, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2006.00773.x.

Kohring, M., 2016, Misunderstanding trust in science—A critique of the traditional discourse on science communication: Journal of Science Communication, v. 15, no. 5, p. 1–4.

Kontos, E.Z., Bennett, G.G., and Viswanath, K., 2007, Barriers and facilitators to home computer and internet use among urban novice computer users of low socioeconomic position: Journal of Medical Internet Research, v. 9, no. 4, p. e31, accessed May 2018 at https://doi.org/10.2196/jmir.9.4.e31.

Krauss, R.M., and Fussell, S.R., 1991, Perspective-taking in communication—Representations of others' knowledge in reference: Social Cognition, v. 9, no. 1, p. 2–24. [Also available at https://doi.org/10.1521/soco.1991.9.1.2.]

Kunz, M., and Hurni, L., 2011, How to enhance cartographic visualisations of natural hazards assessment results: The Cartographic Journal, v. 48, no. 1, p. 60–71, accessed May 2018 at https://doi.org/10.1179/1743277411Y.0000000001.

Lachlan, K., and Spence, P.R., 2010, Communicating risks—Examining hazard and outrage in multiple contexts: Risk Analysis, v. 30, no. 12, p. 1872–1886, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2010.01511.x.

Laughlin, L., 2011, Who's minding the kids? Child care arrangements—Spring 2011 (Current population reports): Washington, DC, U.S. Census Bureau, p. 70–135, accessed May 2018 at https://www.census.gov/prod/2013pubs/p70-135.pdf.

Lee, K.L., Meyer, R.J., and Bradlow, E.T., 2009, Analyzing risk response dynamics on the web—The case of Hurricane Katrina: Risk Analysis, v. 29, no. 12, p. 1779–1792, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2009.01304.x.

Leiserowitz, A., 2006, Climate change risk perception and policy preferences—The role of affect, imagery, and values: Climatic Change, v. 77, no. 1–2, p. 45–72, accessed May 2018 at https://doi.org/10.1007/s10584-006-9059-9.

Leiserowitz, A.A., 2004, Before and after the day after tomorrow—A U.S. study of climate change risk perception: Environment, v. 46, no. 9, p. 22–39. [Also available at https://doi.org/10.1080/00139150409603663.]

Levin, I.P., Schneider, S.L., and Gaeth, G.J., 1998, All frames are not created equal—A typology and critical analysis of framing effects: Organizational Behavior and Human Decision Processes, v. 76, no. 2, p. 149–188. [Also available at https://doi.org/10.1006/obhd.1998.2804.]

Lindell, M.K., Huang, S.-K., Wei, H.-L., and Samuelson, C.D., 2016, Perceptions and expected immediate reactions to tornado warning polygons: Natural Hazards, v. 80, no. 1, p. 683–707, accessed May 2018 at https://doi.org/10.1007/s11069-015-1990-5.

Lindell, M.K., and Prater, C.S., 2010, Tsunami preparedness on the Oregon and Washington coast—Recommendations for research: Natural Hazards Review, v. 11, no. 2, p. 69–81. [Also available at https://doi.org/10.1061/(ASCE)1527-6988(2010)11:2(69).]

Lindell, M.K., and Whitney, D.J., 2000, Correlates of household seismic hazard adjustment adoption: Risk Analysis, v. 20, no. 1, p. 13–26, accessed May 2018 at https://doi.org/10.1111/0272-4332.00002.

Lindsay, B.R., 2011, Social media and disasters—Current uses, future options, and policy considerations: Washington, D.C., Congressional Research Service. [Also available at https://www.nisconsortium.org/portal/resources/bin/Social_Media_and_Dis_1423591240.pdf.]

Linville, P.W., and Fischer, G.W.,1991, Preferences for separating or combining events: Journal of Personality and Social Psychology, v. 60, no. 1, p. 5, accessed May 2018 at http://dx.doi.org.ezproxy.cul.columbia.edu/10.1037/0022-3514.60.1.5.

Lipkus, I.M., Samsa, G., and Rimer, B.K., 2001, General performance on a numeracy scale among highly educated samples: Medical Decision Making, v. 21, no. 1, p. 37–44, accessed May 2018 at https://doi.org/10.1177/0272989X0102100105.

Liu, B., Wood, M., Egnoto, M., Bean, H., Sutton, J., Mileti, D., and Madden, S., 2017, Is a picture worth a thousand words? The effects of maps and warning messages on how publics respond to disaster information: Public Relations Review, v. 43, no. 3, p. 493–506. [Also available at https://doi.org/10.1016/j.pubrev.2017.04.004.]

Liverman, D., 2008, Environmental geoscience; communication challenges: Geological Society, Special Publication, v. 305, p. 197–209.

Liverman, D., and Jaramillo, M., 2011, Communicating environmental geoscience—An international survey: Episodes, v. 34, no. 1, p. 25–31.

Loewenstein, G.F., Weber, E.U., Hsee, C.K., and Welch, N., 2001, Risk as feelings: Psychological Bulletin, v. 127, no. 2, p. 267–286, accessed May 2018 at https://doi.org/10.1037/0033-2909.127.2.267.

Lopes, R., 1992, Public perception of disaster preparedness presentations using disaster damage images: American Red Cross National Headquarters Disaster Services, accessed May 2018 at https://hazdoc.colorado.edu/bitstream/handle/10590/1895/NHC-A-WP-1992-79.pdf.

Love, J., 2016, Weathering a perfect storm from space: Earth Magazine, p. 8–9.

Ludy, J., and Kondolf, G.M., 2012, Flood risk perception in lands “protected” by 100-year levees: Natural Hazards, v. 61, no. 2, p. 829–842, accessed May 2018 at https://doi.org/10.1007/s11069-011-0072-6.

Lundgren, R.E., and McMakin, A.H., 2013, Risk communication—A handbook for communicating environmental, safety, and health risks (5th ed.): Hoboken, N.J., John Wiley and Sons. [Also available at https://doi.org/10.1002/9781118645734.]

Lupia, A., 2013, Communicating science in politicized environments: Proceedings of the National Academy of Sciences of the United States of America, v. 110, suppl. 3, p. 14048–14054, accessed May 2018 at https://doi.org/10.1073/pnas.1212726110.

MacInnis, B., Howe, L., Krosnick, J.A., Markowitz, E., and Socolow, R., 2014, The impact of acknowledging bounded and unbounded uncertainty on persuasion—The case of scientific uncertainty and global warming: 56 p., accessed July 2016, at http://fiesta.bren.ucsb.edu/~sanderson/Krosnick%20Adaptation%20Uncertainty.pdf.

Mani, L., Cole, P.D., and Stewart, I., 2016, Using video games for volcanic hazard education and communication—An assessment of the method and preliminary results: Natural Hazards and Earth System Sciences, v. 16, no. 7, p. 1673–1689, accessed May 2018 at https://doi.org/10.5194/nhess-16-1673-2016.

Martens, T., Garrelts, H., Grunenberg, H., and Lange, H., 2009, Taking the heterogeneity of citizens into account—Flood risk communication in coastal cities—A case study of Bremen: Natural Hazards and Earth System Sciences, v. 9, no. 6, p. 1931–1940. [Also available at https://doi.org/10.5194/nhess-9-1931-2009.]

Martin, I.M., Bender, H., and Raish, C., 2007, What motivates individuals to protect themselves from risks—The case of wildland fires. Risk Analysis, v. 27, no. 4, p. 887–900, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2007.00930.x.

Martin, W.E., Martin, I.M., and Kent, B., 2009, The role of risk perceptions in the risk mitigation process—The case of wildfire in high risk communities: Journal of Environmental Management, v. 91, no. 2, p. 489–498, accessed at https://doi.org/10.1016/j.jenvman.2009.09.007.

Maslow, A.H., 1943, A theory of human motivation: Psychological Review, v. 50, no. 4, p. 370–396. [Also available at https://doi.org/10.1037/h0054346.]

McClure, J., White, J., and Sibley, C.G., 2009, Framing effects on preparation intentions—Distinguishing actions and outcomes: Disaster Prevention and Management, v. 18, no. 2, p. 187–199, accessed May 2018 at https://doi.org/10.1108/09653560910953252.

McIvor, D., Paton, D., and Johnston, D., 2009, Modelling community preparation for natural hazards—Understanding hazard cognitions: Journal of Pacific Rim Psychology, v. 3, no. 2, p. 39–46, accessed May 2018 at https://doi.org/10.1375/prp.3.2.39.

Merson, M., 2017, Four principles to guide interactions—Assisting communities confronting environmental contamination: Science Communication, v. 39, no. 1, p. 125–136. [Also available at https://doi.org/10.1177/1075547016688685.]

Meyer, R., Broad, K., Orlove, B., and Petrovic, N., 2013, Dynamic simulation as an approach to understanding hurricane risk response—Insights from the Stormview lab: Risk Analysis, v. 33, no. 8, p. 1532–1552, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2012.01935.x.

Meyer, R.J., Baker, J., Broad, K., Czajkowski, J., and Orlove, B., 2014, The dynamics of hurricane risk perception—Real-time evidence from the 2012 Atlantic hurricane season: Bulletin of the American Meteorological Society, v. 95, no. 9, p. 1389–1404. [Also available at https://doi.org/10.1175/BAMS-D-12-00218.1.]

Mileti, D.S., 1999, Disasters by design—A reassessment of natural hazards in the United States: Washington, DC, Joseph Henry Press, 371 p.

Mileti, D.S., and Darlington, J.D., 1997, The role of searching in shaping reactions to earthquake risk information: Social Problems, v. 44, no. 1, p. 89–103. [Also available at https://doi.org/10.2307/3096875.]

Mileti, D.S., and Fitzpatrick, C., 1992, The causal sequence of risk communication in the Parkfield earthquake prediction experiment: Risk Analysis, v. 12, no. 3, p. 393–400, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.1992.tb00691.x.

Mileti, D.S., and O'Brien, P.W., 1992, Warnings during disaster—Normalizing communicated risk: Social Problems, v. 39, no. 1, p. 40–57. [Also available at https://doi.org/10.2307/3096912.]

Mileti, D.S., and Peek, L., 2000, The social psychology of public response to warnings of a nuclear power plant accident: Journal of Hazardous Materials, v. 75, no. 2–3, p. 181–194. [Also available at https://doi.org/10.1016/S0304-3894(00)00179-5.]

Mileti, D.S., and Sorensen, J.H., 1990, Communication of emergency public warnings—A social science perspective and state-of-the-art assessment: U.S. Department of Energy Office of Science and Technical Information. [Also available at https://doi.org/10.2172/6137387.]

Monmonier, M., 1995, Drawing the line—Tales of maps and cartocontroversy: New York, Henry Holt and Co., 368 p.

Montz, B.E., and Tobin, G.A., 2008, Livin' large with levees—Lessons learned and lost: Natural Hazards Review, v. 9, no. 3, p. 150–157, accessed May 2018 at https://doi.org/10.1061/(ASCE)1527-6988(2008)9:3(150).

Moore, D.W., 2005, At least 100,000 Katrina victims still separated from families: The Gallup Organization, accessed May 2018 at http://www.gallup.com/poll/19225/Least-100000-Katrina-Victims-Still-Separated-From-Families.aspx.

Morewedge, C.K., Gilbert, D.T., and Wilson, T.D., 2005, The least likely of times—How remembering the past biases forecasts of the future: Psychological Science, v. 16, no. 8, p. 626–630. [Also available at https://doi.org/10.1111/j.1467-9280.2005.01585.x.]

Morrow, B., and Gladwin, H., 2005, Hurricane Ivan behavioral analysis: Prepared for the Federal Emergency Management Agency and the U.S. Army Corps of Engineers, Wilmington and Mobile Districts, 66 p.

Morss, R.E., Demuth, J.L., Bostrom, A., Lazo, J.K., and Lazrus, H., 2015, Flash flood risks and warning decisions—A mental models study of forecasters, public officials, and media broadcasters in Boulder, Colorado: Risk Analysis, v. 35, no. 11, p. 2009–2028, accessed May 2018 at https://doi.org/10.1111/risa.12403.

Nakayachi, K., and Nagaya, K., 2016, The effects of the passage of time from the 2011 Tohoku Earthquake on the public's anxiety about a variety of hazards: International Journal of Environmental Research and Public Health, v. 13, no. 9, p. 866–878, accessed May 2018 at https://doi.org/10.3390/ijerph13090866.

Napolitano, G.F., 2011, The language of science and communication with Congress: Eos, v. 92, no. 47, p. 424–424, accessed May 2018 at https://doi.org/10.1029/2011EO470005.

Nicholls, N., 2001, Atmospheric and climatic hazards—Improved monitoring and prediction for disaster mitigation: Natural Hazards, v. 23, no. 2–3, p. 137–155. [Also available at https://doi.org/10.1023/A:1011130223164.]

Nickerson, R.A., 1999, How we know—and sometimes misjudge—what others know—Imputing one's own knowledge to others: Psychological Bulletin, v. 125, no. 6, p. 737–759. [Also available at https://doi.org/10.1037/0033-2909.125.6.737.]

Nickerson, R.S., 1998, Confirmation bias—A ubiquitous phenomenon in many guises: Review of General Psychology, v. 2, no. 2, p. 175–220. [Also available at https://doi.org/10.1037/1089-2680.2.2.175.]

Nomura, S., Parsons, A.J.Q., Hirabayashi, M., Kinoshita, R., Liao, Y., and Hodgson, S., 2016, Social determinants of mid- to long-term disaster impacts on health—A systematic review: International Journal of Disaster Risk Reduction, v. 16, p. 53–67, accessed May 2018 at https://doi.org/10.1016/j.ijdrr.2016.01.013.

Noriega, G.R., and Ludwig, L.G., 2012, Social vulnerability assessment for mitigation of local earthquake risk in Los Angeles County: Natural Hazards, v. 64, no. 2, p. 1341–1355, accessed May 2018 at https://doi.org/10.1007/s11069-012-0301-7.

Paton, D., Smith, L., Daly, M., and Johnston, D., 2008, Risk perception and volcanic hazard mitigation—Individual and social perspectives: Journal of Volcanology and Geothermal Research, v. 172, no. 3–4, p. 179–188, accessed May 2018 at https://doi.org/10.1016/j.jvolgeores.2007.12.026.

Patt, A.G., and Schrag, D.P., 2003, Using specific language to describe risk and probability: Climatic Change, v. 61, no. 1–2, p. 17–30. [Also available at https://doi.org/10.1023/A:1026314523443.]

Patt, A., Suarez, P., and Gwata, C., 2005, Effects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe: Proceedings of the National Academy of Sciences of the United States of America, v. 102, no. 35, p. 12623–12628. [Also available at https://doi.org/10.1073/pnas.0506125102.]

Paveglio, T., Carroll, M.S., Absher, J.D., and Norton, T., 2009, Just blowing smoke? Residents' social construction of communication about wildfire: Environmental Communication, v. 3, no. 1, p. 76–94, accessed May 2018 at https://doi.org/10.1080/17524030802704971.

Perry, R.W., and Nelson, L., 1991, Ethnicity and hazard information dissemination: Environmental Management, v. 15, no. 4, p. 581–587. [Also available at https://doi.org/10.1007/BF02394747.]

Perry, S.C., Blanpied, M.L., Burkett, E.R., Campbell, N.M., Carlson, A., Cox, D.A., Driedger, C.L., Eisenman, D.P., Fox-Glassman, K.T., Hoffman, S., Hoffman, S.M., Jaiswal, K.S., Jones, L.M., Luco, N., Marx, S.M., McGowan, S.M., Mileti, D.S., Moschetti, M.P., Ozman, D., Pastor, E., Petersen, M.D., Porter, K.A., Ramsey, D.W., Ritchie, L.A., Fitzpatrick, J.K., Rukstales, K.S., Sellnow, T.S., Vaughon, W.L., Wald, D.J., Wald, L.A., Wein, A., and Zarcadoolas, C., 2016, Get your science used—Six guidelines to improve your products: U.S. Geological Survey Circular 1419, 37 p. [Also available at http://dx.doi.org/10.3133/cir1419.]

Perry, S.C., and Bruce, J.L., 2017, The HayWired Scenario—An urban earthquake in a connected world: U.S. Geological Survey geo-narrative, accessed June 1, 2018, at https://www.usgs.gov/haywiredvol1geonarrative.

Peters, E., Västfjäll, D., Slovic, P., Mertz, C.K., Mazzocco, K., and Dickert, S., 2006, Numeracy and decision making: Psychological Science, v. 17, no. 5, p. 407–413. [Also available at https://doi.org/10.1111/j.1467-9280.2006.01720.x.]

Peters, H.P., 2013, Gap between science and media revisited—Scientists as public communicators: Proceedings of the National Academy of Sciences of the United States of America, v. 110, suppl. 3, p. 14102–14109, accessed May 2018 at https://doi.org/10.1073/pnas.1212745110.

Pew Research Center, 2013, Most expect 'occasional acts of terrorism' in the future: accessed January 2017, at http://www.people-press.org/2013/04/23/most-expect-occasional-acts-of-terrorism-in-the-future/.

Phillips, B.D., and Morrow, B.H., 2007, Social science research needs—Focus on vulnerable populations, forecasting, and warnings: Natural Hazards Review, v. 8, no. 3, p. 61–68, accessed May 2018 at https://doi.org/10.1061/(ASCE)1527-6988(2007)8:3(61).

Pickle, L.W., 2004, Usability testing of map designs: Proceedings of the 2003 Symposium on the Interface of Computing Science and Statistics, v. 35, 42–56.

Pierson, T.C., Wood, N.J., and Driedger, C.L., 2014, Reducing risk from lahar hazards—Concepts, case studies, and roles for scientists: Journal of Applied Volcanology, v. 3, no. 16, p. 1–25, accessed May 2018 at https://doi.org/10.1186/s13617-014-0016-4.

Prater, C.S., and Lindell, M.K., 2010, Tsunami preparedness on the Oregon and Washington coast—Recommendations for research: Natural Hazards Review, v. 11, no. 2, accessed May 2018 at https://doi.org/10.1061/(ASCE)1527-6988(2010)11:2(69).

Preppernau, C.A., and Jenny, B., 2015, Three-dimensional versus conventional volcanic hazard maps: Natural Hazards, v. 78, no. 2, p. 1329–1347, accessed May 2018 at https://doi.org/10.1007/s11069-015-1773-z.

Price, M., Cameron, R., and Butow, P., 2007, Communicating risk information—The influence of graphical display format on quantitative information perception—Accuracy, comprehension and preferences: Patient Education and Counseling, v. 69, no. 1–3, p. 121–128, accessed May 2018 at https://doi.org/10.1016/j.pec.2007.08.006.

Rampey, B.D., Finnegan, R., Goodman, M., Mohadjer, L., Krenzke, T., Hogan, J., and Provasnik, S., 2016, Skills of U.S. unemployed, young, and older adults in sharper focus—Results from the Program for the International Assessment of Adult Competencies (PIAAC) 2012/2014 first look: Washington, DC, U.S. Department of Education, National Center for Education Statistics, 58 p., accessed May 2018 at http://nces.ed.gov/pubs2016/2016039rev.pdf.

Renooij, S., and Witteman, C., 1999, Talking probabilities—Communicating probabilistic information with words and numbers: International Journal of Approximate Reasoning, v. 22, no. 3, p. 169–194. [Also available at https://doi.org/10.1016/S0888-613X(99)00027-4.]

Roncoli, C., 2006, Ethnographic and participatory approaches to research on farmers' responses to climate predictions: Climate Research, v. 33, p. 81–99. [Also available at https://doi.org/10.3354/cr033081.]

Sandman, P.M., Weinstein, N.D., and Miller, P., 1994, High risk or low risk—How location on a "risk ladder" affects perceived risk: Risk Analysis, v. 14, no. 1, p. 35–45. [Also available at https://doi.org/10.1111/j.1539-6924.1994.tb00026.x.]

Sanfey, A., and Hastie, R., 1998, Does evidence presentation format affect judgment?: Psychological Science, v. 9, no. 2, p. 99–103. [Also available at https://doi.org/10.1111/1467-9280.00018.]

Schapira, M.M., Nattinger, A.B., and McHorney, C.A., 2001, Frequency or probability? A qualitative study of risk communication formats used in health care: Medical Decision Making, v. 21, no. 6, p. 459–467. [Also available at https://doi.org/10.1177/0272989X0102100604.]

Scheufele, D.A., 2013, Communicating science in social settings: Proceedings of the National Academy of Sciences of the United States of America, v. 110, suppl. 3, p. 14040–14047, accessed May 2018 at https://doi.org/10.1073/pnas.1213275110.

Science Application for Risk Reduction, 2018, The SAFRR Project, Innovating the Application of Hazard Science: accessed May 2018 at https://www.usgs.gov/natural-hazards/science-application-risk-reduction.

Sellnow, T.L., and Seeger, M., 2001, Exploring the boundaries of crisis communication—The case of the 1997 Red River Valley Flood: Crisis Communication, v. 52, no. 2, p. 153–167.

Sellnow, T.L., Seeger, M.W., and Ulmer, R.R., 2002, Chaos theory, informational needs, and natural disasters: Journal of Applied Communication Research, v. 30, no. 4, p. 269–292. [Also available at https://doi.org/10.1080/00909880216599.]

Sellnow, T., and Sellnow, D., 2010, The instructional dynamic of risk and crisis communication—Distinguishing instructional messages from dialogue: The Review of Communication, v. 10, no. 2, p. 112–126. [Also available at https://doi.org/10.1080/15358590903402200.]

Shah, P., and Hoeffner, J., 2002, Review of graph comprehension research—Implications for instruction: Educational Psychology Review, v. 14, no. 1, p. 47–69. [Also available at https://doi.org/10.1023/A:1013180410169.]

Shao, W., Xian, S., Lin, N., Kunreuther, H., Jackson, N., and Goidel, K., 2017, Understanding the effects of past flood events and perceived and estimated flood risks on individuals' voluntary flood insurance purchase behavior: Water Research, v. 108, p. 391–400, accessed May 2018 at https://doi.org/10.1016/j.watres.2016.11.021.

Sharma, U., and Patt, A., 2012, Disaster warning response—The effects of different types of personal experience: Natural Hazards, v. 60, no. 2, p. 409–423, accessed May 2018 at https://doi.org/10.1007/s11069-011-0023-2.

Siegrist, M., 1997, Communicating low risk magnitudes—Incidence rates expressed as frequency versus rates expressed as probability: Risk Analysis, v. 17, no. 4, p. 507–510, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.1997.tb00891.x.

Siegrist, M., and Gutscher, H., 2008, Natural hazards and motivation for mitigation behavior—People cannot predict the affect evoked by a severe flood: Risk Analysis, v. 28, no. 3, p. 771–778, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2008.01049.x.

Sims, J.H., and Baumann, D.D., 1983, Educational programs and human response to natural hazards: Environment and Behavior, v. 15, no. 2, p. 165–189. [Also available at https://doi.org/10.1177/0013916583152003.]

Slovic, P., 1987, Perception of risk: Science, v. 236, no. 4799, p. 280–285. [Also available at https://doi.org/10.1126/science.3563507.]

Slovic, P., 1993, Perceived risk, trust, and democracy: Risk Analysis, v. 13, no. 6, p. 675–682. [Also available at https://doi.org/10.1111/j.1539-6924.1993.tb01329.x.]

Slovic, P., 2000, The perception of risk: London, Earthscan, 511 p.

Slovic, P., 2010, The feeling of risk—New perspectives on risk perception: New York, Routledge, 456 p.

Slovic, P., Finucane, M.L., Peters, E., and MacGregor, D.G., 2004, Risk as analysis and risk as feelings—Some thoughts about affect, reason, risk, and rationality: Risk Analysis, v. 24, no. 2, p. 311–322, accessed May 2018 at https://doi.org/10.1111/j.0272-4332.2004.00433.x.

Slovic, P., Fischhoff, B., and Lichtenstein, S., 1978, Accident probabilities and seat belt usage—A psychological perspective: Accident Analysis and Prevention, v. 10, no. 4, p. 281–285. [Also available at https://doi.org/10.1016/0001-4575(78)90030-1.]

Slovic, P., Fischhoff, B., Lichtenstein, S., Corrigan, B., and Combs, B., 1977, Preference for insuring against probable small losses—Insurance implications: The Journal of Risk and Insurance, v. 44, no. 2, p. 237–258. [Also available at https://doi.org/10.2307/252136.]

Slovic, P., Monahan, J., and MacGregor, D.G., 2000, Violence risk assessment and risk communication—The effects of using actual cases, providing instruction, and employing probability versus frequency formats: Law and Human Behavior, v. 24, no. 3, p. 271–296. [Also available at https://doi.org/10.1023/A:1005595519944.]

Smith, S.L., 1963, Color coding and visual separability in information displays: The Journal of Applied Psychology, v. 47, no. 6, p. 358–364. [Also available at https://doi.org/10.1037/h0041203.]

Spence, A., Poortinga, W., Butler, C., and Pidgeon, N.F., 2011, Perceptions of climate change and willingness to save energy related to flood experience: Nature Climate Change, v. 1, no. 1, p. 46–49. [Also available at https://doi.org/10.1038/nclimate1059.]

Stanovich, K.E., and West, R.F., 2000, Individual differences in reasoning—Implications for the rationality debate?: Behavioral and Brain Sciences, v. 23, no. 5, p. 645–665. [Also available at https://doi.org/10.1017/S0140525X00003435.]

Stewart, I.S., and Nield, T., 2013, Earth stories—Context and narrative in the communication of popular geoscience. Proceedings of the Geologists' Association, v. 124, no. 4, p. 699–712, accessed May 2018 at https://doi.org/10.1016/j.pgeola.2012.08.008.

Stone, E.R., Sieck, W.R., Bull, B.E., Frank Yates, J., Parks, S.C., and Rush, C.J., 2003, Foreground:background salience—Explaining the effects of graphical displays on risk avoidance: Organizational Behavior and Human Decision Processes, v. 90, no. 1, p. 19–36, accessed May 2018 at https://doi.org/10.1016/S0749-5978(03)00003-7.

Stone, E.R., Yates, J.F., and Parker, A.M., 1997, Effects of numerical and graphical displays on professed risk-taking behavior: Journal of Experimental Psychology—Applied, v. 3, no. 4, p. 243–256. [Also available at https://doi.org/10.1037/1076-898X.3.4.243.]

Sutton, J., and Woods, C., 2016, Tsunami warning message interpretation and sense making—Focus group insights: Weather, Climate, and Society, v. 8, no. 4, p. 389–398, accessed May 2018 at https://doi.org/10.1175/WCAS-D-15-0067.1.

Sweetser, K.D., and Metzgar, E., 2007, Communicating during crisis—Use of blogs as a relationship management tool: Public Relations Review, v. 33, no. 3, p. 340–342. [Also available at https://doi.org/10.1016/j.pubrev.2007.05.016.]

Taylor, J.G., Gillette, S.C., Hodgson, R.W., Downing, J.L., Burns, M.R., Chavez, D.J., and Hogan, J.T., 2007, Informing the network—Improving communication with interface communities during wildland fire: Human Ecology Review, v. 14, no. 2, p. 198–211. [Also available at https://www.fs.fed.us/psw/publications/chavez/psw_2007_chavez(taylor)002.pdf.]

Taylor-Clark, K.A., Viswanath, K., and Blendon, R.J., 2010, Communication inequalities during public health disasters—Katrina's wake: Health Communication, v. 25, no. 3, p. 221–229, accessed May 2018 at https://doi.org/10.1080/10410231003698895.

Terpstra, T., 2011, Emotions, trust, and perceived risk—Affective and cognitive routes to flood preparedness behavior: Risk Analysis, v. 31, no. 10, p. 1658–1675, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2011.01616.x.

Thompson, M.A., Lindsay, J.M., and Gaillard, J., 2015, The influence of probabilistic volcanic hazard map properties on hazard communication: Journal of Applied Volcanology, v. 4, no. 1, p. 6, accessed May 2018 at https://doi.org/10.1186/s13617-015-0023-0.

Trainor, J.E., Nagele, D., Philips, B., and Scott, B., 2015, Tornadoes, social science, and the false alarm effect: Weather, Climate, and Society, v. 7, no. 4, p. 333–352, accessed May 2018 at https://doi.org/10.1175/WCAS-D-14-00052.1.

Trope, Y., and Liberman, N., 2010, Construal-level theory of psychological distance: Psychological Review, v. 117, no. 2, p. 440–463, accessed May 2018 at https://doi.org/10.1037/a0018963.

Tversky, A., and Kahneman, D., 1973, Availability—A heuristic for judging frequency and probability: Cognitive Psychology, v. 5, no. 2, p. 207–232. [Also available at https://doi.org/10.1016/0010-0285(73)90033-9.]

Tversky, A., and Kahneman, D., 1981, The framing of decisions and the psychology of choice: Science, v. 211, no. 4481, p. 453–458. [Also available at https://doi.org/10.1126/science.7455683.]

U.S. Geological Survey, 2013, The SAFRR tsunami scenario—Improving resilience for California: U.S. Geological Fact Sheet 2013–3081, 4 p. [Also available at https://pubs.er.usgs.gov/publication/fs20133081.]

U.S. National Library of Medicine, 2016, How to write easy-to-read health materials: MedlinePlus, accessed March 2017, at https://medlineplus.gov/etr.html.

U.S. Office of Personnel Management, 2011, Paperwork Reduction Act (PRA) guide—Version 2.0: 44 p., accessed May 2018 at https://www.opm.gov/about-us/open-government/digital-government-strategy/fitara/paperwork-reduction-act-guide.pdf.

Vaughan, E., 1995, The significance of socioeconomic and ethnic diversity for the risk communication process: Risk Analysis, v. 15, no. 2, p. 169–180. [Also available at https://doi.org/10.1111/j.1539-6924.1995.tb00311.x.]

Vaughan, E., and Seifert, M., 1992, Variability in the framing of risk issues: Journal of Social Issues, v. 48, no. 4, p. 119–135. [Also available at https://doi.org/10.1111/j.1540-4560.1992.tb01948.x.]

Vaughan, E., and Tinker, T., 2009, Effective health risk communication about pandemic influenza for vulnerable populations: American Journal of Public Health, v. 99, no. S2, p. S324–S332. [Also available at https://doi.org/10.2105/AJPH.2009.162537.]

Verrucci, E., Perez-Fuentes, G., Rossetto, T., Bisby, L., Haklay, M., Rush, D., Rickles, P., Fagg, G., and Joffe, H., 2016, Digital engagement methods for earthquake and fire preparedness—A review: Natural Hazards, v. 83, no. 3, p. 1583–1604, accessed May 2018 at https://doi.org/10.1007/s11069-016-2378-x.

Viglione, A., Di Baldassarre, G., Brandimarte, L., Kuil, L., Carr, G., Salinas, J.L., Scolobig, A., and Blöschl, G., 2014, Insights from socio-hydrology modelling on dealing with flood risk—Roles of collective memory, risk-taking attitude and trust: Journal of Hydrology, v. 518, part A, p. 71–82. [Also available at https://doi.org/10.1016/j.jhydrol.2014.01.018.]

Visschers, V.H.M., Meertens, R.M., Passchier, W.W.F., and De Vries, N.N.K., 2009, Probability information in risk communication—A review of the research literature: Risk Analysis, v. 29, no. 2, p. 267–287, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2008.01137.x.

Visschers, V.H., and Siegrist, M., 2008, Exploring the triangular relationship between trust, affect, and risk perception—A review of the literature: Risk Management, v. 10, no. 3, p. 156–167, accessed May 2018 at https://doi.org/10.1057/rm.2008.1.

Wachinger, G., Renn, O., Begg, C., and Kuhlicke, C., 2013, The risk perception paradox—Implications for governance and communication of natural hazards. Risk Analysis, v. 33, no. 6, p. 1049–1065, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2012.01942.x.

Wagner, K., 2007, Mental models of flash floods and landslides: Risk Analysis, v. 27, no. 3, p. 671–682, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2007.00916.x.

Waters, R.D., and Williams, J.M., 2011, Squawking, tweeting, cooing, and hooting—Analyzing the communication patterns of government agencies on Twitter: Journal of Public Affairs, v. 11, no. 4, p. 353–363. [Also available at https://doi.org/10.1002/pa.385.]

Weber, E.U., 2006, Experience-based and description-based perceptions of long-term risk—Why global warming does not scare us (yet): Climatic Change, v. 77, no. 1–2, p. 103–120. [Also available at https://doi.org/10.1007/s10584-006-9060-3.]

Weinstein, N.D., 1989, Effects of personal experience on self-protective behavior: Psychological Bulletin, v. 105, no. 1, p. 31–50. [Also available at https://doi.org/10.1037/0033-2909.105.1.31.]

Whitney, D.J., Lindell, M.K., and Nguyen, H.-H.D., 2004, Earthquake beliefs and adoption of seismic hazard adjustments: Risk Analysis, v. 24, no. 1, p. 87–102, accessed May 2018 at https://doi.org/10.1111/j.0272-4332.2004.00414.x.

Wood, M.M., Mileti, D.S., Kano, M., Kelley, M.M., Regan, R., and Bourque, L.B., 2012, Communicating actionable risk for terrorism and other hazards: Risk Analysis, v. 32, no. 4, p. 601–615. [Also available at https://doi.org/10.1111/j.1539-6924.2011.01645.x.]

Xie, X.-F., Wang, M., Zhang, R.-G., Li, J., and Yu, Q.-Y., 2011, The role of emotions in risk communication: Risk Analysis, v. 31, no. 3, p. 450–465, accessed May 2018 at https://doi.org/10.1111/j.1539-6924.2010.01530.x.

Yamagishi, K., 1997, When a 12.86% mortality is more dangerous than 24.14%—Implications for risk communication: Applied Cognitive Psychology, v. 11, no. 6, p. 495–506. [Also available at https://doi.org/10.1002/(SICI)1099-0720(199712)11:6<495::AID-ACP481>3.0.CO;2-J.]

Yechiam, E., Rakow, T., and Newell, B.R., 2015, Super-underweighting of rare events with repeated descriptive summaries: Journal of Behavioral Decision Making, v. 28, no. 1, p. 67–75, accessed May 2018 at https://doi.org/10.1002/bdm.1829.

Zabrucky, K.M., and Moore, D., 1999, Influence of text genre on adults' monitoring of understanding and recall: Educational Gerontology, v. 25, no. 8, p. 691–710, accessed May 2018 at https://doi.org/10.1080/036012799267440.

Zarcadoolas, C., and Vaughon, W., 2016a, Introduction to user-centered design: How to Health Literacy video, 00:16:13, posted October 26, 2016, accessed May 2018 at https://youtu.be/44tkqSh-f9M.

Zarcadoolas, C., and Vaughon, W., 2016b, NSHM product usability testing—Public map and web content: New York, How to Health Literacy, LLC, 37 p. [Also available at https://www2.usgs.gov/natural_hazards/safrr/projects/images/NSHMUsability_H2HL_Jan2016.pdf.]

Zarcadoolas, C., and Vaughon, W., 2016c, Task analysis as a part of user-centered design: How to Health Literacy video, 00:13:28, posted October 26, 2016, accessed May 2018 at https://youtu.be/TMDp-lVwt38.

Zhu, D., Xie, X., and Gan, Y., 2011, Information source and valence—How information credibility influences earthquake risk perception: Journal of Environmental Psychology, v. 31, no. 2, p. 129–136, accessed May 2018 at https://doi.org/10.1016/j.jenvp.2010.09.005.

Appendix 1. Interview Questions and Online Questionnaire

At the start of this project, to understand the scope of information U.S. Geological Survey (USGS) hazard scientists communicate and the range of audiences they aim to reach, co-author Milch conducted interviews with 10 current USGS hazard scientists, 1 emeritus USGS hazard scientist, and 2 staff members of the Office of Communication and Publication (OCAP). The hazard scientists were chosen to span backgrounds in floods and coastal hazards, earthquakes, volcanoes, geomagnetic hazards, landslides, environmental health, and tsunamis. These interviews included discussions of the kinds of audiences with whom the scientists communicate, the kinds of information they convey, success stories, and obstacles to better communication. All interviewees recommended topics that would be important to include in a hazards communication guide.

Based on these initial interviews, we created an online questionnaire and invited participation from all USGS personnel with an interest in hazard communication. Fifty people completed the online questionnaire, including scientists, managers, and a cartographer. The interviewees first saw a list of topics that emerged from the interviews and selected all that they thought would be important to include in a hazards communication guide. The topics were as follows:

- Uncertainty (how people interpret uncertainty; importance of explaining the cause of uncertainty)
- Visual displays of information (how people read/interpret maps and other graphics)
- Audience (choosing, identifying, and understanding an audience)
- Risk perception and risk tolerance (individual differences in how people judge risk and their comfort with different levels of risk)
- Language (avoiding jargon; conflicting meaning of words like “risk,” “hazard,” “probable,” and “possible”)
- Framing (for example, discussing damage in terms of economic versus physical impacts; chance of “X” happening versus chance of “X” not happening)
- Personalization (relating scientific information to the audience’s lives; using analogies and the familiar)
- Timeframes (for example, long term versus short term)
- Cultural sensitivity (for example, how to simplify without talking down; understanding a group’s values and knowledge base)
- Situational context (for example, crisis versus noncrisis communication)
- Role of emotion (for example, vivid versus alarming versus memorable versus motivating)

Below are the numbers of respondents (out of 50) who selected each topic as being important (fig. 1.1). They could select as many as they liked.

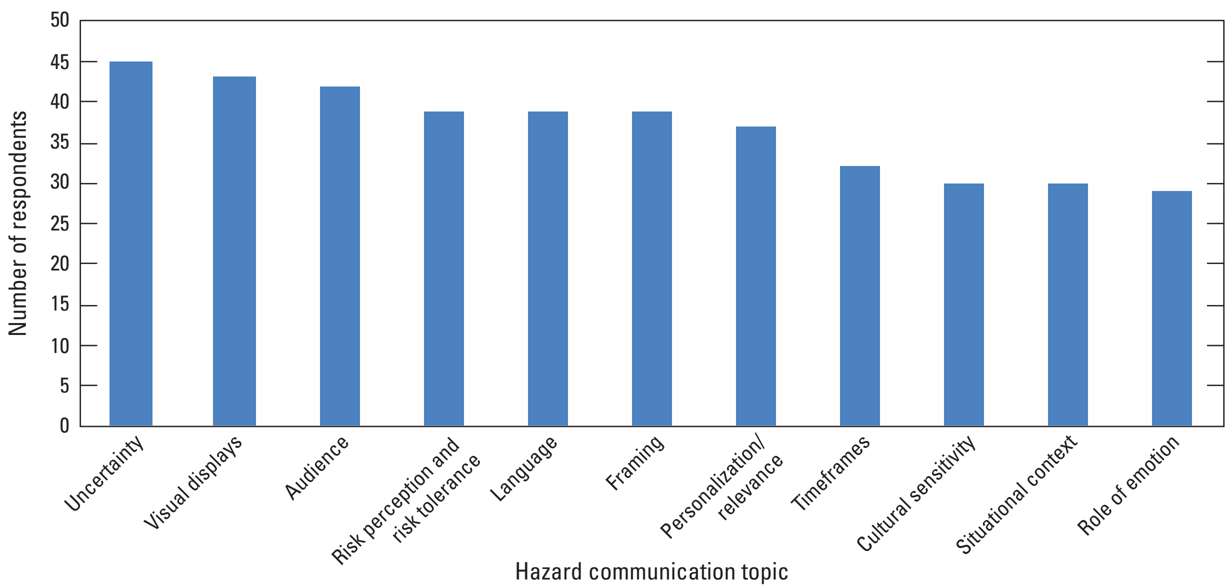

Figure 1.1. Degree of importance of hazard communication topics for inclusion in this report, according to 50 U.S. Geological Survey personnel with an interest in hazard communication.

Next, respondents selected the three topics they thought were most important. The most commonly selected responses were visual displays (52 percent), audience (48 percent), and uncertainty (42 percent). All of the above topics are included in this report, although not all as discrete topics.

The next part of the questionnaire focused on target audiences. An initial list of possible audiences again came from Milch's initial interviews. Shown the list, questionnaire respondents selected all the audiences with whom they communicate. Below are the number of respondents that selected each option (fig. 1.2). Again, respondents could select as many as they wanted. (One respondent skipped this question, so responses are out of 49 total).

Several additional audiences were mentioned in an open-ended comment section: narrowly focused citizen groups (such as Chamber of Commerce, Retired Physicists, first responders); international scientists; international businesses; relatives; Native American tribes; and the military.

Finally, questionnaire respondents selected the three audiences they thought would be most important to include in the guide. They selected general public (74 percent), media (66 percent), and emergency management (50 percent). The report does mention all three, as well as others, but focuses more generally on non-technical audiences.

At the USGS, the role of OCAP includes media communication, so the report defers to OCAP for these resources.

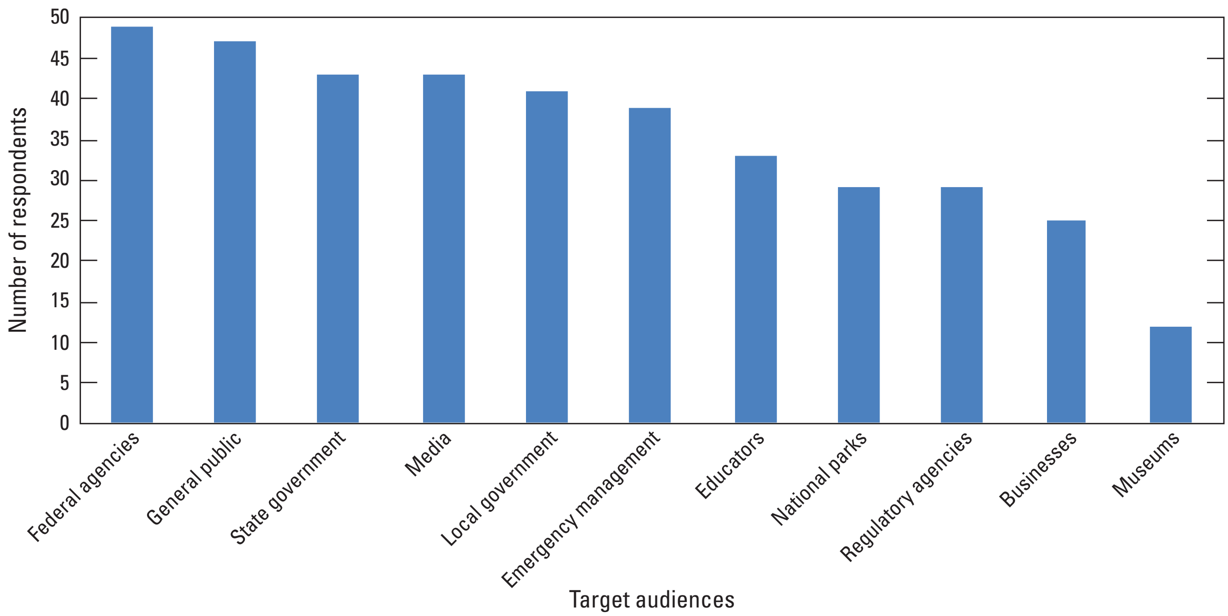

Figure 1.2. Types of target audiences for hazard communication, based on responses from 50 U.S. Geological Survey personnel with an interest in hazard communication.

Appendix 2. Authors' Experience

Kerry Milch

Kerry Milch is currently Assistant Director for Undergraduate Enrichment at Temple University. During the development of this report, she was a social psychologist at the Center for Research on Environmental Decisions, part of the Earth Institute at Columbia University. Prior to earning her Ph.D., she taught English at a junior-senior high school in Tokyo and worked as an Asia Studies research associate at the Council on Foreign Relations in New York. She has long been interested in the different ways individuals and groups make sense of their world and approach decisions. She enjoys collaborating with scholars in other fields, like economics and anthropology, through the Center for Research on Environmental Decisions (CRED) to study topics such as group decision making, how people think about their future well-being, and why people fail to adequately prepare for natural disasters. She was a contributor to CRED's original climate change communication guide.

Sue Perry

Sue Perry, now retired, was a disaster scientist with the Science Application for Risk Reduction project in the Hazards mission area. Her official job title was "staff scientist" but she changed it to add meaning for people outside the U.S. Geological Survey. She became an earthquake geophysicist as a midlife career change. Before that, she was a published novelist and low-budget television producer. She first became interested in risk communication when big earthquakes hit southern California over the course of several years; the media regularly interviewed scientists about the earthquakes but only rarely could anyone understand them. Her frustration and confusion drove her to focus on improving the understanding and use of scientific information.

Sue has also served as a consultant to local governments, led the intern programs at the Southern California Earthquake Center, and taught a natural hazards class for non-science students at Pasadena City College.

Jen Bruce

Jen Bruce is a cartographer and communications specialist for the U.S. Geological Survey Water Resources Mission Area. She spent much of her early life trying to choose between her scientific and artistic interests, and is very happy to have found a career where she can embrace both of them. She has degrees in graphic design, physical geography, and environmental management, and has worked for many sectors including business communications, telecom, and environmental advocacy. She is proud to bring her diverse experience and skills to help make U.S. Geological Survey science and information more usable and accessible.

For more information concerning the research in this report, please contact:
Office of Associate Director, Natural Hazards
U.S. Geological Survey
12201 Sunrise Valley Drive
Reston, VA 20192
https://www.usgs.gov/science/mission-areas/natural-hazards

Publishing support provided by the U.S. Geological Survey Science Publishing Network, Menlo Park and Rolla Publishing Service Centers

Milch and others—**Communicating Hazards—A Social Science Review to Meet U.S. Geological Survey Needs**—Circular 1449

ISSN 2330-5703 (online)
https://doi.org/10.3133/cir1449